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Extended Summaries
Vol. 1

Voluntary Papers

Climate Smart Agronomy
Organic Agriculture
Agriculture Diversification for Sustainable Resources
Integrated Farming Systems for Smallholder Farmers
Abiotic and Biotic (Weeds) Stress Management
Efficient Soil, Water and Energy Management

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Improving cold tolerance ability of late sown lentil through foliar application of auxin and zinc

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Pulses are the staple source of protein to the majority of Indian population and contribute significantly to the nutritional security of the country (Deokara *et al*, 2014). Lentil is one of the major rabi pulse crop of Bihar (Singh and Bhatt, 2015). Lentil is probably the first food legume that ever cultivated dates back to almost 13000 to 9500 years ago is none other than lentil. However lentil accounted for 7- % share of total Indian pulse production. Lentil sowing gets delayed due to delayed and long duration rice cultivar.

Experiment entitled "*Effect of Auxin and Zinc on Performance of Late Sown Lentil*", was undertaken with an objective to improve its productivity through application of auxin & zinc.

METHODOLOGY

A field experiment was conducted at main campus of ICAR Research Complex for Eastern Region, Patna 800 014 India, during 2014–15 and 2015–16 in split plot design (SPD) replicated thrice to evaluate the effect of auxin and zinc on performance of late sown lentil. Date of planting was kept in main plot, whereas six treatments combination of auxin and zinc, were allocated in the subplot. Treatments were superimposed twice as per given in table 1. All nutrients especially NPK and agronomic management practice was as per recommended practices. The texture of soil of experimental plot was silty clay loam with mean pH value of 6.9, electrical conductivity 0.19 ds/m in 1:2 soils: water solution, organic carbon 0.62 per cent, with available nitrogen 245.3 kg/ha, available phosphorus 29.3 kg/ha, available potash 183.7 kg/ha.

RESULTS

Perusal of data presented in Table 2, revealed that lentil seed yield ranges in between 722 to 1500 kg/ha due to imposed treatments. Individually minimum 753.6 kg seed yield was recorded with the control plots sown at 10 December, whereas maximum 1623.2 kg/ha was harvested in the plots

Table 1. Treatments details

Main Plot Treatment: Sowing time: (04)	Subplot Treatment: Auxin & Zinc concentration (6)
D_1= 10 November	A_1= Auxin (0.0 ppm) + Zinc (0.0 ppm)
D_2 = 20 November	A_2= Auxin (0.0 ppm) +Zinc (10.0 ppm)
D_3 = A1= 30 November	A_3= Auxin (2.0 ppm) +Zinc (0.0 ppm)
D_4 = 10 December	A_4= Auxin (4.0 ppm) + Zinc (0.0 ppm)
	A_5= Auxin (2.0 ppm) + Zinc (10.0 ppm)
	A_6 = Auxin (4.0 ppm) + Zinc (10.0 ppm)

Time of application: (02): S_1= January 30 ; S_2= February 15; Variety: Arun; Replication: 03; Plot size: 4.0 X 3.0m

Table 2. Effect of Auxin and Zinc on Performance of Late Sown Lentil seed yield (kg/ha)

Sub plot treatment	Time of Planting				Treatment
	10 November	20 November	30 November	10 December	(Mean)
Control	1014.5	956.5	898.6	753.6	905.8
Zn (10ppm)	1,101.4	1,072.5	1,072.5	927.5	1,043.5
Auxin (2.0 ppm)	1,623.2	1,449.3	1,333.35	1,188.4	1,398.6
Auxin (4.0 ppm)	1,565.2	1,536.2	1,072.5	1,246.4	1,355.1
Auxin (2.0 ppm) + Zinc (10 ppm)	1,507.2	1,478.3	1,043.5	898.6	1,231.8
Auxin (4.0 ppm) + Zinc (10 ppm)	1,246.4	1,275.4	985.55	840.6	1,086.9
Planting Mean	1,343	1,294.7	1,067.6	975.8	

sown on 10 December with Auxin (2.0 ppm) (Singh and Bhatt, 2015).. Overall control treated produced 905.8 and maximum 1398.6 kg seed yield with Auxin (2.0 ppm) in case of hormonal treatments. Similarly in case of date of sowing, the production of lentil decreases with each delayed planting ranging from 1343 to 975.8 kg/ha (Table 2).

CD for comparing two dates of planting: 65.9; CD for comparing 2 hormonal treatments: 42.7; CD for comparing 2 hormonal treatments at given planting time = 78.4; CD for comparing 2 planting time either at same or diff hormonal treatments = 94.7

Perusal of data presented in table 3 revealed that heat unit and gestation period was reduced with the successes delay in planting. Individually minimum 105 day was recorded with 10 December and maximum 121 days was taken by the planting of 10 November. Similarly in case of Heat Unit (^{o}C day) it was noticed that maximum 1503 was recorded with 10 November and minimum 1364with 10 December planting.

Table 3. Gestation period influenced due to planting time and Auxin and Zinc on Performance of Late Sown Lentil

Sowing dated	Harvesting date	Gestation Period	Heat Unit (^{o}C day)
10.11.2014	10.03.2015	121	1503
20.11.2014	17.03.2015	118	1461
30.11.2015	23.03.2015	112	1432
10.12.2014	26.03.2015	105	1364

CONCLUSION

It was noticed that application of auxin alone and along with zinc has positive influence on cold tolerance ability of late sown and improved the podding as well as boldness of lentil seed.

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Rainfall probability analysis for crop planning at Akola, Maharashtra

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The greatest risk in agriculture production is attributed to the variability of seasonal rainfall and the uncertainty in the amount and its distribution in a given season. The rainfall pattern decides the cultivation of crops, their varieties, adoption of cultural operations and harvesting of excess rain water of any region (Kar, 2002). The weekly distribution of rainfall and its probability is helpful in crop planning by identifying the period of drought, normal and excess rainfall (Ray *et al*, 1980). Gupta *et al.* (1975) suggested that the rainfall at 80 per cent probability could safely be taken as assured rainfall, while 50 per cent probability is medium limit for taking risk. Akola is known for the cultivation of soybean, cotton tur, mug, in *kharif* season and wheat, chickpea, groundnut in *rabi* season. In this regard, an attempt has been made to understand the rainfall climatology by analyzing the temporal and spatial distribution and its probability of occurrence of dry and wet spell and their distribution by analyzing rainfall data of Akola, Maharashtra.

METHODOLOGY

Akola is situated at in Vidarbha meteorological sub-division of Maharashtra State, India, with latitude/ longitude 20.7^0 N/77.0^0 E and altitude of 282 m AMSL. District falls in assured rainfall zone, and receives monsoon rains during June to September. The daily rainfall data of last 46 years (1971-2015) for the study were taken from the Agromet observatory located at Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. The dry and wet spell analysis was carried out by using standard Markov-chain process. Rainfall of 20 mm per week is adequate for all the growth stages of all the crops grown.

Thus, if in a given week the rainfall received is less than 20 mm, that week can be designated as a dry week and vice-versa. On the basis of this criterion, each week was categorized as a dry week and wet week and respective probabilities were calculated. The incomplete gamma distribution (IGD) was used to derive expected weekly rainfall at different probability levels.

RESULTS

The mean annual rainfall at Akola was found to be 818.6 mm and it varied from 3.1 mm (lowest) to 215.7 mm (highest) with standard deviation (SD) of 336.75 mm and coefficient of variation (CV) of 30.19 %. The probability of dry week, P (2D) was found to be more than 60% during most of the rainy season period except during 36th SMW (Fig.1). The initial dry spell results revealed that, Akola experiences more dry spell at early and middle stages of rainy season. Similar trends were observed with consecutive dry spells also, i.e., three consecutive dry weeks, P (3D) and four consecutive dry weeks, (4D). High probability of occurrence of dry spells hint for importance of in situ moisture conservation measures and need of supplementary irrigation during early and middle stages of rainy season. Hence farmers need to be cautious while selecting early sowing window to avoid the plausible early season drought. The probability of week being wet P (2W) was observed to be more than 50 % on 37th week (SMW) during rainy season which is an indication for potential rain water harvesting it may be utilize during dry spells. Further, critical observation regarding consequent wet weeks, i.e., P (3W) and P (4W) also indicate that there may be probability of getting rain water for harvesting during 36th to 40th SMW. The overall, dry and wet spell analysis revel that dry land crops sowing at Akola can be initiated during 24th and 25th SMW as 24th SMW was found to be mean week of onset of rainy season and comparatively less dry spells were pronounce during mid rainy season which can be conjunctively planned with in-situ moisture conservations measures and supplemental irrigation at critical crop growth periods. The minimum expected weekly rainfall at 10, 25, 50, 75 and 90 % probability levels during rainy season were derived and are presented in Fig. 2. The results revealed that, the expected weekly rainfall at 10 % probability level ranged between 21.4 mm (47th week) to 140.5 mm (32nd week) and at 90 % probability level, it varied from 0.1 mm to 5.1 mm. At 75 % probability level, the weekly expected rainfall was found to be between 0.6 mm to 14.4 mm which is an indication of deficit rainfall during rainy season weeks which in turn indicates high risk for growing dry land

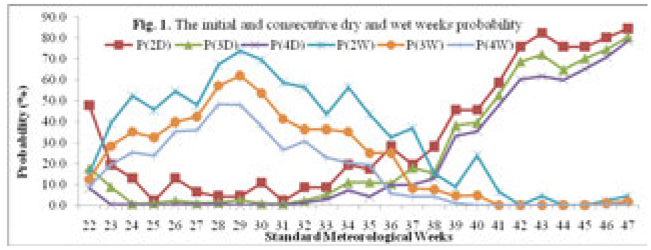

Fig. 1. The initial and consecutive dry and wet weeks probability

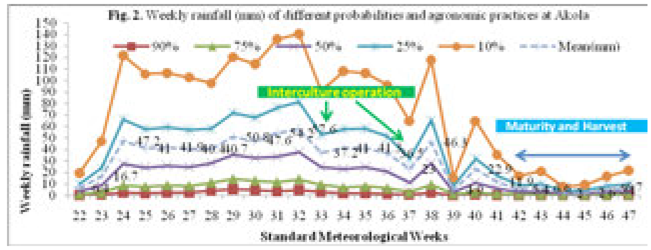

Fig. 2. Weekly rainfall (mm) of different probabilities and agronomic practices at Akola

crops which likely to suffer by frequent dry spells

CONCLUSION

The major crops of Akola were cotton, soybean, tur, and mug during *kharif* season with about 150-160 days for cotton and 100 -120 days for soybean crop for high yielding varieties this analysis clearly indicates that the rainfall received during May could be utilize for land preparation and sowing of long duration rainfed crops. Optimum time for sowing of *kharif* season crop would be 24th to 27th SMW (Ist and IInd fortnight of June) with average weekly rainfall of 27.6, 24.4, 25.9 and 24.9 mm, respectively at 50 % probability level. The inter culture and other operations can be taken up during 33rd to 37th SMW with an average rainfall of 24.9, 23, 24.6, 20.9, and 11.3 mm. The crop sown during 24th-26th week, reaches the maximum growth or grand growth period during 29th to 43rd week, during this stage crop requires highest amount of water, which is available during the period. Hence, successful dependable rainfed cropping of cereals- pulses can be taken up during south west monsoon.

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Performance of *Brassica juncea* (RGN-73) under changing climatic scenario

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Rapeseed-mustard (*Brassica* spp.) is a major group of oilseed crops of the world being grown in 53 countries across thesix continents with India being the third largest cultivator and producer after Canada and China. It is highly sensitive to temperature and photoperiod, and requires high temperature during early growth stage; and cool weather, clear sky during reproductive phase for better growth and development. About 18-25°C temperature, low humidity, practically no rains, especially at the time of flowering along with cold , frost free days during flowering, seed formation and other developmental stages are desirable atmospheric conditions for the crop. Optimization of date of sowing and planting geometry (Kumari *et al.*, 2012) for Indian mustard cv. RGN-73 is one of the main objectives of the present study.

METHODOLOGY

A field experiment was conducted at the Norman E. Borlaug Crop Research Centre ofG.B. Pant University of Agriculture and Technology, Pantnagar to evaluate the performance of *B. juncea* variety RGN-73under changing climate during *rabi*, 2014-15. The experiment was laid out in split plot design (SPD) taking three dates of sowing i.e. Oct 22, Nov 01 and Nov 11 in main plots and five planting geometries viz. 30 cm × 10 cm, 30 cm × 20 cm, 30 cm × 30 cm, 45 cm × 15 cm and 45 cm × 30 cm in sub- plots with three replications. Normal crop husbandry practices were followed for the successful raising of crop.

RESULTS

Growth parameters, yield attributes and seed yield were significantly influenced by the sowing date and planting geometries (Table 1). Dry matter accumulation at 120 days after sowing (DAS) was higher in crop sown on October 22 being statistically superior over the other two sowing dates. Among the different planting geometries maximum dry matter was found with 30 cm × 20 cm spacing being statistically on a par with other planting geometries except 45 × 15 and 45× 30 cm spacing. Crop sown on October, 22 took significantly more time to than the other two sowing dates. Widely spaced plant took more time to mature. Crop sown on October, 22 produced more number of siliquae/plant being significantly superior over November, 01 and 11 sowing. Among the various planting geometries, the wider geometries resulted into more number of siliquae/plant. 45 cm × 30 cm spacing produced the highest number of siliquae which was significantly superior over that of 30 ×10 cm. The highest value of

Table 1. Growth parameters, yield attributes and yields of Indian mustard as influenced by dates of sowing and planting geometry

Treatment	Dry matter 120 DAS (g/plant)	Days taken to mature	Siliquae/ plant	1,000-seed weight (g)	Seed yield (kg/ha)
Date of sowing					
October 22	50.2	140.2	299	3.8	1665
November 01	38.2	138.7	232	3.2	1513
November 11	30.7	136.9	171	2.4	1266
SEm±	2.9	0.3	10	0.1	40
CD (P=0.05)	10.0	1.0	35	0.3	137
Planting geometry					
30 cm × 10 cm	44.1	137.1	182	2.7	1635
30 cm × 20 cm	47.1	137.9	206	2.3	1650
30 cm × 30 cm	45.9	139.2	239	3.3	1611
45 cm × 15 cm	34.7	138.3	230	3.2	1357
45 cm × 30 cm	26.9	140.3	308	3.8	1140
SEm±	2.7	0.5	22	0.14	42
CD (P=0.05)	7.9	1.5	64	0.41	122

Table 2. Interaction effect of sowing dates and planting geometry on seed yield (kg/ha)

Planting geometry (P) / Date of sowing (D)	30 cm × 10 cm	30 cm × 20 cm	30 cm × 30 cm	45 cm × 15 cm	45 cm × 30 cm
October 22	1780	1795	1978	1492	1281
November 01	1569	1732	1599	1484	1180
November 11	1556	1454	1259	1097	961
CD (P=0.05): To compare two P at same D					211
CD (P=0.05): To compare two D at same or different P					233

1000-seed weight (3.8) was recorded in October 22 sown crop being significantly superior over the delayed sowing. The geometry of 45 cm × 30 cm outplayed significantly over rest of the four geometries in case of 1,000 seed weight. The seed yield decreased significantly with delay in sowing date from 22nd of October to the 11th of November, showing the highest yield 1665.3 kg/ha for 22nd October and the lowest yield 1265.8 kg/ha for 11^{th} of November. Among the various planting geometries 30 cm × 20 cm produced the highest seed yield being significantly superior over the two geometries of 45 cm × 15 cm and 45 cm × 30 cm. The interaction between the date of sowing and planting geometry was found to be significant on seed yield (Table 2). Sowing on Oct, 22 showed its supremacy under all the planting geometries over Nov, 01 and Nov, 11 sowing. However, Nov 01 sowing did not differ significantly under 30 cm × 10 cm, 30 cm × 20 cm, 45 cm × 15 cm and 45 cm × 30 cm planting geometries.

CONCLUSION

From the above study it could be concluded that sowing *B. juncea* variety 'RGN-73' on October 22 with 30 cm × 30 cm planting geometry could be beneficial under the *tarai* conditions of Uttarakhand.

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Management and mitigation of terminal heat stress in wheat through conservation agriculture–A review

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Wheat is a main cereal crop grown in India and its cultivation is a gamble of temperature. Wheat performance and yield depend largely on environmental interaction. Among these, temperature plays an important role in growth, development and yield of wheat. High temperature at the both ends of wheat growing season in India is a limiting factor. In case of delayed sown crop due to late harvesting of paddy, stages like flowering and grain filling coincide with rise in temperature and atmospheric drought during March and April, which causes poor growth and low grain yield. High temperature stress has become a major concern for wheat production worldwide because it greatly affects the growth, development, and productivity of plants. With the threat of climate change looming large on agriculture, emphasis should be on conserving resources with sustained production which matches with ecological demands of our soils. Keeping in view, the discussion has been put in this review to study the management and mitigation strategies to reduce the impact of high temperature stress in wheat.

METHODOLOGY

For the present study, research carried out at different research farms was consulted through published research papers and then collaborated in the form of a review paper. Among the research papers consulted major were on wheat crop grown under different temperature conditions to study the effect of temperature on growth, development and yield of crop. In most of the research papers consulted, wheat crop has been grown with recommended package and practices.

RESULTS

Data pertaining to different planting methods have been put in Table 1. Experiments conducted in different locations viz. Ludhiana, Hisar, U.P. and Modipuram observed that plant height, dry matter accumulation and LAI were found to be significantly higher in bed planting as compare to conventional planting. It shows that with the change in planting methods, adverse impact on the reproductive stages of crop can be alleviated to an extent. Another study conducted at New Delhi and Birsa Agricultural University, Ranchi concluded that in rice-wheat cropping system, zero tillage recorded statistically higher yield as compared to conventional tillage due to more number of tillers, better establishment and lesser weeds. It might also be due to the advancement in sowing time due to zero tillage. Thus, it helps in avoiding high temperature stress on the later stages of crop growth. Data pertaining to mulching and its effect on evapotranspiration and soil moisture depletion has been put in table 2. Mulching has been proved to be beneficial in reducing evapotranspiration and conserving soil moisture. Application of plant mulch combined with minimum tillage helps in reducing soil erosion, maintaining soil structure and conserving soil water. Adequate water within the plant system helps in maintaining turgidity and heat stress can be easily mitigated.

Table 1. Effect of different planting methods on grain yield of wheat

Planting method	Grain yield (t/ha)
Conventional	5.085
3 wheat rows per bed	5.306
2 wheat rows per bed	4.223
CD at 5%	0.269

CONCLUSION

Efficient planting method plays an important role in alleviating heat stress in wheat. Bed planting proves to be more beneficial that flat planting for better results. Moreover, mulching helps in conservation of resources and ensures a better environment for plant growth.

Table 2. Effect of straw mulch and irrigation on evapotranspiration and soil water depletion

Year	Factor	Treatments				
		No straw mulch and no irrigation	Straw mulch and no irrigation	No straw mulch and irrigation 15 mm	No straw mulch and irrigation 30 mm	No straw mulch and irrigation 45 mm
1997	Evapotranspiration	239.2	219.5	250.6	260.8	271.1
	Soil water depletion	58.1	38.4	54.5	49.7	45.0
1998	Evapotranspiration	369.6	355.3	349.9	338.8	264.4
	Soil water depletion	91.2	76.9	71.5	38.4	84.7

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Rice varieties respond differently to transplanting dates and weather vagaries under temperate conditions

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Agricultural production and productivity of any region is being regulated by the prevailing climate of that area through temperature, rainfall, light intensity, radiation and sunshine duration. Apart from being food rice is intimately involved in the culture as well as economy of Jammu and Kashmir. Rice sowing time in Kashmir valley starts from mid of April to Mid of May and likewise the transplanting starts from mid of May to mid of June. In mono cropped areas farmers are able to take up the rice operations early in the season. However, a substantial area is under a double cropping system and late transplanting becomes inevitable. Mid of May is considered as early and 20th of June is considered as late with definite yield penalties. Kashmir valley has a temperate type of climate with abundant sunshine from May to October, However, a drop in temperature during flowering and grain filling stages results in significant yield reductions. Late planted crop becomes more vulnerable to low temperatures at flowering stage. Time of transplanting assumes greater importance owing to shorter growing season of 140-150 days under Kashmir valley conditions (Bali *et al*. 1995). Two newly released rice varieties namely Shalimar Rice 2 (SR2), and Shalimar Rice 3 (SR3) and two relatively older varieties *viz* Jhelum and Shalimar Rice 1 (SR1) have been bred from the parents having wide genetic backgrounds and therefore have different maturity durations. Sowing/transplanting dates is the most important non monetary input keeping in view relatively short and the crop is exposed to suboptimal temperatures during. Planting date can have a dramatic effect on crop development and yield. In this backdrop a field evaluation of the diverse varieties under varied transplanting dates was conducted to; evaluate the effect of transplanting dates on the productivity of rice varieties and growing degree day accumulation (GDD).

METHODOLOGY

A field experiment on four transplanting dates and four rice varieties was conducted at Mountain Research Centre for Field Crops during *Kharif* seasons of 2013 and 2014. Khudwani is at located at latitude of 33°43’15' N, longitude of 75°5’39' E and altitude 1,596 m amsl. Year 2013 experienced almost a normal weather, but year 2014 experienced incessant rainfall, low temperatures and wide spread floods during flowering/grain filling stages. The soil of the experimental field was silty clay loam in texture, low in available N (208 kg/ha), medium in available P (12.5 kg/ha) and K (198 kg/ha). Four transplanting dates *viz* 20th May, 30th May, 10th June, 20th June were factorially combined with four rice varieties *viz* SR-1, SR-2, SR-3 and Jhelum forming 16 treatment combinations. The experiment was laid out in Randomized Block Design with three replications. The GDD was calculated by using the formula: $GDD = Ó\ [(Tmax + Tmin) / 2 – 10°C]$.

RESULTS

Dates of transplanting and varieties had a significant effect on yield attributes and grain yield of rice (Table 1). During 2013 no. of panicles/m^2 was significantly decreased with delay in transplanting. Early transplanting on 20th of May resulted in maximum no. of panicles/m^2 and delay in transplanting resulted in 36% reduction in no. of panicles. Among the varieties SR-2 produced maximum no. of panicles/m^2. The varieties in general produced a larger no. of panicles/m^2 for early dates of transplanting. The same trend was reflected in no. of grains/panicle, sterility (%), grain yield and straw yield. Due to heavy rainfall, low temperature and widespread floods during first week of September, 2014 which coincided with flowering/grain filling stages of different rice varieties, there was a significant reduction in no. of panicles/m^2 of all the rice varieties. However, SR-1 and SR-2 suffered more heavily in terms of the panicles/m^2, no. of grains/ panicle, sterility (%) and grain yield when transplanted late. One of the parents of both SR-1 and SR-2 are from sub tropical backgrounds and therefore respond positively to higher GDD accumulation which could be achieved by early transplanting. Late transplanting on June 20th resulted in a yield reduction of 35%, 50%, 26%, and 29 % over early date of 20th May during the year 2013. The corresponding figures for the year 2104 were

Table 1. Effect of transplanting dates on yield attributes yield, growing degree day accumulation

Treatment	No. of panicles/m^2		No. of grains/panicle		Grain yield (t/ha)		Straw yield (t/ha)		GDD accumulation at maturity	
	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
Dates of transplanting										
20th May	469	412	143	130	6.80	6.14	6.76	6.83	1390	1199
30th May	427	380	137	117	6.09	5.45	6.81	7.20	1356	1146
10th June	361	297	122	103	5.33	4.44	6.98	7.01	1326	1100
20th June	299	223	110	84	4.34	3.20	6.85	6.14	1290	1051
C.D (P=0.05)	20.57	18.43	3.46	3.73	0.30	0.27	NS	0.38	14.63	12.71
Varieties										
SR-1	384	309	126	106	5.57	4.47	6.95	6.76	1375	1165
SR-2	425	323	136	113	6.16	4.75	7.86	7.57	1421	1258
SR-3	382	344	124	104	5.54	5.06	6.17	6.32	1298	1037
Jhelum	366	336	127	111	5.30	4.94	6.42	6.54	1269	1034
CD (P=0.05)	20.57	18.43	3.46	3.73	0.30	0.27	0.409	0.38	14.63	12.71
Dates × varieties	41.1	36.86	6.92	7.47	0.596	0.54	NS	0.76	NS	NS

54%, 66%, 31%, 36% respectively. Early transplanting resulted in higher GDD accumulation for longer duration varieties *i.e.* SR-1 and SR-2 during 2013 that resulted in their higher grain yield heat use efficiency. However, a significant finding of the study is that SR1 and SR-2 were the worst sufferers under adverse climatic condition in terms of tillers/ m^2, grains/panicle, sterility (%) and these were finally reflected in drastic reduction in the grain yield. Interaction between the plant dates and genotypes have also been observed by Safdar *et al*. (2008). Under normal conditions early transplanting resulted in higher yield increments for SR-1 and SR-2, however under adverse weather conditions these two varieties gave lowest yield under late transplanting. SR-3 and Jhelum yielded better even under late transplanting when the conditions worsened due floods and low temperature during the flowering/ grain filling stage.

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Transplanting in cotton as emerging climate smart technique for sustainable production

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Cotton is the major source of natural fibre and has always attracted lot of commercial as well as research interest. Though sowing commences as early as in May second fortnight in rainfed regions of Western Ghats in Karnataka with a potential of 1.5 to 1.8 t/ha under rainfed condition, while in the irrigation commands in the peninsular region the crop is sown in the first or second fortnight of July based on the release of water in the canal which is always late because of delay in monsoon which is a rule rather than exception due to climate change and/or other aberrations in the rainfall. Consequently crop suffers from reduced growing period due to early exposure to onset of winter cold and also due to leaf reddening which is so common in *Bt* hybrids and the incidence is more in late sown crop. As a result in spite of their best efforts farmers fail to realize potential yields.

METHODOLOGY

The novel technique of raising hybrid cotton seedlings in poly bag well in advance of planting has, therefore, were investigated separately in UKP and TBP irrigation commands from 2009 to 2015-16 to evaluate the production potential at different planting geometry, comparative performance with traditional system and performance under various dates of planting at College of Agriculture, Bhimarayanagudi and Raichur and further large scale demonstrations were conducted on farmers' field.

RESULTS

The increased yield in transplanted cotton plots over farmer's practice was 20% under irrigated condition. There was 15-16 fruiting bodies/plant at 60 days after transplanting, while plants raised from seed dibbling were yet to bloom during same time. This was also attributed attainment of required heat units early in transplanted crop. At first picking plants in farmers practice (dibbling) attained similar height at par with transplanted plants, but they did not achieve similar stem girth and sympodial branches which have enabled to retain more number of flowers and ultimately bolls (Salakinkop, 2011). The number of early-season flowers and number of bolls retained per unit area in transplanting system were significantly higher than those in normal planting system in China (Li *et al*., 2000). In Indian situation also, direct seeding gave less number of bolls/plant than transplanting of poly bag raised seedlings. Leaf reddening was less than 50% of that under dibbled condition which further enhanced photosynthetic efficiency under transplanting. Another advantage of transplanting under rainfed condition is that the date of planting is advanced by 1–2 months, so that farmers get an early peak harvest. Under dibbled condition development of bolls take place under drought / stress during later in the season resulting in poor yield. Transplanting of seedlings is also considered as an effective seed-saving technique in China (Hezhong *et al*., 2004). Among the different transplanting geometry, significantly higher seed cotton yield was obtained in the spacing of 90 cm

× 90 cm (Rs. 48610/ha) against the traditional recommendation of 90 cm X 45 cm (Rs. 34790/ha) under dibbling. Under rainfed situation spacing of 90 cm X 60 cm recorded higher yield and yield attributes than closer spacing. Generally, advantage with wider spacing is noticed in fertile soil and when time of sowing is optimum. But under poor soil and late sowing condition higher plant densities are preferred to minimize reduction of yield. Hence, the potential yield of *Bt* cotton both under normal and delayed sowing conditions could be enhanced by transplanting which resulted in better establishment, early vigour, early flowering, increased yield attributes and seed cotton yield. The cost of transplanting could be covered from increased income (39%) realized in the technique. Transplanting in cotton is productive and economical and it ensures efficient use of water and growing season particularly in regions where release of water is always delayed resulting in low productivity.

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Screening of suitable crops to different dates of sowing under rainfed conditions for contingent crop planning

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Agriculture in rainfed areas continues to be a gamble and rainfed farmers face several uncertainties like aberrant weather, lack of timely inputs and credit leading to low and unstable productivity and profitability. The monsoon period is beset with breaks of rain in almost all parts of the country. Sudden "bursts" of rain alternated with "breaks" is common in rainfed areas. The increasing uncertainly of weather conditions such as below or untimely rains are causing great negative impact on crop production. This necessitates for contingency crop planning which is an integrated part of agricultural production planning. Development and dissemination of short duration varieties, which can withstand the climatic anomalies expected in the future, should be given priority in the mountain region (Hussain and Mudasser, 2007). Though, some work have been carried out by many research organizations/SAUs for different states but very little information is available for Uttarakhand region. As the climate change is increasingly important as a policy issue for both the international community and for India it was a dire need to address these issues for the farming community by way of selecting appropriate varieties of crop or appropriate alternate crop and production technologies. Keeping in view, the present experiment was carried out at Vivekananda Parvatiya Krishi Anusandhan Sansthan Experimental Farm, Hawalbagh, Almora with an objective to minimize the reduction in the production due to delayed monsoon through screening of suitable crops for different sowing dates.

METHODOLOGY

A field experiment was conducted during 2012 to 2015 at the Experimental Farm of ICAR-Vivekananda Parvatiya Krishi Anusandhan Sansthan, Almora, India. The site is located at 29° 36´ N latitude and 79° 40´ E longitude at an elevation of 1,250 m amsl. The experiment comprised six crops, viz. finger millet, buckwheat, soybean, okra, amaranth, and horsegram that were evaluated for 3 dates of sowing (10 July, 20 July and 30 July).

RESULTS

The results of four years experiment showed that the highest finger millet equivalent yield was recorded by okra (42.71 q/ha) followed by amaranth (27.18 q/ha), finger millet (23.65 q/ha) and horse gram (21.19 q/ha). Soybean was found the poorest yielder among all crops with delayed sowing (Fig. 1). Okra, finger millet and amaranth found better during 2012 and 2013 however Okra, Amaranth and horsegram gave bet-

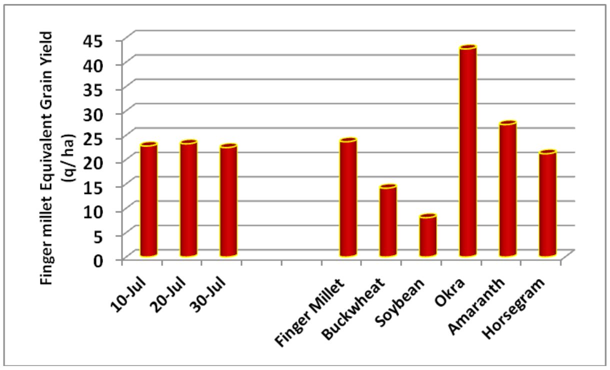

Fig. 1. Finger millet equivalent yield of different kharif crops in delayed sowing

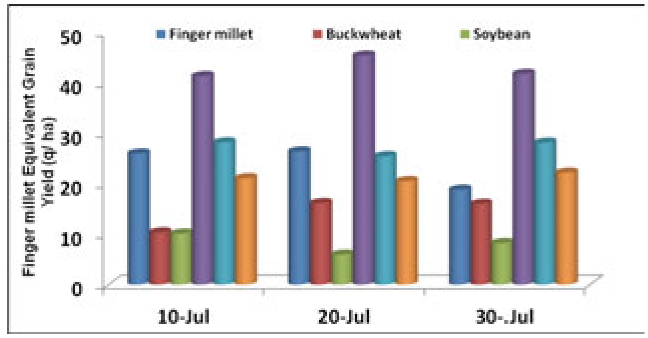

Fig. 2. Finger millet equivalent yield of different kharif crops with varying sowing dates

ter yield in 2014 and 2015. Okra, amaranth, horse gram and buckwheat gave positive response for sowing upto 30 July however finger millet gave only up to 20 July. There was no positive response in soybean for delayed sowing (Fig. 2).

CONCLUSION

Planting of okra, amaranth and horse gram in different dates didn't show any significant difference which showed their suitability for delayed monsoon.

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Development of climate change scenarios for Western Ghats

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Climate change has become one of the most important global concerns because of its wide spread effect on food production, natural ecosystems, fresh water supply, human health, etc. In recent past, global mean surface temperature and precipitation has been used in number of studies to predict climate change. Predictions at the global scale, or even at hemispheric or continental scale, prove to be of little use as climate is highly variable spatially well below these scales particularly, parameters like mean temperature and precipitation. So there is a need for regional scale assessment of climate change and its associated impacts which was also stressed in the UN Framework Convention on Climate Change in Rio de Janeiro in 1992. Since then, numerous studies have been conducted in different regions worldwide, e.g. Norway (Benestad, 2002) and India (Chaturvedi *et al.,* 2012) using General Circulation Models (GCMs). As the GCMs are coarser in resolution, there is an increasing demand of finer resolution climate change scenarios from impact analysts. Keeping all these in views, a study was undertaken to develop a Multi-Model Ensemble (MME) from the best performing models to construct the future climate change scenarios.

METHODOLOGY

IMD gridded temperature (1°x1°) and rainfall (0.25°x0.25°) data were used as observed data. The model simulations for both the present-day climate and future climate projections (RCP 2.6, RCP 4.5, RCP 6.0 and RCP 8.5 experiments from 2006 to 2100) are obtained from the CMIP5 data website (http://pcmdi9.llnl.gov). We have used conventional statistics and Taylor plot for evaluation of the CMIP5 models.

RESULTS

For temperature, the models which were having d-index >0.95, nRMSE<50, pbias between -10 to 10 and correlation

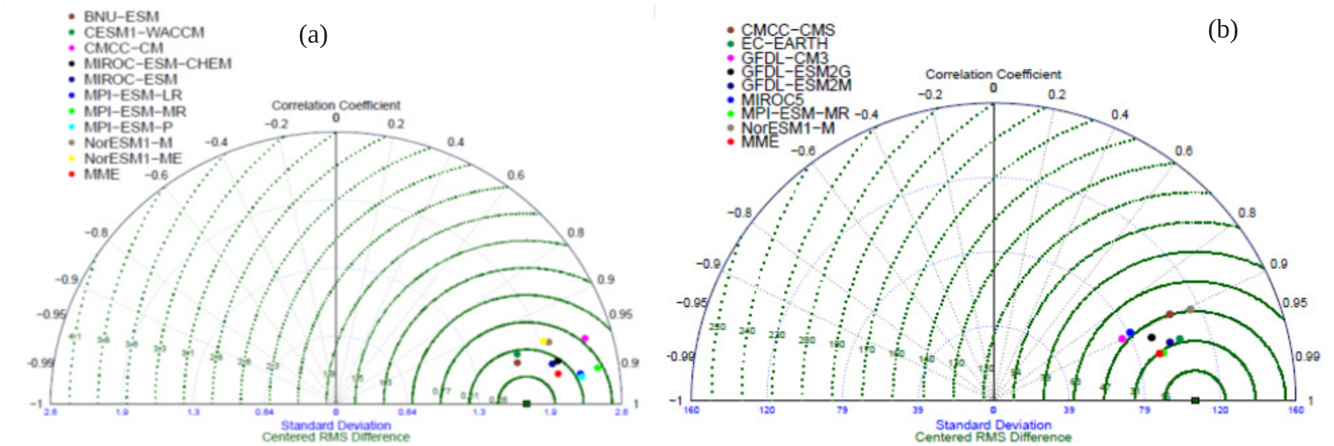

Fig. 1. Taylor plot of temperature (a) and rainfall (b) over Western Ghats

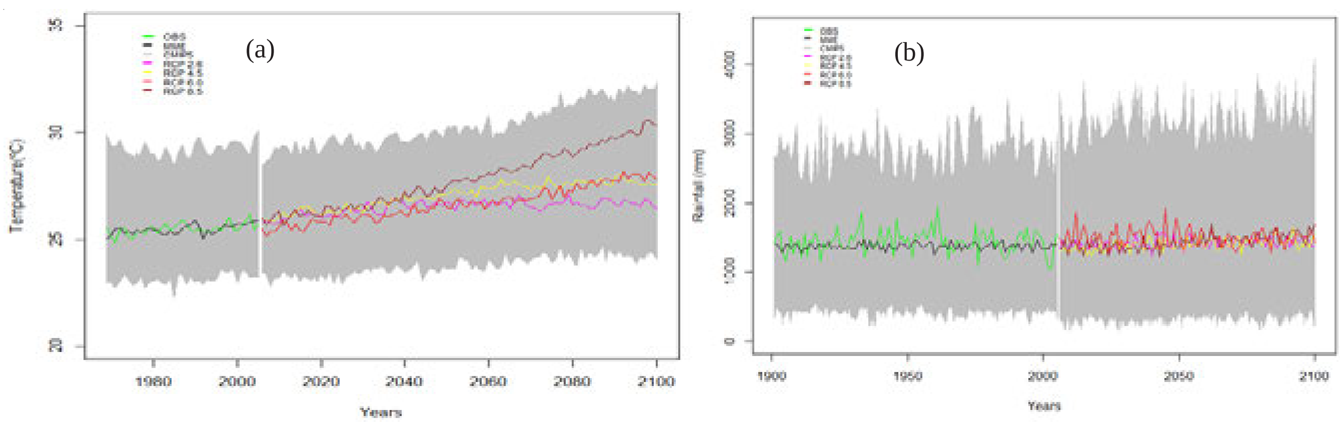

Fig. 2. Past and future time series for temperature (a) and rainfall (b) over Western Ghats

>0.95 were selected. The selected models were BNU-ESM, CESM1-WACCM, MIROC-ESM-CHEM, MIROC-ESM, MPI-ESM-LR, MPI-ESM-MR, MPI-ESM-P, NorESM1-M, and NorESM1-ME. For rainfall, the models which were having d-index >0.90, nRMSE<50, pbias between -20 to 20 and correlation >0.85 were selected. On the basis of these criteria the selected models for rainfall were CMCC-CMS, EC-EARTH, GFDL-CM3, GFDL-ESM2G, GFDL-ESM2M, MIROC5, MPI-ESM-MR and NorESM1-M.Performance of the best GCMs is also assessed using Taylor Diagram where IMD gridded data is assumed as reference (Fig. 1). The results of Taylor diagram indicate that all the selected models were able to simulate IMD gridded observed temperature and rainfall adequately as the correlation values were greater than 0.85. We have developed a MultiModel Ensemble (MME9, MME8 for temperature and rainfall, respectively) from the best performing models for both past and future time period (1969-2100 and 1901-2100 for temperature and rainfall, respectively) (Fig. 2). MME9 indicates that temperature is projected to be increased in the range 4.19-9.31% for different RCPs in the period of 2006-2100 with respect to the base period of 1970-2000. The multi-model ensemble for rainfall (MME8) indicated a very marginal increase in rainfall in RCP2.6 and RCP6.0 but it will decrease according to RCP4.5 and RCP8.5.

CONCLUSION

The GCM models were almost able to simulate the temperature and rainfall. In general, future temperature may increase but rainfall may not increase significantly. So rainfed agriculture in the study region may face acute water crises in future.

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Extended Summaries Vol. 1 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Suitability of promising maize hybrids to adapt rainfall changes and climatic aberrations under dryland temperate ecologies of Kashmir

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In changing climate scenario there is a need to change research strategies especially under dryland temperate ecologies. There is an urgent need to develop strategy for judicious use of available precipitation. Maize (*Zea mays* L.), being a C_4 plant, is expected to be comparatively less affected due to climate change but change in onset of western disturbances particularly in the months from April -June will vary its planting period and consequently the choice of suitable maize cultivars. Varietal replacement and lithe planting time to fit weather and climate change are main non monitoring inputs need to be highlighted in dryland temperate ecologies.

METHODOLOGY

A field experiment was conducted during *kharif* 2011-12 at Dryland Agriculture Research Station, Budgam (33° 98'N Latitude, 74° 80'E Longitude and 1292 m above msl) of Sheri Kashmir University of Agricultural Sciences & Technologies, Shalimar Srinagar to find out suitable maize genotypes under different date of sowing. The soil of the experiment field was having pH 7.2, organic carbon 0.59%, 380 kg N/ha, 9.0 P kg/ha and 202 K kg/ha. Four maize hybrids of different maturity durations viz NK6607, Ujala, Shalimar Maize Hybrid-1 and Shalimar Maize Hybrid-2 were tested at four dates of planting viz, 10 days before normal date of sowing (NDS), NDS(10th of April), 10 days after NDS and 20 days after NDS. Dates were tested in main plots and genotypes in sub-plot design with three replications.

RESULTS

In order to understand the change in the climatic variables, monthly rainfall was used to understand any fluctuation in the rainfall and its pattern to represent any change in the climate. The rainfall during crop season (April to September) was irregular and low in this region for years 2011-12 and was 347.6 mm, 231.8 mm, respectively indicating that there is reduction in total precipitation during crop season. Plant height measured and ancillary characters were affected significantly with delay in sowing particularly after the normal date of sowing (Table 1). Delay in sowing by 10 days recorded significantly lowest number of cobs, plant height, placement of cob above ground and cob yield per unit area. Productivity of maize was significantly reduced as the planting was delayed.

Table 1. Effect of date sowing and maize genotypes on maize growth and yield attributes

Treatment	No. of cobs (000/ha)	Cob height (cm)	Ear length (cm)	Plant height (cm)
Date of sowing				
10 days advance from NDS	84.2	136.3	24.8	209.5
Normal date of sowing (NDS)*	83.1	127.5	23.7	211.6
10 days delayed from normal sowing	79.0	115.7	22.9	200.2
20 days delayed from normal sowing	79.8	106.5	20.8	199.3
CD (P=0.05)	1.8	9.2	1.2	4.6
Genotypes				
NK6607	85.6	145.5	25.6	202.3
Ujala	83.4	133.6	22.8	206.4
Shalimar Maize Hybrid-1	80.9	129.2	19.9	215.4
Shalimar Maize Hybrid-2	82.1	124.7	21.7	196.6
CD (P=0.05)	1.1	4.7	1.6	4.2

*NDS= Normal date of sowing is 10th of April

Similar trend with regard to reduction in cob yield and productivity was observed by Mankotia *et al.* (2012). Averaged over the genotypes and date of sowing, delay in maize sowing from I[st] April to 30[th] April resulted in maximum yield reduction of 25.16 kg/ha/day. Delay in planting by 20 days after NDS resulted in yield reduction of 14.75 kg/ha/day as there is decline in rainfall and distribution pattern that hampers vegetative growth and subsequent forced flowering under moisture stress conditions which resulted low productivity. Hybrid NK6607 appeared to be more stable/adopted to sowing date as it recorded 18.85% reduction in yield due to delayed sowing by one month followed by Ujala,(19.59%), Shalimar Maize Hybrid-1(31.12%) and Shalimar Maize Hybrid-2 (34.61%). Among hybrids NK6607 has comparatively longer duration, on Ist April resulted in highest grain yield (6700 kg/ha). Productivity variation among genotypes with date of sowing have also been observed by Bunting (2009).

CONCLUSION

Consequently, if rains due to onset of western disturbances particularly from April –July are uniform and well distributed, hybrid NK6607 should be grown under dryland rainfed ecologies of Kashmir.

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Are nutrient secure agro-ecosystems climate resilient?

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Climatic factors mainly rainfall and temperature play a crucial role in determining productivity of crops. Climate changes in last few decades have drawn attention to understand effects of these changes on food production especially cereals which constitute significant part in world food production. Rice-wheat cropping systems are one of the most important production systems in Indo-Gangetic region. Fertilizer use is related to productivity, however, environmental quality and long term effects on soil health have led to search for attractive source of soil fertility management like legumes, green manuring, crop residues in these systems. According to report of FAO (2012) Asia is the largest consumer of the fertilizers. Consumption of fertilizer and nutrient in Asia is 58.7% of the world and the bulk of which is used in East and South Asia. Inclusion of organic materials provides multi-prongedbenefits like addition of carbon (C) to soil as well as available nutrient enrichment. Sources like green manure crops (e.g. *Sesbania esculeata*) and legumes (e.g. *Vigna radiata),* when included in rotation, provide higher amount of nitrogen (besides micronutrients) as well as, organic matter and can be considered as 'nutrient secure' system.

METHODOLOGY

A field experiment was initiated in 2005 on a soil with sandy loam texture (Aquic Natrustalfs) at ICAR-Central Soil Salinity Research Institute (CSSRI), Karnal, India, located at 29.43ºN and 76.58ºE. The study involved seven treatments in total, including five treatments with reduced inorganic fertilizer doses in combinations with organic sources [LEG- legume (*Vigna radiata*), GM-green manure (*Sesbania aculeata*), FYM- farmyard manure, WS- wheat straw, PS-paddy straw], compared to 'full recommended doses of inorganic fertilizer' (F) treatment and 'no fertilizer at all' (O) treatment. The total N supplied in the treatments from inorganic and organic sources is provided in Table 1. Plant assimilated C was also measured by taking the above and below ground biomass of the R-W system. Samples of the soil and plants have been collected from all the seven treatments at different depths (0-15, 15-30 cm and 30-60 cm) on monthly basis and C stock, C assimilated and C return were estimated at different depths.

RESULTS

On the basis of seasonal rainfall during rice and wheat seasonseparately, weather data were divided into rain-excess and rain- deficit seasons. In case of rice, during rainfall excess years, grain yield responded linearly to C return to soilfor all treatments (O, F, FYM, WS and PS) except LE and GM

Table 1. Treatment details

Treatment	Inorganic Fertilizer (N: P: K: Zn) kg/ha	Organic Source
O	0	0
F	180: 26: 42: 7	0
LEG	100: 16: 28: 0	Moong (*Vigna radiata*)
GM	100: 16: 28: 0	Green Manure (*Sesbania esculeata*)
FYM	100: 16: 28: 0	Farmyard manure
WS	100: 16: 28: 0	Wheat Straw
PS	100: 16: 28: 0	Paddy Compost

wherethere was no significant effect. During rainfall-deficit years, green manure turned responsive to C return yet LE still hadno effect of C returned on grain yield.In case of wheat, in rainfall excess years, all treatments responded positively and significantly to C return to soil. In rainfall deficit years, the LE and GM had a no significant interaction. On the other hand, wheat straw and rice straw had negative correlation, indicating effect of soil moisture and plant material added to the soil in wheat. Since moisture is less intensely managed in wheat, nutrient availability is constrained mostly by soil water availability.The fertilizer NUE was highly affected by C return in all the treatments except LE and GM, in case of both rice and wheat.

CONCLUSION

Long term studies indicated different relationships for rice and wheat crops. Differences in response of treatments, during rain excess and rain deficit years indicated intricate relationship between water availability and nutrient pools in organic material and soil. These relationships were elaborated in this study.

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Terminal heat stress management in wheat (*Triticum aestivum* L.) through growth regulators and sowing date interventions: A review

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Wheat (*Triticum aestivum* L.) occupies prime position among the food crops of the world in terms of acreage and production. It is second most important cereal crop in India, next to Rice (Anonymous 2015). Global climate models predict an increase in mean ambient temperatures between 2.5 and 7.8°C by the end of this century (IPCC 2014) and are likely to cause large negative impact on crop productivity. Globally, about 7.0 million ha of wheat is affected by heat stress throughout the life cycle and upto 40% of the irrigated wheat growing areas in the developing world faced terminal heat stress (Ruwali and Bhawsar, 1998). So, there is a need to develop various agronomic techniques to mitigate terminal heat stress. Date of sowing plays an important role in productivity of wheat. Late sown wheat is exposed to both extremes of temperature i.e. low temperature during early growth period and high temperature during anthesis period. Late sown wheat experienced high canopy temperature results in reduced dry matter accumulation in leaf, stem and ear at different phenophases (Basu *et al.,* 2014) and change the phenology (Hossain *et al.,* 2015), ultimately lower grain yield. Crop sown on October 25 took maximum calendar days, growing degree days for earing and maturity and highest grain yield under Punjab conditions (Ram *et al.,* 2012). Late sown wheat result in lower chlorophyll content, lower membrane thermostability and ultimately lower yield due to higher temperature conditions at reproductive stage of wheat (Singh *et al.,* 2014). Generally wheat like other cool season crops is seeded early to take maximum period for growth and development towards maturity before the (possible) heat stress. Among the various methods to induce high temperature stress tolerance in plant, foliar application or pre-sowing seed treatment with growth hormones are the common approaches (Wahid *et al.,* 2007). Salicylic acid is involved in many plant physiological processes such as photosynthesis, transpiration, nutrient uptake, and chlorophyll and protein synthesis and endogenous signaling, mediating in plant defense mechanisms against biotic and abiotic stresses (Wahid *et al.,* 2007, Wang *et al.,* 2014). Application of low concentrations of sulphydryl group of bioregulators improves the tolerance of wheat to terminal heat stress (Nilesh *et al.,* 2012). Foliar application and seed treatment of thiourea improved leaf membrane stability and enzymes performance leading to increased yield components (Asthir *et al.,* 2013). Wheat crop sprayed with indole acetic acid, gibberellic acid and abscisic acid significantly improved grain yield under high temperature conditions (Cai *et al.*, 2014). So, optimum sowing time should be followed for raising successful crop. Application of growth regulators may be helpful in ameliorating terminal heat stress.

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Effect of agronomic manipulations to manage climate variability impacts on growth and yield of cotton

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Cotton, commonly known as white gold, is an industrial commodity of worldwide importance. It is the most important fibre crop meeting almost 85 percent of the total fibre requirement of the Indian textile industry. The risk and uncertainty imposed by climate change especially during recent decades could be managed by adoption of agronomic manipulations such as planting methods, mulch application, sowing time and irrigation management. In situ soil moisture conservation techniques such as ridges and furrow, opening of furrow after every rows of cotton, black polythene (25 microns), and spread of crop residue were found to be promising. Cotton fiber quality is determined primarily by genetics, but can also be influenced by environmental factors such as soil type, insect pressure, weather, growing season length and harvest and ginning management. Large-scale adoption of rice-wheat cropping system in Punjab has resulted in over-exploitation of

Table 1. Yield and yield attributing characters of cotton under different planting methods, dates of sowing and irrigation levels

Treatment	Maximum leaf area index	Monopodial branches per plant	Sympodial branches per plant	Seed cotton yield (t/ha)	Total biomass (t/ha)
Planting method					
Flat without mulch	4.67	3.67	25.17	2.22	5.44
Flat with mulch	5.21	3.78	28.12	2.31	5.76
Ridge	3.71	3.62	19.54	1.99	4.34
LSD (P=0.05)	0.63	NS	3.2	0.07	0.25
Date of sowing					
Normal	5.05	3.77	26.67	2.32	5.83
Late	4.00	3.66	21.88	2.07	4.52
LSD (P=0.05)	0.52	NS	2.6	0.06	0.20
Irrigation level					
IW/CPE=0.90	4.51	3.86	25.78	2.14	5.18
IW/CPE=0.75	4.52	3.66	24.62	2.23	5.26
IW/CPE=0.60	4.55	3.62	22.55	2.21	5.11
LSD (P=0.05)	NS	NS	NS	NS	NS
Interaction	NS	NS	NS	0.15	0.35

ground water resources. Thus, cotton can be an alternative to rice for diversification in Punjab state. In view of this, the present investigation was carried out to manage climate variability impact on growth and yield of cotton by agronomic manipulations.

METHODOLOGY

A field experiment was conducted to investigate the growth and yield of cotton under different agronomic manipulations at the Research Farm, School of Climate Change ans Agril. Meteorology, PAU, Ludhiana. Cotton variety MRC 7017 was sown on two dates viz. Normal (D_1: 28th April) and Late (D_2: 27th May) under three planting methods i.e. sowing on flat surface without mulch (M_1), sowing on flat surface with straw mulch (M_2) and sowing on ridges (M_3) and three irrigation levels viz. IW/CPE = 0.90 (I_1), IW/CPE = 0.75 (I_2) and IW/CPE = 0.60 (I_3) in a split plot design. Periodic leaf area index was recorded at 30 days interval starting from 30 DAS till harvesting by using canopy analyser. At maturity, the monopodial (vegetative) branches of the five tagged plants were counted and average was worked out. Sympodial branches (reproductive) branches of the five tagged plants were also counted at maturity and averaged was expressed on per plant basis. Seed cotton yield of each picking was weighed separately and added to get the total yield per plot, which was then converted to per hectare. After all the pickings were done, the plants were pulled out manually and the bundles were weighed separately plot wise.

RESULTS

Agronomic manipulations viz. planting methods and dates of sowing significantly affected maximum leaf area index, sympodial branches, seed cotton yield and total biomass, which could be due to the more moisture availability, better seedling establishment and suppression of the weeds by the mulch, whereas different irrigation schedules could not make significant impact, which could be due to good rainfall distribution during the crop growing period. Flat sowing with mulch application produced significantly higher maximum leaf area index, seed cotton yield as well as total biomass as compared to as compared to flat sowing without mulch and ridge sowing (Table 1). This might be due to temperature regulation and moisture retention by the mulch. Dong *et al* (2008) also reported mulching as a common practice for improving emergence, plant growth and yield of cotton. Timely sown crop also recorded significantly higher yield and yield attributing characters as compared to late sown crop. This might be due to longer vegetative phase in the normal sown crop, due to which more light and nutrition was available to the crop resulting in higher leaf area index, yield and yield attributing characters.

CONCLUSION

Agronomic manipulations like alteration in sowing time and mulch application can be highly beneficial to sustain growth and productivity of cotton under climate change scenarios.

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Impact of crop weather relationship under different dates of sowing on linseed varieties

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In view of the rapid spread of linseed crop, studies on integrated production factor would throw much light to increase the productivity of crop. Since, the area under linseed is decreased now a day due to less yield, hence production technology suitable to its high production needs to be perfected. As reintegrated increase in crop production can be realized by either extending the total area under this crop or by enhancing the crop productivity. To ensure high crop productivity, adoption of improved agronomic techniques is essential. Among the standardized agronomic practices required for realizing yield potential of linseed, sowing time and varieties play pivotal role. It is true that prevalence of congenial weathers conditions is the only factor which neutralizes the good heritable potentiality of a variety under systematic agronomic practices. Recent studies confirm that, varieties differ extensively in the physiological processes determining the yield which are also influenced by environmental factors. With this background, to identify suitable variety and influencing sowing date on yield of linseed, the present investigation was taken up.

METHODOLOGY

The soil samples were drawn for studying the soil properties and then the experiment was laid out during *Rabi* season of 2014-2015 on field of Agronomy farm, College of Agriculture, Nagpur. The experiment was laid out in Split Plot Design with eight treatment combinations with three replications consisting four levels of sowing date *i.e.* 40th MW (D1-1st to 7th October), 41st MW (D1-8th to 14th October), 42nd MW (D1-15th to 21st October), 43rd MW (D1-22nd to 28th October) and two varieties i.e. PKV NL-260 (V1) and NL-97 (V2). The distance between two replications was 1.2 m and 0.9 m between two plots. The gross and net plot size were 3.6 m × 4.8 m and 2.7 m × 4.2 m respectively. The biometric observations were recorded and statistically analyzed as per method given by Panse and Sukhatme (1971).

RESULTS

Different dates of sowing significantly influenced the growth characteristics and yield components of the varieties used in the experiment i.e. number of capsule/plant, number

Table 1. Influence of various treatments on different traits, temperature (^{0}C) and relative humidity (%) requirement for linseed

Treatments	No. of capsule/ plant	Seed yield/ plant(g)	Seed yield (t/ha)	Straw yield/ plant (g)	Straw yield (t/ha)	Biological yield (t/ha)	Harvest Index (%)	No. of Seed per capsule	B:C ratio	Temp. requirement (^{o}C)	RH (%)
Sowing Dates											
D_1 – 40th MW	43.09	2.82	0.793	4.27	1.227	2.020	39.26	8.11	1.88	22.50	52.83
D_2 – 41st MW	44.87	3.24	0.852	4.77	1.321	2.148	39.66	8.69	2.03	25.17	57.83
D_3 – 42nd MW	42.82	2.57	0.745	4.12	1.217	1.950	38.21	7.55	1.79	23.50	64.17
D_4 – 43rd MW	42.20	2.45	0.702	3.60	1.096	1.783	39.38	6.79	1.67	20.83	57.79
SEm±	0.38	0.15	0.012	0.14	0.042	0.028	-	0.14	-		
CD (P=0.05)	1.30	0.51	0.042	0.49	0.146	0.098	-	0.48	-		
Varieties											
V_1–PKVNL-260	43.88	2.95	0.803	4.56	1.253	2.039	39.39	8.20	1.91	23.17	58.60
V_2 – NL-97	42.61	2.59	0.743	3.81	1.177	1.912	38.85	7.38	1.77	22.83	57.71
SEm±	0.38	0.11	0.018	0.20	0.015	0.039	-	0.13	-		
CD (P=0.05)	1.25	0.36	0.060	0.65	0.050	0.126	-	0.42	-		
Interaction											
SEm±	0.77	0.22	0.037	0.40	0.030	0.078	-	0.26	-		
CD (P=0.05)	-	-	-	-	-	-	-	-	-		
GM	43.24	2.77	0.773	4.19	1.215	1.975	39.14	7.79	1.84	23.00	58.16

of seeds/capsule, seed yield/plant (g), seed yield/ha (t), straw yield/plant (g), biological yield/ha (t), harvest index (%) and number of seeds/capsule except for plant stand. Among the four dates of sowing D_2 (41st MW) proved to be significantly superior over other dates of sowing for all the traits studied. Among the four sowing dates, D_2 (41st MW) was found to record higher benefit : cost ratio of 2.03 and lowest benefit : cost ratio (1.67) was recorded by sowing date on D_4 (43rd MW)- There was significant difference among the varieties with respect to their performance in the field for all the characters studied except for plant stand. The variety V1 (PKV-NL-260) recorded significant superiority for all the traits studied over V2 (NL97). Among the two varieties V1 (PKV-NL-260) recorded higher benefit: cost ratio of 1.91 and was followed by V2 (NL-97) with benefit: cost ratio of 1.77. The interaction effect between dates of sowing x varieties were non-significant for all the traits studied. The temperature requirement and relative humidity requirement varied with sowing time and also with varieties. Mean thermal requirement of linseed during growth period is 23.00 thermal units. The linseed sown during 41st MW showed maximum GDD (25.17 thermal units) as more number of bright sunshine hours associated with 41st MW sowing. Variety PKV-NL-260 recorded higher thermal (23.17 thermal units) and relative humidity (58.60) requirement as compared to NL-97. Sowing taken on 42nd MW recorded highest relative humidity (%) during crop period as higher number of rainy or cloudy days are associated with 42nd MW.

CONCLUSION

It is concluded from this study that sowing of linseed crop on D_2 (41st MW) i.e. 8th to 14th October would be suitable and variety V_1 (PKV-NL-260) would be better than V_2 (NL-97) which also is likely to give maximum benefit: cost ratio.

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Effect of sowing date on oil content and yield of safflower cultivars

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Safflower is mainly grown in India for its much-valued edible oil. The seeds of safflower contain 24 to 36 % oil rich in polyunsaturated fatty acids (linoleic acid 78 %), which play an important role in reducing blood cholesterol level and is considered as a healthy cooking medium. In Madhya Pradesh safflower crop is grown mainly in *rabi*season and covers an area of 0.1 thousand ha with total production of 0.025 thousand tones. Then on monetary agronomic practices like choice of appropriate cultivars and time ofs owing are crucial to realize maximum yield. Sowing date can be a major factor that affects oil content and fatty acid composition at the time of seed development (Samanci and Ozkaynak, 2003). Hence study effect of date of sowing on oil content and yield of safflower cultivars was initiated with the objective to find out suitable date of sowing for maximum yield and oil content of safflower, and towork out the economics of different treatments.

METHDOLOGY

To study the effect of sowing time on yield and yield components of safflower cultivars an experiment entitled "Effect of dateofsowing on oil content and yield of Safflower cultivars"was conducted at Field No. 17 under All India Coordinated Research Project on safflower, at R.V.S.K.V.V., College of Agriculture, and Indore (M.P.) during the year 2014-15. Experiment was carried out using split-plot design with four replications and 9 treatment combinations. Dates of sowing were the main factor (D1=1st November, D2=15th November, D3=30th November) and 3 cultivars (V1='A-1', V2='NARI-6', V3='NARI-57') were the sub-factor.

RESULTS

The data presented in Table 1 indicated that dates of sowing brought about significant variation in seed yield. The highest seed yield (1850 kg/ha) was obtained under 1st November sown crop, which was significantly higher over 15th November (1710kg/ha) and 30th November (1375kg/ha) sown crop. Whereas the maximum seed yield (1856kg/ha) recorded with ''A-1'', this was significantly higher over ''NARI-57'' cultivar. The cultivar ''NARI-57'' also recoded significantly higher seed yield as compared to ''NARI-6'' cultivar. The maximum harvest index (26.04%) was recorded with 30thNovember

Table 1. Effect of date of sowing and cultivars on seed yield, harvest index, oil yield , net return and B: C ratio

Treatment	Seed yield (kg/ha)	Harvest index (%)	Oil yield (kg /ha)	Net Return (₹/ha)	Benefit Cost Ratio
Date of sowing					
1 November	1850	21.36	616	45170	4.09
15 November	1711	23.07	512	39445	3.70
30 November	1375	26.04	393	27546	2.88
SEm	26.25	0.43	8.95	619.119	0.042
CD (P= 0.05)	90.84	1.50	30.95	2142.49	0.15
Cultivar					
'A-1'	1908	24.29	501	45173	4.09
'NARI-6'	1272	20.68	394	27217	2.86
'NARI-57'	1758	25.51	625	39771	3.72
SEm	26.81	0.43	8.46	591.93	0.040
CD (P= 0.05)	79.66	1.27	25.15	1758.75	0.12

sown crop followed by 15thNovember sown crop (23.07%). However, 15th November sown crop also gave significantly higher harvest index over 1st November sown crop. There was a significant difference among cultivars in harvest index.'NARI-57' registered the highest harvest index (25.51%) at par with 'A-1' (24.29 %) whereas 'NARI-6' gave the lowest harvest index of 20.68 %.Oil content of safflower was significantly influenced by different dates of sowing. The maximum oil content (33.36%) and oil yield (615.19 kg / ha)was observed with 1stNovembersown crop followed by 15th November and 30thNovember sowing. The different cultivars registered a significant variation in oil content of safflower. The maximum oil content (35.30%) and oil yield (624.87 kg /ha) was received with 'NARI-57' followed by 'NARI-6' and 'A-1' cultivar which was significantly higher over 'A-1' (500.95) and 'NARI-6' (394.50). The highest net return of 45170/ha was obtained with 1st November sown crop which was significantly higher over 15th November (39445/ha) and 30th November (27546/ha) sown crop. The maximum net returns of 45173/ha was obtained in cultivar 'A-1' which was significantly superior over 'NARI-6' and 'NARI-57'. B: C ratio was significantly decreased with delay in sowing. The highest B: C ratio of 4.09 was recorded under 1stNovember sown crop which was significantly superior over 15th November and 30th November sown crop. Whereas the highest B: C ratio of 4.09 was recorded in cultivar 'A-1' which was significantly superior over 'NARI-57' and 'NARI-6'.

CONCLUSION

On the basis of above findings, it may be concluded that 1st November is found ideal time for sowing of safflower as it recorded higher grain yield and oil yield than other sowing dates. Safflower cultivars, 'A-1' and 'NARI-57' are found promising. Cultivar 'A-1' recorded significantly higher seed yield (2129.62 kg /ha), Gross returns of (68095/ha), net return of (53470/ha), B: C ratio of (4.66) and energy output: Input ratio of (8.42) sown on 1st November as compared to other treatment combinations. But the combination of Cultivar 'NARI-57' and 1st November sowing gave the higher oil content (38.80%) and oil yield (758.66 kg /ha) than all other treatments.

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Climate smart agricultural practices: Improving productivity, profitability and resource use efficiency of small-hold farms of Eastern Indo-Gangetic Plains of India

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The Eastern IGP is characterized as small and fragmented farm holding, poor input and output marketing infrastructure, poor access to new technologies and frequent climatic aberration (floods, drought and temperature), shorter wheat growing season compared to Western IGP.Ever increasing input, energy and labour cost , poor access to mechanization and knowledge, forced farmers to opt sub-optimal crop management practice which leads less crop yield and farm profit.In recent years, the impact of climate change also affecting small holder production system in the region. To address these challenges, several conservation agriculture based management practices, developed and disseminating since last 15 years by the ICAR, SAU and CGIAR organizations in the region. These conservation agriculture based practices improved productivity and profitability with improved resource use efficiency and also have better adaptation potential to aberrant weather situations and climate change (Jat *et al*., 2014). These conservation agriculture based resource use efficient technologies termed as climate smart agriculture (CSA) practices CSA is defined as an approach that promotes sustainable increase in agricultural productivity and income, adapting and building resilience to climate change and reducing greenhouse gas emissions. Farmers of the region using a range of CSA practices but the large scale adoption realised for zero tillage wheat. The main constraint in adoption CSA practices was timely availability of appropriate knowledge and inputs including machinery. To resolve these issues we started working in cluster mode which we termed as climate smart village in which we demonstrating a range of climate smart practices with side by side comparison of existing practices to evaluate the potential yield and economic benefits and to develop the confidence of small and marginal farmers to adopt these CSA practice.

METHODOLOGY

During 2012 to 21015, developed about 40 climate smart villages in Vaishali and Samastipur district of Bihar where we have demonstration a range of climate smart agriculture practices developed under our long-term strategic research trials in the region. The major CSA practices demonstrated in CSV were Zero tillage wheat (ZTW), ZT Direct seeded rice (ZTDSR), permanent raised bed wheat (PBW), permanent raised bed maize (PBM), zero tillage maize, laser land levelling, new climate resilient varieties, cropping systems intensification through adjusting the planting dates and selecting the suitable varieties which fit into the system, green seeker and nutrient expert based nutrient management, better water and weed management. We have used the weather information for planning the different cropping system intensification models and for better utilization of residual soil moisture as well as monsoon rains. Farmer practices involved puddled transplanted rice (PuTPR), conventional till broadcasted wheat using higher seed rate (CTW) with sub optimal nutrient management and old varieties. All these CSA interventions were compared with the existing conventional farmer's practices by side by side comparison. In all demonstrations, we have recorded all inputs used and output for economic comparison of new interventions with existing practices.

RESULTS

The results of different farmer's participatory demonstrations showed that CSA interventions improved productivity, profitability and resource use efficiency over conventional farmer's practices. Direct seeded rice recorded similar or higher rice yield and INR 6709 higher net returns as compared to PuTPR. The higher net return of DSR was mainly due lower cost production of DSR as compared PuTPR. Zero tillage and permanent raised bed planting systems in wheat improved wheat productivity by 21 to 24% and net returns by 50 to 66% as compared to conventional broadcasted wheat. The higher profitability in wheat under ZT and PB was mainly due to higher productivity with the improved planting system. The laser land levelling and Bed planting also save irrigation water by 17% to 22% over conventional farmers practices and increased wheat yield by 10 and 21%, respectively as compared to CTW. Zero tillage and permanent raised beds increased maize productivity by 47 and 52%, respectively, and net returns by 21 and 49%, respectively, as compared to conventional maize. Precise land levelling increases water and nutrient use efficiency, improves crop establishment and weed control in the crop field that lead tohigher yields than in unlevelled fields. Nutrient expert based nutrient management improved nitrogen use efficiency by 4% and also increased the wheat productivity by 8%.

CONCLUSION

The different components of CSA practices improving the productivity profitability and resource use efficiency of the small hold farms of eastern IGP. Improved climate resilient varieties with better management practices (planting systems, water management and nutrient management) increasedthe productivity of rice, wheat and maize ranging from21 to 102% and net returns of the small holder farmer by 34 to 39% with improved resource use efficiency as compared to traditiontional varieties and conventional high energy input based management practices.

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Diminishing effect of aberrant weather condition through foliar spray of chemicals

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Soybean [*Glycine max (L.) Merrill*] is playing an important role in augmenting both the production of edible oil and protein. In India it occupies an area of 12.20 million ha and its production is 11.99 million tonnes with an average productivity of 983 kg/ha (Anonymous, 2014). The crop suffers by aberrant weather (dry spells) and insect attack during growth and development stages. By considering these situation soybean crop is evaluated with some corrective measures to mitigate the aberrant monsoon conditions with and without mixing of common insecticide *i.e*. Trizophos.

METHODOLOGY

The field experiment was conducted at the Research Farm, College of Agriculture, Indore, during *kharif* season of 2015 under AICRP for dry land. The experimental soil was clay in texture having 0.43% organic carbon, 180.0 kg available N, 12.02 kg available P_2O_5, 504 available K_2O/ha and pH 7.53. The study involves nine treatments, *viz*., T_1: Absolute control, T_2: Water spray at 29 and 60 DAS, T_3: Foliar spray of 1% KNO_3 solution at 29 and 60 DAS, T_4: Foliar spray of 2% KCl solution at 29 and 60 DAS, T_5: Foliar spray of thiourea @ 250 g/ha solution at 29 and 60 DAS, T_6: T_3 + Trizophosh @ 600 ml/ha (tank-mix), T_7: T_4 + Trizophosh @ 600 ml/ha (tank-mix), T_8: T_5 + Trizophosh @ 600 ml/ha (tank-mix) and T_9 Interculture operations. Experiment was conducted in randomized block design with 3 replications. The dry spells experienced during the crop period are given in Table 1.

Table 1. Dry Spells during crop period

Dry spells		Stage of the
Duration (Days)	Dates & months	Soybean crop
24 days	26 June-18 July	Seedling stage
31 days	13 Aug-13 Sept	Reproductive stage (Flowering; and pod filling in soybean)
10 days	20 Sept-30 Sept	Grain filling

RESULTS

The number of pods/plant differed significantly due to different treatments. The treatment T_8 (foliar spray of tank-mix thiourea @ 250 g/ha + Trizophas insecticide @ 600 ml/ha at 29 and 60 DAS) recorded highest number of pods (13.33 plant), which was significantly higher as compared to T_1 and T_2 and at par with rest of the other treatments. The significantly higher weight of 100-seeds 9.60 g was recorded with treatment T_8. The maximum seed yield of 365 kg/ha was obtained with treatment T_8 followed by T_6 (350 kg/ha), T_9 (345 kg/ha) and T_5 (333 kg/ha) and all these treatment resulted in 53.36 percent increase seed yield over control. Significantly

Table 2. Effect of different treatments on No. of pods, Pod length, seed index, seed yield, straw yield and harvest index of soybean.

	Treatment	Pods per plant	Pod length (cm)	Seed Index (g)	Seed Yield (kg/ha)	Straw Yield (kg/ha)	HI (%)
T_1	Absolute control	9.40	3.42	7.13	238	1225	16.42
T_2	Water Spray at 29 and 60 DAS	9.91	3.60	7.87	249	1306	16.06
T_3	Foliar Spray of 1% KNO_3 solution at 29 and 60 DAS	10.44	3.66	8.06	327	1617	16.85
T_4	Foliar spray of 2% KCl solution at 29 and 60 DAS	10.87	3.79	8.11	306	1287	19.27
T_5	Foliar spray of thiourea @250g ha^{-1} solution at 29 and 60 DAS	12.18	3.72	8.27	333	1519	18.51
T_6	T3 + Trizophos @600 ml/ha tank mix	12.64	3.94	8.98	350	1665	19.22
T_7	T4 + Trizophos @600 ml/ha tank mix	11.31	3.71	8.63	331	1650	16.80
T_8	T5 + Trizophos @600 ml/ha tank mix	13.33	3.99	9.60	365	1702	18.29
T_9	Inter culture	11.17	3.50	8.50	345	1501	16.23
	SEm(±)	0.52	0.11	0.39	19	131	1.20
	CD (P=0.05)	1.57	0.33	1.16	58	NS	3.59

higher straw yield (1702 kg/ha) recorded in T_8 but at par with treatment T_9 (1665 kg/ha), T_7 (1650 kg/ha), T_3 (1617 kg/ha), T_5 (1519 kg/ha) and T_4 (1501 kg/ha).

CONCLUSION

On the basis of above findings, it may be concluded that foliar spray of thiourea @ 250 g/ha + Trizophas @ 600 ml/ha (tank-mix) at 29 and 60 DAS gave higher growth and yield attributing characters, seed yield as well as net income with maximum benefit cost ratio under aberrant monsoon conditions (Dry spells during seedling, vegetative and reproductive stage)

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Enhancing the production through weather based agro advisories of the farmers under climate chance scenario

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Weather is one of the most important factors determining success or failure of agriculture production. It effects on every phase of growth and development of plant. Any variability in the weather during the crop season, such as delay in the monsoon excessive rains, flood, droughts, spells of too - high or too – low temperatures would affects the crop growth and finally the quality and quantity of the yield. The losses in crop can be reduced by doing proper crop management in time by timely and accurate weather forecasts. The objective of the weather forecasting is to advice the farmers on the actual and expected weather and impact on the various day to day farming operations i.e. field preparation and sowing, seed and seed treatments, manure & fertilizer weeding & thinning, plant protection, harvesting and threshing etc. and overall package and practices. Weather forecast helps to increase agriculture production, minimize losses, risks, minimize costs of inputs, improve quality of productivity, labour and energy and reduce pollution. The benefit by the formers using agromet advisory bulletin and weather forecast for making farm level decisions by farmers from different village have been discussed in this paper.

METHODOLOGY

The integrated agromet advisory services (IAAS), Zonal Agricultural Research station, Chhindwara has been serving the farming community in satpura platue agroclimatic zone. The major objective of this programme is to advise timely and need based crop management practices. Weather forecast on

Table 1. Economic impact of AAS on maize (Rs/acre) during 2014-15

Type/Crops	Field preparation & sowing	Seed & seed treatment	Manure & fertilizer	Weeding & thinning	Plant protection	Harvesting/ threshing	Input benefit	Yield (kg/ac)	Rupees	Net benefit
AAS	1150	530	2382	1060	500	1000	6622	2160	23760	
Non AAS	1600	620	3034	1600	384	1128	8366	1890	20790	
Benefit	450	90	652	540	-116	128	1744	370	2970	4714

Table 2. Economic impact of AAS on gram (Rs/acre) during 2014-15

Type/Crops	Field preparation & sowing	Seed & seed treatment	Manure & fertilizer	Weeding & thinning	Plant protection	Harvesting/ threshing	Input benefit	Yield (kg/ac)	Rupees	Net benefit
AAS	900	1200	1384	500	350	1100	5434	780	27300	
Non AAS	1100	1600	1632	1000	900	1230	7462	690	24150	
Benefit	200	400	248	500	550	130	2028	90	3150	5178

rainfall, maximum and minimum temperature, wind speed, wind direction, could over, maximum and minimum humidity are being received on every Tuesday and Friday from IMD, Bhopal. Once the forecast was received the experts, operation from different disciplines was obtained. Based on the advice, the agro advisories are being prepared on every Tuesday and Friday in Hindi as well as in English. The advisories are sent to IMD Bhopal for preparation of regional bulletins and up-loaded of national bulletin on the IMD website in both Hindi and English. Bulletins are regularly communicated to the farmers on real time basis through telephone/SMS. Agromet advisory bulletins are also sent by e-mail to local Hindi news-papers, as well as two KVK, Chhindwara and Betul, NGO, ATMA, State Agriculture, e-choupal, Krishi Darson and all India radio through email messages. The weather forecast based on agro advisory bulletin contains a summary of previ-ous weeks, weather forecast information for the next five days. Weather forecast and weather based agromet advisories help in increasing the economic benefit to farmers by suggest-ing them the suitable management practices according to the weather conditions. A study was, therefore undertaken on ad-aptation of agromet advisory bulletin and economic impact of agromet advisory services for maize from kharif season and gram from rabi season during 2014-2015. For assessing the impacts of agromet advisory services, users of agromet advi-sory services (AAS) and non users of agromet advisory ser-vices (non AAS) were selected for maize and gram crop. The study area covers over all district of Chhindwara, Madhya Pradesh.

RESULTS

The results revealed that the farmers who followed the agromet advisories are able to reduce the input cost up to 21 % in maize and 27 % in gram and increases the net profit by 14 % in maize (table 1) and 13 % in gram crop (table 2) as compared to the non AAS farmers. AAS formers were able to reduce the input cast up to Rs. 1744/acre in maize and Rs. 2028/acre in gram. Increases in the net profit were Rs. 4714/ acre in maize and ‘ 5178/acre in gram compared to non AAS farmers. More net returns of AAS farmers over non AAS farmers can be due to low input cost, following weather based management practices and timely management of pest and diseases. This profit was due to the crop management done by the farmers such as timely field preparation and sowing adap-tation of recommended seed rate and suitable varieties, timely weeding, harvesting and plant protection measures according to agromet advisory bulletins.

CONCLUSION

The studies showed that the application of agromet advi-sory bulletin, based on forecasted weather is a useful tool for minimizing the climatic risk in production and income. AAS farmers received weather forecast based on advisories includ-ing optimum use of inputs for different farm operations. Due to judicious and timely utilization of inputs, reduced the pro-duction cost for the AAS farmers, increased yield level and reduced cast of cultivation and to increased net returns.

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Study of meteorological drought indices for Amravati Tehsil in Vidarbha region of Maharashtra

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Precipitation deficiency, due to natural climatic variability in space and time, is the primary cause of drought. The most common tool for monitoring drought conditions in any area is a drought index. A drought index can be used to quantify the moisture condition of a region and the spatial extent of a drought severity (Alley, 1984). The drought preparedness can be developed and drought impacts can be managed. Drought indices are used in determining the drought proneness of an area. Although none of the major indices is inherently superior to the rest in all circumstances, some indices are better suited than others for certain uses (Ntale and Gen, 2003). Most decision makers and resource managers find it useful to consult and integrate one or more indices before making a decision in a convergence of evidence approach. The different drought indices *viz.,* AI, DI, EDI, SPI, PDSI, etc. have been used by several researchers *viz.,* Gibbs and Maher (1967) for drought characterization of different places. For proper crop planning and management there is an urgent need of analysis of droughts occurred in this area by quantifying and categorizing them using suitable drought index. Standardized Precipitation Index (SPI), Decile Drought Index (DI) and Effective Drought Index (EDI) are some of the widely used meteorological drought indices for drought quantification. These indices are solely based on precipitation data. Considering above facts, a study of meteorological drought indices in Amravati tehsil of Amravati district in Vidarbha region of Maharashtra was undertaken to analyze long term seasonal rainfall records, to estimate DI, EDI and SPI for assessment of drought and study of different meteorological drought indices.

METHODOLOGY

The study was conducted for Amravati tehsil of Amravati district of Vidharbha region in Maharashtra. The 22 years (1991-2012) rainfall data and yield data of soybean crop was used for this study. The average seasonal rainfall of the tehsil is 799 mm. The decile value for each monsoon month from June to September has been calculated and compared with actual rainfall of that month to identify the severity of drought according to the classification given by Gibbs and Maher (1967). The drought years were computed using the criteria given by George and Kalyansundaram (1969). The index, which is having more consistency with historical drought events, was characterized as good indicator of drought for this study area. The three indices were checked with the well-known historic drought event during 1991, 1995, 2000 and 2002 in Amravati district. Due to the discrete variation of two variables (i.e. yield and drought year), Spearman rank correlation was chosen as a measure of how well years ranked by drought index value are compared to years ranked by yield of the area. For all drought indices, a positive index value indicates wetter than normal condition and negative index value imply dryer than normal conditions. Correlation between the drought years and yield of the year can range between -1 and 1. A positive correlation indicates a direct relationship between two variables and vice-versa.

RESULTS

The drought years identified by three drought indices i.e., DI, EDI and SPI at Amravati tehsil during 1991–2012 are sorted out according to drought severity and presented in Table 1, 2 and 3 respectively. The climatic condition identified by DI during 1991-2012 was determined and presented in Table 1. From Table 1, it is seen that, out of 22 years, 8 years (36 %) were mild drought years, 7 years (32%) were moderate drought years, 2 years (9%) were severe drought years and 5 years (23%) were normal years. The climatic condition identified by EDI during 1991-2012 is presented in

Table 1. Climatic condition as identified by decile drought index during 1991 -2012 for Amravati tehsil

	Climatic Condition			
Above normal	Normal	Mild drought	Moderate drought	Severe drought
—	1998 2007 2010 2011 2012	1992 1994 1996 1999 2001 2005 2006 2008	1991 1993 1997 2000 2002 2003 2009	1995 2004

Table 2. Climatic condition as identified by EDI during 1991 – 2012 for Amravati tehsil

Climatic Condition								
Extremely wet	Severewet	Moderate wet	Mild wet	Normal condition	Mild drought	Moderate drought	Severe drought	Extremely dry
2010	—	1998 2000 2001	2005 2007	1991 1992 1993 1994 1999 2003 2006 2011 2012	2008 2009	2002	1995 1997 2004	1996

Table 2. It is observed that maximum number of years falls under normal climatic category (9 years i.e., 41%) followed by severe drought (3 years i.e., 14%), moderate wet (3 years i.e., 14%). The EDI identified two years each in mild wet and mild drought category whereas one year each in extremely wet, moderate drought and extremely dry climatic condition. The seasonal climatic condition by considering the 3-months SPI for September is summarized in Table 3. From Table 3, it is revealed that maximum number of years falls under mild wet category (8 years i.e., 36%), mild drought category (7 years i.e., 32%) followed by moderate wet (4 years i.e., 18%) climatic category. The SPI identified one year each in severe wet, severe drought and extremely dry climatic condition. From Table 1, 2 and 3, it is observed that SPI and decile index methods had identified most of the drought years which were not observed by EDI method. However, decile index method has identified more years in moderate and severe category compared to SPI and EDI methods. From the above results, it can be concluded that SPI method identifies all the drought years consistently and distinctly over DI and EDI method which proves the superiority of SPI method over the latter two drought indices. The three indices have identified the four major historical droughts in Amravati district viz., 1991, 1995, 2000 and 2002. Decile index and SPI are showing more consistency with historical drought events indicating the superiority of these two indices over EDI in identifying proper severity of drought in the area. From the correlation between soybean crop yield data and drought years severity obtained by different indices, it can be revealed that for Soybean crop, DI gives highest positive correlation (0.71) followed by SPI (0.58) and EDI (0.49). It can be concluded that the performance of decile index and SPI can be considered as better in identification of drought over EDI.

CONCLUSION

The monthly rainfall at Amravati tehsil in Amravati district of Vidarbha region of Maharashtra was analyzed to estimate and compare DI, EDI and SPI for identifying drought years in Amravati tehsil using 22 years rainfall data. Decile index and SPI are showing more consistency with historical drought events indicating the superiority of these two indices over EDI in identifying proper severity of drought in the region. From the correlation between soybean crop yield data and drought years severity obtained by different indices, it can be concluded that the performance of decile index and SPI can be considered as better in identification of drought over EDI. The three indices were compared using seven assessment criterion adopted by Ntale and Gan (2003) and Dabare (2007). Standardized precipitation index (SPI) satisfies the entire seven assessment criterion followed by Decile index which fulfills only four criteria, SPI can be considered as the most suitable index for drought assessment in Amravati district.

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Recovery potential of popular wheat varieties under climatic stress

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Wheat (*Triticum aestivum* L. em Thell.) is the important cereal crop used as the staple food by the majority of world's populations and is cultivated over a wide range of climatic conditions. Wheat contains almost 55% of the carbohydrates and 20% of the food calories as food for consumers and farmers. In India, wheat contributes an annual production of 95.85 Mt, covering area of 30.47 Mha and productivity of 3.15 Mt per hectare (DES, 2014). Currently agriculture is facing multidimensional challenges including climate change. In India, wheat is challenged by climatic risks such as early and terminal heat stress, and unseasonal rainfall with heavy winds. The unseasonal rainfall coupled with heavy winds during March 2014 and 2015 coincided with grain filling period and affected wheat yield leading to significant reduction in production. Such climatic risks are projected to increase in future challenging the wheat productivity. Thus there is a need to identify some possible adaptation strategies to minimize the adverse impacts of climate change. Genotypic adaptation is the most important intervention for sustaining wheat productivity. Presently farmers grow short, medium and long duration varieties of wheat. Since the duration of preceding crop influences the succeeding one, it is essential to know the region specific variety. This sort of information becomes important in changing climatic conditions where there is a possibility of shift in sowing times as well as change in suitable growing periods. In wheat, conversion of late sown areas into timely sown areas could significantly improve yield even with the existing varieties in the future (Naresh *et al.*, 2014).

METHODOLOGY

A field experiment was conducted during *Rabi* season of 2014-15 in the Research Farm of ICAR-Indian Agricultural Research Institute, New Delhi. Geographically, Delhi is situated between latitude of 28°37' and 28°39' N and longitude of 77°9' and 77°11' E at an altitude of 225.7 meter above mean sea level. It has semi-arid, sub-humid and sub-tropical climate with hot dry summer and severe cold winter. The mean maximum temperature during the crop season was 22.93°C, while the mean minimum temperature was 9.28°C. Rainfalls during the crop period was 263.62 mm and mean bright sunshine hours were 4.3. The soil of experimental field was slightly alkaline with low electrical conductivity and was well drained. The soil issandy loam in texture with pH 7.5 and has about 0.43% SOC. Experiment was laid out in a homogenous field with six varieties differing in duration. Two short duration (K – 9423, K – 7903), two medium (WR – 544, HD – 2985) and two long duration (HD – 2967, HD 3086) in a randomized block design with four replications. Crop was sown on 16 November 2014. The uniform dose of fertilizers were applied (120N:60P_2O_5:40K_2O) in this experiment. To facilitate uniform distribution of water, the irrigation channels were prepared between two replications. Total five irrigations were given at all the important physiological growth stages (Crown root initiation, tillering, flowering, milking and dough stages) of wheat.

RESULTS

During 2014 and 2015 march unseasonal rainfall affected the wheat yields because it is coincided with panicle development and grain filling or mid-filling period. In this study, the effect of that event and the recovery potential of the six varieties were studied. The number of hills/m^2 significantly varied in different varieties (Table 1). The highest number of tillers were observed in variety HD 2967 followed by variety WR 544. Analysis of each hill indicated that HD 2967 had more number of tillers/hill while K 7903 had the least number. Rain with heavy wind occurred on 8th march 2015. The following day, overall lodging in the field was observed. Then after a gap of 10 days, the lodging was scored. The highest lodging was observed in HD 2985 and lowest lodging was in HD 2967. Further, observations were done on the number of hills that remained straight, lodged and recovered in a square meter area. The hills which had started to grow upward are designated as recovered hills. The more number of straight hills/m^2 was observed in HD 2967 followed by WR 544 whereas, lodged hills/m^2 were highest in HD 2985 and least in HD 2967. Subsequently, grain yield was taken after physiological maturity. Grain yield varied from 3.04 to 5.72 t/ha among the varieties. Yield deviation was calculated using the formula (variety yield –mean yield)/ mean yield, where mean yield is

Table 1. Overall lodging in the field and yield deviation

Variety	Total number of hills/m^2	No. of tillers/hill	Lodging in overall field (%)	Straight (hills/m^2)	Lodged (hills/m^2)	Recovered (hills/m^2)	Yield deviation from mean performance of all varieties (%)
K 9423	48	15	37.5	21	9	17	-5.26
K 7903	49	14	54.2	15	15	18	-10.29
HD 2967	52	17	12.0	34	3	13	+31.58
WR 544	49	14	25.0	25	15	10	+0.72
HD 2985	45	15	83.7	3	37	5	-32.54
HD 3086	46	16	33.7	18	6	22	+16.75
SEm±	1.15	0.49	10.54	0.76	0.62	0.83	
CD (P=0.05)	3.50	1.48	32.05	2.30	1.89	2.52	

the mean of all varieties. The highest yield deviation was found in the variety HD 2967 (+31.58%) followed by variety HD 3086 (+16.75%), while the other varieties either showed negative deviation or no difference. Hence it can be concluded that the variety HD 2967 is highly resistant to lodging followed by HD 3086.

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Trend analysis of temperature and rainfall data over Bundelkhand Region of India

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Climate change and global warming are worldwide recognized as the most significant environmental problem the world is experiencing today (IPCC, 2007). In India, climate change is particularly a serious challenge that will significantly impact the Indian economy which is highly dependent on climate-sensitive sectors such as agriculture, forestry and fishing. Now a-days, study of long-term temperature and rainfall variability has been a topic of particular attention for climate researchers. In this context, the present study was undertaken to analyse the long term trend of rainfall depth, minimum and maximum temperature of twelve districts of Bundelkhand Region of India using Man-Kendall test.

METHODOLOGY

In this study, the climatic parameters *viz.* maximum temperature, minimum temperature and rainfall of 45 years (1969-2013) of the study region were collected from India Meteorological Department (IMD) and India Water Portal website. Thereafter, data were statistically processed and then reduced to annual mean values for further analysis. The non-parametric Mann-Kendall (MK) test was undertaken on time series data of annual rainfall depth, average maximum and minimum temperature for twelve districts of Bundelkhand Region namely, Banda, Chattarpur, Damoh, Datia, Hamirpur, Jalaun, Jhansi, Lalitpur, Mahoba, Panna, Sagar and Tikamgarh using XLSTAT software at 5% significance level.

RESULTS

The increasing trend was observed in maximum temperature for all the districts but it was found statistically significant for only five districts *viz.* Chattarpur (Sen's slope of 0.023), Damoh (Sen's slope of 0.021), Jhansi (Sen's slope of 0.01), Lalitpur (Sen's slope of 0.02) and Sagar (Sen's slope of 0.018). In case of minimum temperature, the significant increasing trend was noticed for all districts of the study region. The increasing trends in maximum temperature and minimum temperature were also observed for other regions of India. The findings clearly indicate that the annual rainfall depth in most of the districts of the study region generally exhibit no statistically significant trends with respect to time except three districts namely, Chattarpur, Hamirpur and Tikamgarh with a Sen's slope of -7.06, -8.05 and -6.94, respectively.

CONCLUSION

This type of information would be helpful in facilitating a transition to more sustainable and adaptive water resources planning and management. Ultimately, this will help policy makers and scientists to focus on district scale planning measures for climate change adaptation and mitigation, by considering regional and local scale variability in climatic trends in Bundelkhand region of India.

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A study on air pollution across Bangalore and application of GIS

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The worldwide studies have revealed that the gaseous pollutants and particulate matter emissions have got immense tendency to cause impacts on human and animal health, biodiversity including plants. In this study, the Air Quality Index was calculated for different stations in Bangalore. Currently, as per Karnataka State Pollution Control Board, Bangalore, there are 15 stations which monitor the air quality at different locations including the residential areas, sensitive zones like hospitals, kerbside locations and industrial areas. Two out of these 15 locations are those where continuous monitoring takes place and the data is available in real time, whereas at the other 13 locations the manual networks are available where the monitoring frequency is twice a week. In India, about 40 monitoring stations are operated continuously whereas 573 stations monitor the data manually. Air Quality Index was calculated for these non-continuous stations for the month of April 2015. The formula used for the calculation was based on the 'National Air Quality Index' Report, 2014 published by CPCB. The calculations were based on the day wise data that was available when the monitoring took place with the frequency of twice a week. A similar approach was followed for the calculation of month wise Air Quality Index for the year 2014-2015. The spatial representation of the Air Quality Index was also done with the help of GIS, where the month wise data was represented across these 13 locations. A part of the study also included the representation of air quality data using QGIS. Depending upon the type of location, the values of air pollutants also showed significant changes. At kerbside locations; due to huge traffic, the pollutant levels were much higher. The observation of the data stated that the SO_2 and NO_2 values were within the standards for most of the locations, whereas, the particulate matter emissions were comparatively higher. The study further indicated that overall emissions were much higher for the central zone for SO_2, NO_2 and Particulate Matter. Further studies are suggested to know the timely impact of such changes in air quality on health of human beings, animals, agricultural crops and overall ecology of the area.

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Developing and validating climate smart agriculture practices portfolios for smallholder rice-wheat systems of Eastern IGP

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The Eastern IGP is characterized as highly populated, small farm holding size, poor input and output marketing infrastructure, poor access to new technologies and frequent climatic aberration (floods, drought and temperature), shorter wheat growing season compared to Western IGP. In this rain dependent agro-ecology, the conventional system of rice wheat system is intensively dry and wet tillage on imprecise leveled land followed by transplanting of 25–40 days old seedlings and most of the time farmers are not able to transplant rice seedlings in time which leads to reduced rice yield. Moreover, the conventional rice planting system increases production costs and delays the seeding of succeeding wheat crop. Also the repeated wet tillage operations in rice are not only labour, water, time, energy and carbon inefficient but also destroy soil quality and lead to 8–9% reduction in wheat yield compared to wheat grown after dry direct seeded rice (Jat *et al*., 2014). To address these challenges, climate smart agriculture practices (CSAPs) focused on conservation agriculture (CA) based crop management practices coupled with associated inputs (water, nutrient, cultivar choices, weather based decision etc.) are being developed, adapted and promoted in the region. A farmer's participatory strategic research trial was designed and conducted during 2015 to test various CSAPs with differential layering of each other to study their effects on crop productivity, profitability and resource use efficiency in a rice-wheat system.

METHODOLOGY

The participatory strategic research trial was conducted at two climate smart villages [Sindwari (25.44,247N, 85.16,987E) and Kanhauli Dhanraj (25.47,813N, 85.21,236E)] in Vaishali district of Bihar, India. Six scenarios comprising of combination of various management factors as are given in Table 1 were evaluated. For PuTPR, 23 days old seedlings were transplanted after 3 passes of dry tillage followed by 2 passes of wet tillage & planking. In CTW, 4 passes of dry tillage (harrow & cultivator), broadcasting of 150 kg seed/ha followed by 1 pass of tillage and planking was

Table 1. Treatment description of different scenarios

S. No.	Tillage	Crop Establishment	Precision Land levelling	Cultivars	Residue Management	Nutrient anagement ($N:P_2O_5:K_2O$)
S1	FP	PuTPR:CTW	None	Rajshree –PBW 343	FP	FFP(125;50;33)
S2	FP	PuTPR: CT-LSW	None	Rajshree –PBW 343	Incorporation wheat stubble (1.5 to 2 t/ha) – 50 % of rice	FFP(125;50;33)
S3	Reduced till	RTDSR : RT-LSW	None	Arize 6444–HD 2967	-do-	SR(150;60;40)
S4	Reduced till - Zero till	DSR :ZTW	Yes	Arize 6444–HD 2967	Incorporation of wheat stubble (1.5 to 2 t/ha) – 50% of rice Retention	SR(150;60;40)
S5	Zero till	ZT-DSR : ZTW	Yes	Arize 6444–HD 2967	Retention wheat stubble (1.5 to 2 t/ha) – 50 % of rice	SR+ GS guided N
S6	Zero till	ZT-DSR : ZTW	Yes	Arize 6444–HD 2967	-do-	NE + GS guided N

Note: FP, Farmers practice; ZT, Zero tillage; CT, Conventional tillage; RT, Reduce tillage; DSR, Direct seeded rice; PuTPR, Puddled transplanted rice; LSW, Line sown wheat; FPP, Farmers fertilize practice; SR, State recommendation; GS, Green Seeker; NE, Nutrient expert.

Table 2. Effect of CA based management practices on productivity, profitability and resource use efficiency

Scenarios	Grain yield (kg/ha)		Cost of Cultivation (Rs./ ha)		Net Return (Rs./ ha)		Partial factor productivity of Nitrogen (PFP-N; kg/kg N)	
	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat
S_1	3312.50^{E}	3427.50^{D}	37983.76^{A}	35070.57^{AB}	21416.24^{CD}	40534.43^{C}	32.7^{A}	28.61^{CD}
S_2	3304.00^{E}	3778.75^{CD}	38080.26^{A}	36856.15^{A}	21135.99^{D}	43810.73^{C}	32.6^{A}	31.54^{B}
S_3	3475.00^{D}	3971.25^{C}	40228.00^{A}	35172.70^{AB}	21174.50^{D}	47576.05^{BC}	23.2^{C}	26.39^{D}
S_4	3715.00^{C}	4395.00^{B}	39945.90^{A}	32706.52^{C}	25360.35^{C}	61077.23^{AB}	24.8^{C}	29.20^{BC}
S_5	3887.50^{B}	4556.25^{AB}	34481.08^{B}	32507.51^{C}	34395.17^{B}	64211.24^{A}	28.9^{B}	34.51^{A}
S_6	4350.00^{A}	4782.50^{A}	34505.65^{B}	33635.90^{BC}	41776.85^{A}	66788.47^{A}	34.7^{A}	35.68^{A}

practiced. For ZTDSR, 25 kg seed/ha was drilled using a multi-crop zero till seed-cum-fertilizer planter without any tillage. For ZTW and LSW same machine was used, using 100 kg seed/ha. The yields were recorded using the standard protocols. For weed control measure recommended practices were used. Nutrient management was used as described in the table 1 and in S5 and S6 GS and NE guided nutrients were applied. The profitability (net returns) was calculated as the values of the inputs and outputs over the years in Indian rupees.

RESULTS

The results showed that different CSAPs used in various scenarios had significant effect on crop productivity, profitability and resource use efficiency. The best management practices of scenario 6 (S6) including laser levelled field adapted variety and precision nutrient management under zero tillage, improved up to 40% grain yield and 65% net return of wheat as compared farmers practice (S1). Similarly the best management practices for rice in S6 improved rice yield by 30% and net returns up to 95 as compared to conventional management practices and old varieties (S1). Switching wheat crop management practice from conventional broadcasting (S1) to line sowing (S2) increased wheat productivity by 10% and net return by 8%. The scenario 3 treatment including new variety line sowing under reduced tillage and state recommended nutrient management increased grain yield and net returns of wheat by 16 and 17%, respectively. Laser land levelling and zero tillage with new variety and SR nutrient management (S4) increased productivity and profitability over S1 by 12 and 20% respectively in rice and 28 and 39%, respectively in wheat. There was no any yield and economic advantages of DSR without laser land levelling (S3) as compared to farmers practice (S1). Super imposing of green seeker based Nitrogen management over S4 treatment (S5) did not showed much advantage. Super imposition of best nutrient management (Nutrient expert guided NPK along with GS guided N) over S4 (S5) increased productivity, profitability and nitrogen use efficiency by 17, 64 and 10% respectively, in rice, and 9, 10 and 6%, respectively in wheat. The higher profitability of CA based management practices were due to improved resource use efficiency, higher productivity and less production cost which also reported by Jat *et al*.(2014) under the long-term effect of CA on the productivity and profitability of RWCS in eastern IGP.

CONCLUSION

IGP have great scope for improving the productivity and profitability of R-W cropping system with improved resource use efficiency as the management yield gaps are 30% in rice and 40% in wheat. Conservation agriculture based CSAPs including laser land levelling, zero tillage, improved variety, precise nutrient management (nutrient expert and green seeker) increased the net returns by 65 and 95%, respectively in wheat and rice coupled with higher PFP-N.

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Climate resilient villages- a landscape approach for addressing climatic variability and for sustainable management of natural resources

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Climate resilient agriculture involves integration of adaptation, mitigation and other practices in agriculture which increases the capacity of the system to respond to various climate related disturbances by resisting or tolerating the damage and recovering quickly. Such perturbations and disturbances can include events such as drought, flooding, heat/cold wave, erratic rainfall pattern, long dry spells and other perceived threats caused by changing climate (NAAS, 2013). Climate resilient agricultural practices are crop and location speciûc and can be tailored to t into the agro-ecological and socioeconomic conditions and production objectives of farmers. Climate resilient villages (CRVs) involves integrating various resilient practices at a scale to cover the entire village or watershed in a saturation mode depending on the resource endowments of the farmers with one or several interventions for imparting resilience to the production systems. The CRVs adopts a portfolio of interventions that cover the full spectrum of farm activities consisting of adaptation, mitigation, natural resource management, better crop management, livestock production, etc. Through climate resilient agricultural landscapes/villages synergies for agricultural production, climate adaptation and mitigation, as well as other livelihood and environmental objectives can be achieved by coordinated action at farm and landscape scales (Scherr *et al*., 2012).

METHODOLOGY

To address the issues related to climate variability and to enhance the adaptive capacity of communities, extensive farmer participatory demonstrations of location-specific climate resilient technologies were initiated on farmers' fields in each of the 121 climatically vulnerable districts of the country as part of National Innovations on Climate Resilient Agriculture (NICRA). A village or a cluster of villages from each of these 121 vulnerable districts were selected for this purpose and the program is piloted by the Krishi Vigyan Kendra (KVK) located in that particular district. Planning, coordination, implementation and monitoring of the programme at national level is done by CRIDA in association with eight Agricultural Technology Application Research Institute (ATARIs) that coordinate the project in their respective zones. At the district level, the project is being implemented by selected KVK and at the village level by institutions established in the villages through farmers' participatory approach, such as Village Climate Risk Management Committees (VCRMC). To address the climate vulnerabilities of the selected villages, various interventions were planned under the four modules; however, the specific intervention under each module for a particular village was need based and decided based on climatic vulnerability and resource endowments of the particular village. The four intervention modules being implemented are (1) Natural resource management (*in-situ* moisture conservation, biomass mulching, residue recycling, manure management, soil health card–based nutrient application, water harvesting and recycling for supplementary or life saving irrigation, improved drainage in high rainfall/flood prone villages, conservation tillage, and water saving irrigation methods). (2) Crop production module consisting of introduction of short-duration and drought/heat-tolerant varieties, modifications in planting dates for post rainy season crops to cope with terminal heat stress, water saving paddy systems (System of Rice Intensification, aerobic, direct seeding), community nursery in staggered dates to meet delay in onset of monsoon, energy-efficient farm machinery through village custom hiring centers with timely completion of farm operations in limited sowing window, location specific intercropping systems, and suitable agroforestry systems. (3) Module III covers livestock and fisheries interventions through augmentation of fodder production, fodder storage methods, and improved shelters for reducing heat stress in livestock, management of fish ponds/tanks during water scarcity and excess water and promotion of integrated farming systems as adaptation strategy. (4) Module IV consists of village level institutions, collective marketing groups, introduction of weather-based insurance, and climate literacy though establishment of automated weather stations. Inputs from the relevant development departments of the state, zonal agricultural research stations of agricultural universities, progressive farmers were obtained and used in finalizing the interventions and action plans in a participatory manner.

RESULTS

Planned adaptation is essential to impart resilience to agricultural production against climate variability. Short-duration varieties complete life cycle within the growing period of a region escape drought during early withdrawal of monsoon and a good adaptation strategy for delayed onset of monsoon. Improved short duration varieties of various crops were introduced in drought prone regions, effectively escaped terminal drought conditions and produced significantly higher yields in comparison to the varieties traditionally grown by farmers. Rainwater harvesting and recycling through farm ponds, restoration of old rainwater harvesting structures, percolation ponds for recharging of open wells, and injection wells for recharging groundwater were taken up for enhancing farm level water storage which has contributed to the improvement in the cropping intensity up to 150 percent in several villages. Planting methods, viz., ridge and furrow, bed and furrow, and broad bed and furrow sowing provided opportunities for moisture storage as well as draining the excess water in the event of heavy storms reduced the impact of both the drought as well as intense storms during the cropping season and has improved yields in several crops. Application of soil test based–fertilizer minimized the excess use of a nutrient, helped to identify deficient nutrients, and optimized the nutrient use efficiency (Srinivasa Rao *et al*., 2012). Tank silt application enhanced the water holding capacity of the soil and prolonged the availability of moisture to the crops. Introduction of drought/temperature-tolerant varieties, advancement of planting dates of winter crops in areas with terminal heat stress, frost management in horticulture through fumigation, community nurseries for delayed monsoon, location-specific intercropping systems with high sustainable yield index were some of the interventions that were widely demonstrated in varying rainfall regions and were found to be effective in stabilizing yields (Srinivasa Rao *et al*., 2016). Emphasis was placed on identification of suitable fruit tree species based on the resource endowments of the region, supplying quality planting material, mulching with crop residues and agricultural wastes, efficient irrigation systems, capacity building of farmers on these aspects and also on the market opportunities for maximizing the income from the perennial components. Use of community lands for fodder production, improved fodder/feed storage methods, feed supplements, micronutrient use to enhance adaptation to heat stress, preventive vaccination, improved shelters for reducing heat/cold stress in livestock, and management of fish ponds/tanks both during water scarcity and excess water were some key interventions in livestock/fishery sector which have increased the productivity of the animals and improved income significantly. Enhancing the resilience of agricultural production to climate change is critical for ensuring food and nutritional security particularly to the resource poor small and marginal farmers in climatically vulnerable regions of the country. Location-specific integrated management practices consisting of resilient crops and intercropping systems, water harvesting and efficient utilization, etc. contributed towards utilizing the resources efficiently and to the enhancement of system productivity and income at several locations even under variable rainfall situations. Several of these adaptation measures have significant mitigation co benefits as well. The case studies of the impact of various climate resilient interventions being taken up in few climatically vulnerable villages will be presented.

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Effect of weather parameters on growth attributes under drought condition in rainfed *Bt* cotton

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Cotton is the world's most important fiber crop. The growth, development and yield of the cotton crop are considerably affected by abiotic factors, i.e. air temperature, cloud cover, relative humidity, rainfall and radiation (Jadhav, 2014). One of the most important agronomic considerations for growers to optimise yield and of crop (Praharaj *et al*., 2009). Since last one decade onset of monsoon are showing irregular behaviour and it was very difficult to coincide with appropriate sowing time. Hence, present investigation was aimed to find out effect of weather parameters on growth attributes under drought condition in rainfed *Bt* cotton.

METHODOLOGY

A field experiment was conducted during *kharif* season 2015-2016 at experimental farm of Department of Agricultural Meteorology, VNMKV, Parbhani under rainfed condition in split plot design with four sowing dates [*i.e.* 24th, 25th, 26th and 27th Meteorological Week (MW)] and three hybrids (*viz.* Mallika, Ajith-155, Rasi-779) with three replications. The data on plant height, plant width, number of branches plant^{-1} were recorded from randomly selected three plants in each plot and emergence count and seed yield were collected from all the plots. The data recorded were statistically analyzed by using technique of ANOVA i.e. analysis of variance and significance was determined as given by Panse and Sukhatme (1967) by computerised programme.

RESULTS

Perusal of data (Table 1) revealed that 24th MW sowing required significantly highest number of days (110 days) for attaining various phenophases and lowest (83 days) in 26th MW sowing. Whereas, due to this shorter duration in late sown crop seems to have affected the seed cotton yield as well as total biomass production and it was reflected in the obtained data. The data also showed that the variety Mallika was recorded highest days (98 days) for attaining various phenophases than other varieties and lowest (95 days) in Ajit-155. It was also observed that the mean emergence count in per cent was significantly influenced by different date of sowing (Table 1). Whereas, significantly highest emergence count was recorded in 24th MW sowing (97.44 %) and lowest in 26th MW sowing (56.56 %). Amongst the *Bt* hybrids, highest emergence count was recorded in Mallika, compared to rest of *Bt* hybrids Ajit-155 and Rashi-779. Significantly highest plant

Table 1. Number of days required to attain various phenophases and growth attributes in cotton

Treatment	Emergence to Square formation stage	Square formation to flowering	Flowering to boll formation	Boll formation to boll bursting	Emergence count	Plant height	Plant width	No. of branches	Seed yield
24th MW	33	20	4	53	97.44	62.75	60.43	15.94	675.62
25th MW	32	19	4	47	62.45	58.89	45.95	13.99	666.53
26th MW	28	17	3.5	34	56.56	56.48	39.73	12.07	194.20
27th MW	25	18	4.7	42	60.10	48.62	39.35	9.52	178.86
SE	0.54	0.77	0.16	2.01	5.52	1.91	1.28	0.53	40.28
CD (P=0.05)	1.87	2.69	NS	6.9	19.13	6.62	4.45	1.64	139.42
Variety									
Mallika	30	18	3.7	46	70.82	57.63	45.01	12.76	426.47
Ajit-155	30	19	3.8	42	69.34	59.08	49.03	13.41	487.0
Rasi-779	29.5	19	3.8	44	67.25	53.81	44.60	12.25	373.0
SE	0.31	0.80	0.12	1.66	1.50	1.09	1.33	0.34	21.19
CD (P=0.05)	0.94	2.41	0.36	NS	NS	3.2	3.99	1.09	63.54

Table 2. Correlations between weather parameters and different growth stages of cotton with seed cotton yield

Weather parameters	Emergence to Square formation stage	Square formation to flowering	Flowering to boll formation	Boll formation to boll bursting
Rainfall (mm)	-0.971**	-0.936**	0.889**	0.886**
Rainy days	-0.974**	0.028	0.902**	0.940**
Max. T (°C)	0.940**	0.665*	-0.955**	-0.962**
Min. T (°C)	0.952**	0.942**	0.904**	0.966**
T Mean	0.942**	0.599*	0.159	0.946**
R.H. I (%)	-0.956**	-0.509	0.929**	0.961**
R.H. II (%)	-0.932**	-0.530	0.926**	0.964**
R. H. Mean	-0.943**	-0.492	0.746**	0.964**
Evp (mm)	0.936**	0.883**	-0.864**	-0.966**
B.S.S (HRS)	0.489	-0.909**	-0.942**	-0.959**
W.V (Kmph)	0.952**	0.967**	0.905**	0.933**

*Significant at 5 % level (0.567), ** Significant at 1% level (0.708)

height, plant width and mean numbers of branches were recorded in 24th MW sowing at harvest. Whereas, the lowest plant height was observed in 27th MW sowing. It may be due to moisture stress observed during delayed sowing dates which may resulted into reduced plant growth and finally it was reflected into stunted growth and development of plants. The number of nodes and the length of the internodes are influenced by the genetics and environmental factors such as climate, soil moisture, nutrients, disease and insects. The development rate of a new node is significantly slower when the plant is water stressed. Typically this produced shorter stature plants (Anonyms, 2016). Amongst the hybrids, Ajit-155 recorded significantly highest growth attributes at harvest as compared to rest of hybrids. The results showed that among sowing dates the significantly highest seed cotton yield was recorded in 24th MW sowing (675.62 kg /ha). While, lowest was observed in 27th MW sowing (178.86 kg /ha). It may be due to delayed sowing combined with moisture stress condition experienced during the crop growth period. Among the hybrids, highest seed cotton yield (487.0 kg/ha) was recorded by Ajit-155. Whereas, lowest was produced by Rashi-779 (373 kg /ha). These results are similar with those reported by Patil *et al.*, (2009). The data (Table 2) observed during the growing season of cotton crop under study period revealed that weather parameters *viz.,* rainfall, maximum, minimum and mean temperatures, morning relative humidity, evening relative humidity, evaporation, bright sunshine hours and wind velocity were positively correlated during early stages i.e. from seedling stage to boll formation. While, the correlation results revealed that the weather parameters significantly influenced on the growth stages of the crop and finally reflected in to the seed yield.

CONCLUSION

From this study it can be concluded that the 24th MW sowing and *Bt* hybrid Ajit-155 is suitable for getting highest growth attributes and more yield under Parbhani condition. Correlation between weather parameter and growth stages of cotton with seed cotton yield showed that the weather parameters like rainfall, temperature, relative humidity, evaporation and BSS are significantly influencing the critical growth stages of cotton.

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Association of weather parameters with grain yield at different phenological stages of rice in Madhya Pradesh

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Rice (*Oryza sativa* L., Family: Poaceae) is the world's most important crop and is a staple food for more than half of the world's population. Worldwide, it is grown in 162 million hectare (mha) with an annual production of about 678.7 million tones (mt) (FAO, 2009). In India, rice covers 43.8 mha area of which Madhya Pradesh (M.P.) occupies 14.9 mha . In M.P. this area include 2.37 mha under irrigated, 2.63 mha under upland, and 9.94 mha under drought prone rainfed lowland agro-ecosystem (Pathak *et al*. 2011). The productivity of India and M.P. since 1957 – 2013 observed an increase in yield levels from 2012 onwards. This may be due to an improved management practices coupled with normal rainfall and promising varieties planted based on short maturity with high yield potential. However, the demand may increase by more than 25 percent in the coming 25 years with the possibility of expanding area is very limited. Therefore, extra rice production needed has to come from a productivity gain. The major challenge is to achieve this gain with less water, labour, and vagaries due to climate change thereby ensuring long-term sustainability. Duration of different phenological stages of rice showed a wide range of diversity depending on the genotypes and environment that plays a major role in grain production. The purpose of this study is to assess the impact of weather parameters on grain yield of rice at different phenological stages.

METHODOLOGY

A field experiment was initiated during *kharif* season in the years 2001 and continued till 2006 , and started again from 2011 to 2014 (a total of 10 years) under All India Coordinated Research Project on Agrometeorology at Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur Centre. Three sowing dates, as early (2nd week of June), normal (4th week of June), and delayed (2nd week of July) sown with two major medium maturing (120 days) rice varieties, viz Kranti and IR 36. The crop was raised following the recommended practice of direct seeded rice at Jabalpur. Phenological data were collected as 50 % tillering, panicle initiation, 50 % flowering and physiological maturity stages along with daily weather data and grain yield. Data were analyzed through SPSS software using correlation followed by multiple stepwise regression between weather parameters and grain yield for developing equations to influence grain yield at different phenological stages.

RESULTS

The correlation between weather variable and crop yield at different phenological stages were analyzed with no significant correlation (P^3 0.05) was observed among weather parameters and grain yield. The model equations obtained at different phenological stages include:

(a). Sowing to 50 % tillering: Grain yield = -20923+823.4 (Tmax) – 283.2 (Tmin) -7.18 (RF) + 172.2 (RD) – 854.5 (SSH)

[R^2=0.53]

(b). Sowing to panicle initiation stage: Grain Yield = -55040.7+ 864.4 (Tmax) -244.9 (Tmin) + 417.8 (RHe) – 3.2 (RF) +1336.6 (WS) +1114 (SSH.)

[R^2= 0.62]

(c). Sowing to 50 % flowering stage: Grain Yield = -69232.1 + 1587.2 (Tmax) -436.2 (Tmin) – 3.43 (RF) – 336.4 (RHm) + 78.3.6 (RHe) + 1172.7 (WS) +1888.9 (SSH).

[R^2= 0.64]

(d). Sowing to physiological maturity stage: Grain Yield = -53704.7 + 1578.6 (Tmax) – 1102 (Tmin) – 368.7 (RHm) + 826.4 (RHe) – 4.9 (RF) + 67 (RD) + 838.6 (WS) + 2596 (SSH)

[R^2 = 0.75]

The model equations suggest that both maximum and minimum temperatures, rainfall, and sunshine hours are the major weather variables affecting grain yield at the different selective phenological stages. Additionally, wind speed and fewer impact of relative humidity are also the variables affecting at panicle initiation, flowering, and physiological maturity stages. Maximum temperatures observed a positive while minimum temperature a negative association with grain yield. Similarly, wind speed observed a positive correlation with grain yield among all the stages, except at 50 % tillering. A polynomial relationship between grain yield and rainfall from sowing to physiological maturity stage suggest an increase in grain yield with the increase in rainfall (Fig. 1). Change in ambient temperature during vegetative and reproductive stages affect the onset and duration of phenological stages, which directly impact rice yield (*Pal et al.*, 1996).

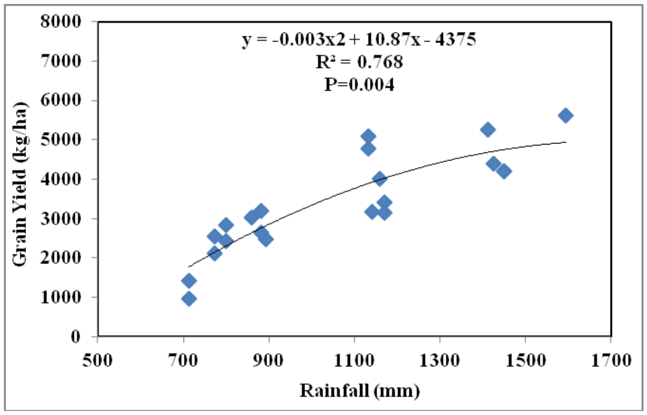

Fig. 1. Response of grain yield to rainfall from sowing to physiological maturity stage

CONCLUSION

Among different weather parameters temperature, rainfall, and sunshine hours are the major variables impacting grain yield at different phenological stages. Among all these temperatures influence grain yield strongly, therefore rice should be planted by June to avoid photorespiration process in M.P.

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Variability in phenological indices of maize variety ‘C-6’ due to time of sowing under temperate condition

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Maize cannot tolerate water stagnation. Rainfall of 50-75 cm during the vegetative period is helpful for proper development of maize plant. Moisture stress at the flowering stage drastically lowers the grain yield. Sowing dates have a pronounced effect on the yield of maize. The field may not be vacant at this appropriate time due to delay in harvesting of some *rabi* crops. Late sowing results in a significant decline in maize production. Temperature is one of the important elements of the climate which determines directly the potential productivity level under temperate condition. Agrometeorological indices like GDD, HTU, PTU, HYTU and PTI are based on the concept that real time to attain the phenological stages is linearly related to temperature in the range between base temperature and optimum temperature (Monteith, 1981). Hence the present investigation was carried out to assess the relationship between thermal time, phenopheses and seed yield.

METHODOLOGY

The experiment was conducted in *kharif* season 2012 and 2013 at Agronomy research field, SKUAST-K, Shalimar, Srinagar (J&K) that is situated at 34º 0.8¢ N latitude and 74º 83¢ E longitude at an altitude of 1605 meters above the mean sea level. The average annual precipitation over past twenty five years is 786 mm (Division of Agronomy, SKUAST-Kashmir) and more than 80 per cent of precipitation is received from western disturbances. Soil was silty clay loam in texture, neutral in reaction low in available nitrogen and medium in phosphorus and potassium. Maize variety C-6 were sown on 3 dates in each year D_1 : 4th , D_2 : 10th , D3 : 25th May in 2012 and D_1 : 28th April, D_2 : 10th , D3 : 25th May in 2013. Phenological indices were calculated with standard formulae.

RESULTS

It was found that the crop yield decreased with delay in sowing. All the agrometeorological indices are indicated vari-

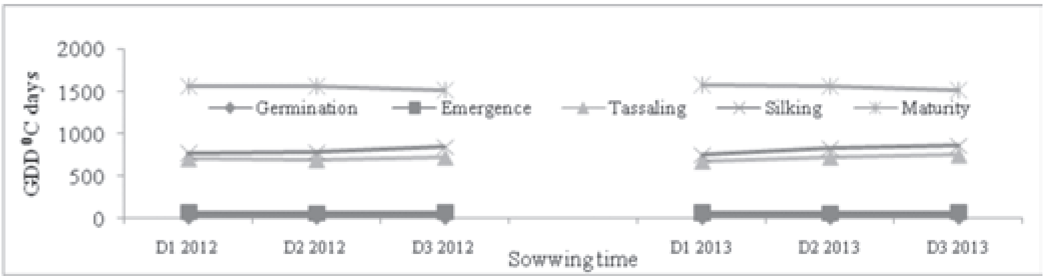

Fig. 1a. GDD of maize variety C-6 influenced by sowin time

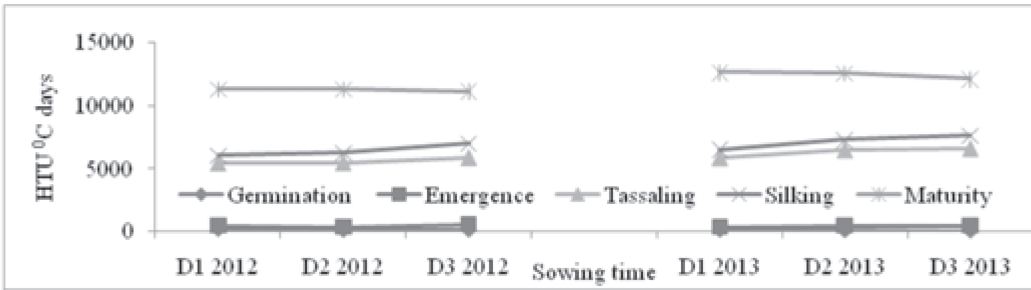

Fig. 1b. HTU of maize variety C-6 influenced by sowin time

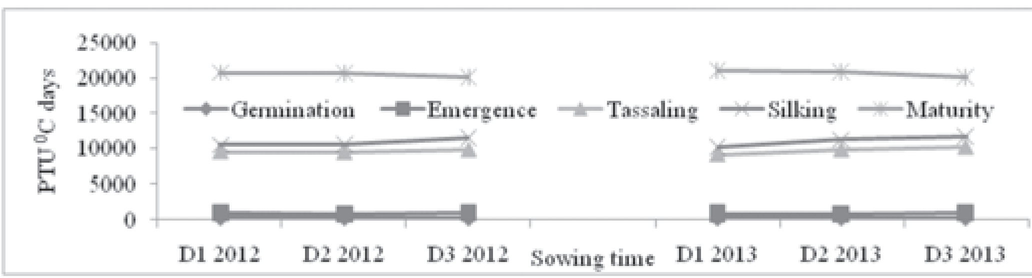

Fig. 1c. PTU of maize variety C-6 influenced by sowin time

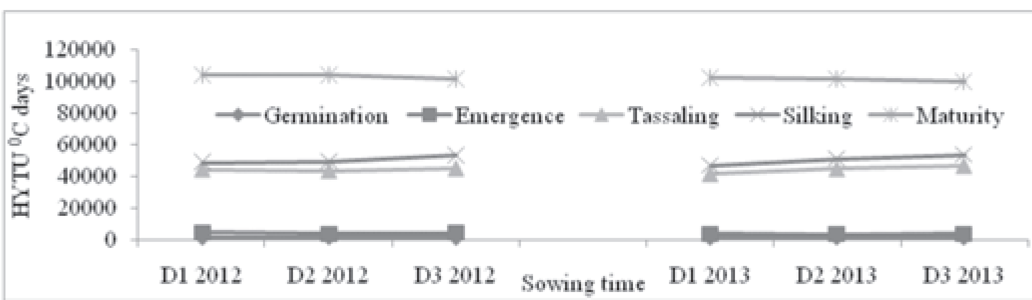

Fig. 1d. HYTU of maize variety C-6 influenced by sowin time

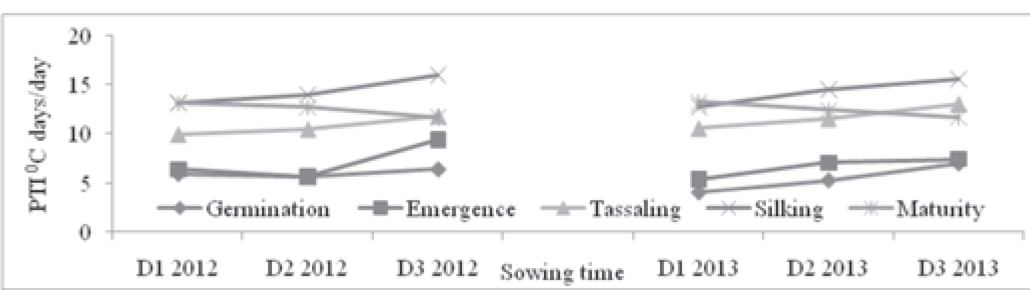

Fig. e. PTI of maize variety C-6 influenced by sowin time able pattern with variable sowing time and variable phenophases. It was observed that up to silking stage GDD, HTU, PTU, HYTU and PTI were increased with delay in sowing (Fig. 1a -e). However, up to maturity total GDD, HTU, PTU and HYTU and PTI between silking to maturity decreased with delay in sowing. Its might be due to variability in temperature regime during different phenophases. Phenothermal index (PTI) were observed in increasing trend with delay in sowing. Up to silking stage, these phenological stages occurs when temperature was increased day by day, while period between silking to maturity occurs when trend of temperature was decreasing. These factors might be responsible for decreasing rates of PTI in between silking to maturity and all other indices due to delay planting. All the indices follows same pattern because all are calculated with GDD. Delay sowing decreased grain yield might be due to reduced growth period by increasing day length and temperature increased respiration rate and reduced net assimilation, and in other hand reproductive phase coincide with decreasing day length may responsible for shortening of reproductive phase and restrict grain filing.

CONCLUSION

The delay in sowing time reduced grain yield due to decreasing rate of GDD, PTI and other Indices by delayed sowing during reproductive phase of the maize crop.

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Optimisation of sowing time and spacing for summer guar (*Cyamopsis tetragonoloba*) using thermal unit concept

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Guar [*Cyamopsis tetragonoloba* (L.) Taub.] a versatile crop with industrial uses and export potential, has transformed economic status of large number of farmers. Low input cost and high returns encourage farmers to cultivate drought tolerant legume guar seed. Among crop production factors, sowing time and spacing contribute much to a proper crop stand establishment in the field. Under paucity of research on sowing time and spacing requirement for gum guar in general and for summer gum guar in particular, the present experiment was carried out to ascertain proper sowing time and spacing for summer gum guar.

METHODOLOGY

A field experiment was carried out at Department of Agronomy, College of Agriculture, Junagadh Agricultural University, Junagadh (Gujarat) during summer seasons of 2013 to 2015. The soil of the experimental plot was clayey in texture and slightly alkaline in reaction (pH 7.9 and EC 0.36 dS/m) as well as low in available nitrogen (262 kg/ha), available phosphorus (26 kg/ha) and high in available potash (325 kg/ha). The experiment comprising of three sowing time (4th week of January, 2nd week of February and 4th week of February) and three spacing (30 cm x 15 cm, 45 cm x 15 cm and 60 cm x 15 cm) was laid out in split plot design with four replications. The guar variety 'Gujarat Guar 2' was sown using seed rate of 15-30 kg/ha and fertilized with 20-40 kg N-P_2O_5/ha as basal dose.

RESULTS

Sowing of guar crop in 2nd week of February significantly enhanced growth and yield attributes viz., plant height, number of pods per plant and test weight and ultimately gave higher seed and stalk yields (Table 1). Enhanced germination due to optimum soil temperature and later on favourable climatic condition might have favoured growth and development under 2nd week of February sowing as compared to early and late sowing. Significantly the highest plant height, number of pods per plant and test weight were recorded with 45 cm x 15 cm spacing, which resulted in higher seed and stalk yields. While, 30 cm x 15 cm spacing resulted in significantly the lowest values of these growth, yield attributes and yields. Absence of inter plant competition for moisture, nutrients and solar radiation in optimum spacing (45 cm x 15 cm) might have been responsible for improved growth and development of individual plant. Various heat indices *viz.*, growing degree days (GDD), helio thermal unit (HTU), photo thermal unit

Table 1. Effect of sowing time and spacing on growth, yield attributes and yield of guar (Pooled over three years)

Treatment	Plant height (cm)	Pods per plant	1000-seed weight (g)	Seed yield (kg/ha)	Stalk yield (kg/ha)
Sowing time					
Jan. 4th week	81.3	56.6	30.2	859	1861
Feb. 2nd week	87.7	66.3	33.6	1387	2846
Feb. 4th week	78.6	58.5	32.9	1146	2458
SEm±	1.3	0.9	1.2	25	52
CD (P=0.05)	4.5	3.2	4.0	74	153
Spacing					
30 cm x 15 cm	78.2	53.7	29.8	1173	2452
45 cm x 15 cm	87.9	68.3	34.5	1272	2680
60 cm x 15 cm	81.6	59.4	32.4	948	2034
SEm±	1.2	0.8	1.0	20	44
CD (P=0.05)	3.7	2.5	3.1	57	125

Table 2. Thermal requirement of guar under different sowing times

Year	Treatment	GDD (°C day)	HTU (°C day h)	PTU (°C day h)	HUE (kg/ha °C day)
2013	Jan. 4th week	1337	13164	16337	0.573
	Feb. 2nd week	1331	13275	16483	1.228
	Feb. 4th week	1231	12354	15342	1.133
2014	Jan. 4th week	1691	16289	21068	0.560
	Feb. 2nd week	1704	16478	21451	0.774
	Feb. 4th week	1578	15482	20055	0.685
2015	Jan. 4th week	1339	12468	16517	0.643
	Feb. 2nd week	1335	12588	16571	0.908
	Feb. 4th week	1209	11484	15138	0.797
Mean	Jan. 4th week	1456	13980	17975	0.592
	Feb. 2nd week	1457	14114	18168	0.970
	Feb. 4th week	1339	13107	16845	0.872

(PTU) and heat use efficiency (HUE) were worked out according to different sowing times (Table 2). The results indicated that the crop accumulated more GDD (1457°C day), HTU (14114°C day h) and PTU (18168°C day h) at the second week of February sowing. The HUE in terms of economic yield was the highest (0.970 kg/ha °C day) in the second week of February sowing followed by late sowing (4th week of February). It was the lowest (0.592 kg/ha °C day) in the early date of sowing. Thus accumulated heat indices utilized by the crop were not constant. This is due to the fact that days required to maturity decreased with the advancement of growing season. This may be attributed to the increase of temperature during the later dates of sowing.

CONCLUSION

It can be concluded thatbased on heat unit concept, summer guar should be sown in second week of February (>22°C soil temperature) at 45 cm x 15 cm spacing for obtaining higher seed yield.

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Drought Proofing Experiences in major cropping of Southern Karnataka

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Rainfed agriculture in India over 80 m.ha of the 143 m.ha net cultivated area, contributes 40% of food grain production (Ramachandrappa *et al.,* 2014). The average productivity in rainfed areas is only 0.7 to 0.8 t/ha (Singh and Venkateswarlu, 1999) against the potential of 2.5 to 3.0 t/ha. Climate change impacts through reduced rainy days and increased rainfall intensity, declined soil fertility with imbalanced nutrition, untimely operation due to labour scarcity, poor preparedness with inefficient weather predictions and input arrangements, market for alternate crops, meager mechanization with small sized holdings are some of the critical issues to be addressed for this fragile ecosystem. Karnataka stands second with respect to larger area under dry farming covering 71 per cent of net sown area after Rajasthan state (Anon., 2006). Finger millet, groundnut, castor, sesame, pigeonpea, cowpea, field bean and horse gram are the major crops in the dry tracts of Southern Karnataka. These crops are prone to water stress, owing to rapid loss of soil water from profile resulting in low water availability for root growth (Mallareddy *et al.,* 2015). Although, the impact of climate change is meager for the state in general, the rainfed ecosystem is oscillating with weather aberrations in terms of rainfall and temperature extremes. Keeping this in view, the dryland agriculture project of UAS, Bengaluru implemented National Innovations on Climate Resilient Agriculture (NICRA) in Bengaluru Rural district since 2011 and Operation Research Project (ORP) on dryland agriculture with its main focus on participatory technology demonstration functioned from 2010 to 2014 in Ramangara district of Karnataka.

METHODOLOGY

The NICRA action research project is in operation at Chikkamaranahalli cluster, Nelamangala Taluk, Bengaluru rural district since 2011. The normal rainfall of the area is 751.9 mm and comes under Eastern Dry Zone-5 of Karnataka. The ORP for Dryland Agriculture initiated its participatory technology development and upscaling in Alanatha cluster of villages, Kanakapura Taluk, Ramanagar district. These villages are largely composed of sandy loam soils with slightly acidic to neutral in soil reaction, low to medium in fertility status. Fields were selected based on the willingness of farmers to engage in participatory research to evaluate the science based strategy. Selected farmers participated in every research intervention from soil sampling to harvest. The yield and economic parameters were calculated adopting standard procedure and analyzed for‘t’ test to test the significance at p=0.05.

RESULTS

During regular onset of monsoon, the long duration variety MR-1 sown on July 2nd fortnight recorded higher grain yield of 2593 kg/ha followed by medium duration variety GPU-28 (2556 kg/ha) sown during 5th August. Delayed onset of monsoon showed better performance of medium duration variety (GPU-28) sown in August first fortnight in terms of higher grain yield, net returns and B: C ratio (1720 kg/ha, Rs.21161 /ha and 2.30, respectively). Similar trends were noticed under ORP also. Finger millet is a crop which can tolerate transplanting shock and establishes well even after transplanting. Establishment of finger millet nursery to raise seedlings of long duration variety (MR-1) and transplanting performed better over direct seeding during *Kharif* 2011 to 2015. Sowing of finger millet using the modified seed drill ensures recommended row spacing (30 cm) with reduced drudgery, timely operation covering larger area and facilitate easy intercultivation. Modified bullock drawn seed drill recorded higher grain yield, Net returns (and B: C ratio as compared to Farmer’s Practice. Simultaneous sowing of groundnut or finger millet with pigeon pea in 8:2 row proportion with 60 cm between the paired rows and opening of conservation furrow between the paired rows of pigeonpea helped in realizing higher yield, net returns and B: C ratio. Pigeonpea intercropping with field bean and cowpea in 1:1 performed better in terms of yield and economics.

Application of organic and inorganic fertilisers along with micronutrients gave maximum net returns of Rs 36504/ha with B: C ratio of 2.90 from finger millet grain yield of 2373 kg/ha and pigeonpea grain yield of 198 kg/ha compared to farmer practice of finger millet +akkadi gave net returns of Rs. 9460/ha and B: C ratio of 1.60. Pre-emergent application of alachlor at 2.5 lt ha^{-1} along with one hand weeding recorded lower weed menace and higher groundnut pod yield (499 kg ha^{-1}) and B:C ratio (1.96) were recorded compared to farmers’ practice 210 kg ha^{-1}and 0.97 respectively in groundnut + Pigeonpea (8:2) intercropping system. Agromet-advisories and crop-weather bulletins were issued twice a week

(Tuesdays and Fridays) in collaboration with AICRPAM and IMD and messages were written in front of milk collection centers and also broadcasted in the local Radio "Neladhani" for the benefit of project farmers was helped in reducing the losses.

CONCLUSION

Real time contingency crop planning for aberrant rainfall plays a crucial role in dryland agriculture for sustaining the productivity and livelihood security of farmers. Selection of right variety depending on the monsoon, transplanting in finger millet, *in-situ* moisture conservation furrow, use of modified seed drill for optimum plant population and quick sowing, intercropping cowpea / field bean in pigeonpea enhanced the productivity, rain water use efficiency and economic benefits to the dryland farmers in *Alfisols* of Southern Karnataka.

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Assessing heat units requirement and grain yield in rice at different sowing dates in Madhya Pradesh

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Rice (*Oryza sativa* L.) is an important staple food for more than 60 % of the world population and supplies 20 per cent of total calories required by world and 31 per cent required by the Indian population (FAO, 2010). The productivity of India and Madhya Pradesh (M.P) since 1957 observed an increasing trend however in M.P., yield increases tremendously after 2012 onwards. The productivity is dependent upon prevailing weather parameters like sunshine hours, rainfall, and heat (measured as temperature). Growing degree days (GDD) is the most common temperature index used to estimate plant development while heliothermal units (HTU), and photothermal units (PTU)) are helpful in studying the comparative efficacy of applied agronomic practices in utilizing natural resources and heat requirements developed based on temperature conditions (Sandhu *et al*., 2013). It can also be used to assess the suitability of a region for production of a particular crop, estimate the growth stages and heat stress on crop however, crop growth and yield are also influenced by photoperiod. Looking to the above facts in view, the present study was undertaken to assess heat unit requirements at different phenological stages and grain yield in rice sown at different dates.

METHODOLOGY

A field experiment was initiated during 2001 - 2006 and 2011 – 2014 (a total of 10 years) kharif season under All India Coordinated Research project on Agrometeorology project at JNKVV, Jabalpur region with three sowing dates as early (2nd week June), normal (4th week June), and delayed (2nd week July) with rice variety , Kranti (120-130 maturity days). The crop was raised following the recommended package of practices of direct seeded rice of a region. The data on crop phenology was taken by visual observations and the grain yield was recorded at maturity.GDD was computed using base temperature (Tb) of 10 °C and were accumulated from the date of sowing to physiological maturity as under (Nuttonson, 1955): Growing Degree-Day (°C day) = $[\Sigma\{(Tmax + Tmin)/2\} - Tb]$. The HTU was estimated by multiplying GDD with corresponding actual measured bright sunshine hours for that day. The PTU was calculated by multiplying GDD with day length or maximum possible bright sunshine hours (Major *et al*., 1975). Grain yield was averaged among sowing dates from previous years dataset.

RESULTS

The result among accumulated heat units with phenologi-

Table 1. Occurrence of accumulated heat units from sowing to physiological maturity at different sowing dates of medium duration Kranti variety

Phenological stage	Growing Degree Days (°C day)			Heliothermal Units (°C day-hour)			Photothermal Units (°C day-hour)		
	Early	Normal	Delayed	Early	Normal	Delayed	Early	Normal	Delayed
50 % tillering	666	674	670	2339	2295	1836	8819	8881	8831
Panicle Initiation	798	809	852	4007	3271	2634	10082	10102	9696
50 % flowering	412	288	227	2730	2286	1848	4927	3502	3586
Milking	184	171	168	727	503	1662	2601	2957	1897
Maturity	118	87	155	1570	1177	1162	855	981	1757
Accumulated Total	2178	2029	2072	11373	9532	9142	27284	26323	25767

cal stages at 50 % tillering, panicle initiation, 50 % flowering, milking, physiological maturity is presented in the Table 1. Among growth duration, 50% tillering occurred at 32 – 38 days, panicle initiation at 72 – 83 days, 50 % flowering at 90-106 days, milking at 97 – 111 days, and physiological maturity at 108 – 128 days after sowing with more duration in early followed by normal and delayed sowing dates. The heat units showed appreciable variation among the sowing dates (Table 1). Maximum GDD was accumulated in early sowing by 5-7 % than the other dates sown. The earlier sown date observed more GDD than late sown date. Among phenological stages, maximum GDD was accumulated during 50 % tillering-panicle initiation stage. Similarly, HTUs was accumulated more at early sown than late sown dates. Among phenological stages, maximum HTU was accumulated during 50 % tillering to panicle initiation stage. The result of PTU was similar to HTU (Table 1). The grain yield observed 3740 kg/ha in early, 3689 kg/ha in normal, and 2954 kg/ha in late sown from the previous year's yield datasets. The trend of accumulated heat units under different sowing dates was in the line of trend observed in the grain yield. The values of accumulate heat units (GDD, HTU, PTU) and grain yield decreases with the delay in sowing.

CONCLUSION

From the foregoing findings, it can be concluded that early sown accumulates more heat units than sown late, and hence yielded more; however fewer difference with normal sown date was observed. Among phenological stage, 50 % tillering to panicle initiation stage accumulates more heat units.

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Evaluation of cotton + red gram intercropping system as climate resilient in alfisols of southern deccan plateau of India

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Cotton is a major crop in Telangana state occupying 16.9 lakh ha, though the is recommended for deep vertisols, farmers have been growing it in alfisols (65-70% of total area) under rainfed situation since last two decades after introduction of Bt technology. In now-a-days Bt cotton yields are ranging from 1.0-1.2 t/ha and with climate change, occurrence of sucking pests and diseases, this ecosystem have become highly fragile. Moreover farmers are incurring high investment on cost of cultivation by lending money from private firm's leads to less remunerative and ultimately trapping in

Table 1. Yield and economics of Cotton + Red gram intercropping system under rainfed alfisols during *kharif* 2015

Treatment	Red gram grain yield (kg/ha)	Lint yield (kg/ha)	Cotton Equivalent yield (kg/ha)	Cost of cultivation (Rs/ ha)	Net returns (Rs/ha)
3:1	1167	467	2670	44203	75964
4:1	699	1000	2320	45150	59265
6:1	290	1434	1982	46097	43126
8:1	250	1250	1722	46854	30646
10:1	188	1375	1729	47233	30594
Sole cotton		1500	1500	48938	18562
Sole red gram	1563		2952	30000	102883
CD (P=0.05)	395	555	841	-	37859

Market prices of cotton: Rs 45/ kg, Red gram: Rs 85/ kg

debts. Farmers are resorting to extreme steps of suicides owing to debt. Traditionally farmers used to cultivate red gram varieties having duration of more than 200 days. As the crop is grown in alfisols under rainfed situations, terminal moisture stress used to be common phenomenon resulting in very low yields (0.25 -0.4 t/ha). Now medium early (140-160 days) varieties were developed by the scientists of RARS, Warangal can successfully address the present problem. Keeping this in view the present experiment was conducted in farmer's fields with an objective for evaluation of sustainable row proportion of cotton + red gram under rainfed alfisols of southern deccan plateau.

METHODOLOGY

The present study was conducted in 12 farm fields spread in three villages of Warangal district, Telangana, India situated in North Telangana Plateau. The geographical co-oridnates of the study area are N 18^o 00' 53.2'' latitude, E 079^o 36' 17.2'' longitude and 275 m above the mean sea level. The study consists different row ratio of cotton + red gram (3:1, 4:1, 6:1, 8:1 and 10:1) in comparison with sole cotton and sole red gram were evaluated under complete rainfed alfisols in randomized block design during *kharif* 2015. Each village was considered as one replication. The test variety in red gram was WRGE-97 which comes to maturity in 140-160 days. During *kharif* 2015, though normal rainfall was received in crop growth period the distribution was erratic as continuous dry spell prevailed in precious July and August months. All crop management practices were done as per recommendation. Observations on yield attributes and yield of both crops were recorded at harvest and the data was analyzed statistically by the procedure outlined by Gomez and Gomez (1984). Economics were calculated as per procedures (Perin *et al*., 1979).

RESULTS

Sole red gram recorded significantly higher cotton equivalent yields as compared to 6:1, 8:1, 10:1 and sole cotton and it was statistically identical with 3:1 and 4:1 (Table1). Higher market price of red gram (Rs 85/kg) contributed higher cotton equivalent yield in sole red gram. Among different row ratios, cotton equivalent yields were significantly higher in 3:1 row ratio compared to 8:1 and 10:1 and sole cotton and statistically comparable with 4:1 and 6:1. Higher red gram yields in 3:1 and 4:1 was the factor for higher cotton equivalent yield. Among different treatments sole red gram earned significantly higher gross and net returns than other treatments and comparable with 3:1 and 4:1 with respect to gross returns and gained at par net returns with 3:1 (Table 1). In sole red gram and 3:1 row ratio, because of higher grain yield and remunerative market price and less cost of cultivation in red gram attributed higher gross and net returns Among different row ratios, 3:1 reported statistically similar gross and net returns with 4:1 and 6:1 and significantly higher than other row ratios and sole cotton. Significantly higher benefit cost ratio got in sole red gram than other row ratios and sole cotton. Among different row ratios, 3:1 recorded significantly higher BC ratio and on par with 4:1 and 6:1.Sole red gram registered 5.5 times higher net income than the sole cotton.

CONCLUSION

This study proved that under drought conditions among different row ratios of cotton + red gram intercropping 3:1 and 4:1 ratio are remunerative. Farmer can also choose 6:1, ratio of cropping systems for sustainable income. For rain fed resource farmers sole red gram proved to be better option over cotton in the alfisols of southern deccan plateau of India.

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Global warming potential and greenhouse gases intensity of rice-wheat cropping system under different portfolios of climate smart agriculture practices in Western Indo-Gangetic plains of South Asia

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In India rice- wheat rotation occupies about 10.5 m ha and contributes about 40% of the country's total food grain basket. However, tillage, water and energy intensive conventional production practices of rice and wheat are not only leading to low inputs efficiency and farm profits but are also contributing to GHG emissions. Projected climate induced variability in weather events will further aggravate these challenges. To counter these challenges, several climate smart agriculture (CSA) practices that are more productive, profitable and environmentally friendly have been developed and validated under different production systems and ecologies (Jat *et al*., 2016). Several CSA practices such as reduced or zero tillage (ZT), dry drill seeding of rice (DSR), rice residue retention and precision nutrient and water management have been evaluated in cereal systems as alternatives to conventional practices but GHG emissions and global warming potential (GWP) of these practices have not been adequately studied. The adoption of various improved agronomic practices in a crop rotation might have positive yield and income effects but their environmental footprints may vary with component technology and its layering with other technologies. This study evaluates the effect of different portfolios of CSA practices on GWP and GHG intensity together with grain yield in rice-wheat cropping system.

METHODOLOGY

A farmer's participatory strategic research trial was conducted for 2 consecutive years (2014-15 and 2015-16) in three different climates smart villages *viz.* Birnarayana, Anjanthali and Chandsam and of Karnal, Haryana, India under CIMMYT-CCAFS flagship project on climate smart agriculture (CSA). The concept of Climate Smart Villages (CSV) is being implemented under the aegis of CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) by CIMMYT in collaboration with ICAR, State Department of Agriculture, Govt of Haryana and other stakeholders' to raise the awareness of farming communities about various technological, institutional and policy options that have a potential to increase their climatic resilience, adaptation, agricultural productivity and income while reducing emissions of greenhouse gases. Karnalis characterized by low rainfall (700 mm) and temperature extremes of 0-4 °C in January and 41-45 ° C in June. Six scenarios with layering of various climate smart agriculture practices (CSAPs) i.e. Farmers' practice; FP (S1), improved FP with low intensity of adaptive measure (S2), improved FP with high intensity of adaptive measure (S3), climate smart agriculture (CSA) with low-intensity of adaptive measure (S4), CSA with medium intensity (S5) and CSA with high intensity of adaptive measure (S6) were evaluated. These scenarios basically consisted of 9 interventions which plays critical role in improving adaptive capacity to climate risks, yield and income efficiency of the system. The interventions in the scenarios consisted of i) *Tillage:* In S1 and S2, six tillage operations (for rice and wheat?) were done, whereas in S3 and S4 only three operations were done. Zero till (ZT) was practiced in S4, S5 and S6 for wheat and in S5, S6 for rice; ii) *Crop establishment*: In S1 and S2, transplanted rice followed by conventional wheat. In S3 DSR (direct seeded rice) was followed by rotary till drill wheat. In S4, S5 and S6ZT, the crops were planted under ZT using Happy seeder; iii) *Precision land-levelling*: Practiced in S4, S5 and S6; iv)*Cultivars*: For rice, Pusa-44 was cultivated in S1, S2 and S3 and PR-114 in S4, S5 and S6 followed by wheat PBW-343 was cultivated in S1, S2 and HD-2967 in S3,S4,S5 and S6 scenarios; v) *Crop residue (CR) management*: Straw removed in FP. However, in other scenarios anchored residue of wheat (1.5-2 t/ha) and full (100%) residues of rice was recycled; vi) *Water management*: State recommendation (SR) were followed in S1 to S4, while in S5 and S6 irrigation water was applied based on soil metric potential using tensiometer; vii) *Nutrient management*: Farmers fertilizer practice was used in S1, S2 whereas in S3, SR practice was followed. In S4- SR using N source as neem coated urea (NCU); S5- SR wherein N application was guided by GreenSeeker sensor and was applied using NCU; S6- Site-Specific Nutrient Management (SSNM) using Nutrient Expert (NE)

Table 1. Grain yield, GWP and GHG intensity under different scenarios of CSAPs in rice-wheat system during 2014-15 and 2015-16.

Scenarios	2014-15				2015-16			
	RW system grain yield (kg/ha/yr)	GWP (kg CO_2 eq./ha/yr)	GHG Intensity (kg/kg CO_2 eq. ha/yr)	% change in GHG Intensity over S1	RW system grain (kg/ha/yr)	GWP (kg CO_2 eq. ha/yr)	GHG Intensity (kg/kg CO_2 eq. ha/yr)	% change in GHG Intensity over S1
S1	11289 ^{C}	5192 ^{B}	0.461 ^{B}		11921 ^{D}	5225 ^{B}	0.439 ^{B}	
S2	11241 ^{C}	5556 ^{A}	0.495 ^{A}	7	12179 ^{CD}	5598 ^{A}	0.460 ^{A}	5
S3	11829 ^{B}	4502 ^{C}	0.381 ^{C}	-17	12140 ^{CD}	4510 ^{C}	0.372 ^{C}	-15
S4	11983 ^{AB}	4500 ^{C}	0.377 ^{C}	-18	12405 ^{BC}	4525 ^{C}	0.366 ^{C}	-17
S5	12116 ^{AB}	4040 ^{D}	0.335 ^{D}	-27	12640 ^{B}	3876 ^{D}	0.308 ^{D}	-29
S6	12300 ^{A}	3877 ^{E}	0.316 ^{E}	-31	13014 ^{A}	3655 ^{E}	0.282 ^{E}	-36

Note: Different letters in a single column indicate significant difference between treatments at $p < 0.05$.

decision support tool wherein N rates were guided by Green-Seeker sensor and applied through NCU; viii) *Information & Communication Technology* for weather information to take real time decisions on farming operations and ix) *Index based crop insurance* were followed in S5 and S6. Each scenario was replicated thrice in production scale plots in a randomized complete block design. GHG emissions were calculated by using CCAFS Mitigation Option Tool- MOT (Feliciano. D *et al* 2015) and global warming potential (GWP) were computed using the following equation. GWP (kg CO_2 -eq/ha) $=CO_2$ (kg /ha) + N_2O (kg /ha) × 298 + CH_4 (kg /ha) × 34. Total GWP were divided by the grain yield to obtain GHG emission intensity (IPCC, 2013).

RESULTS

Results from two-year participatory strategic research (Table 1) revealed that in first year (2014-15), scenario 6 (S6)having the elements of high intensity climate smart practice though recorded RW system productivity on par to S4 and S5 but had significantly lower GWP over all the scenarios. Similar trend was recorded in terms of greenhouse gases emission intensity. The changes in GHG intensity in S6, S5, S4, S3 and S2 over S1 were in the order of -31, -27, -18, -17 and 7 percent, respectively (Table 1). An identical trend in GWP and GHG intensity was recorded in year 2 (2015-16) of experimentation. However, the RW system productivity in S6 during 2015-16was significantly higher over rest of the scenarios unlike in 2014-15. Synthesis of large number of published research across South Asia and Latin America also revealed that improved management practices have high adaptive capacity to combat climatic adversities in agriculture with lower environmental footprints however, their degree varies with situation (Sapkota *et al*., 2015; Jat *et al.,* 2016).

CONCLUSION

We studied the effect of the portfolios of climate smart agriculture practices (CSAPs) on GHG emissions in a RW system which indicates that the layering of CSA practices have additive effects in terms of improving productivity through better adaptation and also minimizing environmental footprints. In RW systems, among different management practices, with layering of CSAPs, the GWP and GHG intensity of RW systems can be reduced by ~40%.

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CropSyst model performance for cotton and clusterbean in hot arid region

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In future, less water will be available for agricultural production, while at the same time food production must be increased to feed the growing population. Recent forecasts warn of impending global problems unless appropriate action is taken to improve water management and increase crop water productivity (Falkenmark and Rockstrom, 2004; Rosegrant *et al*., 2002). Studying different factors and their interactions affecting water productivity and measurements of the required hydrological variables under field conditions are difficult, time consuming, expensive and need sophisticated instrumentation. To overcome these problems, simulation model with field experiments offers the opportunity to gain detailed insights into the system behavior in space and time. Models make it possible to evaluate the effects of different yield-affecting factors simultaneously in order to identify optimal water and nutrient regimes for specific scenarios. Assessment of crop and water productivity of crops under existing situation is essential pre-requisite for designing and developing efficient water management practices. Drawing on these insight a two-year study was undertaken to assess yield, returns and water productivity and performance evaluation of CropSyst model for Bt cotton and clusterbean in IGNP Stage – I of hot arid region.

METHODLOGY

The study was undertaken in a Village Mainawali (74° 20'34" - 74° 20'60" E and 28° 37'62" N - 29° 21'39" N) in district Hanumangarh, Rajasthan having 28 farmer household were selected. The study site has area of 187 ha receiving water from a common water course.The yields of crops were determined from three randomly selected (2 m × 2 m) area of each farmer. Total water applied was measured by totaling rainfall and irrigation. Periodic soil moisture was determined in 15 fields by TDR and gravimetric method. Water productivity was calculated as ratio of yield to amount of water applied or ET and ratio of returns to amount of water applied or ET. CropSyst simulation model was selected.The information required for four input data files i.e. location (latitude, rainfall, sunshine hour, daily solar radiation, temperature, VPD) , soil (surface soil CEC and pH, surface soil texture, and parameters specified by soil layer: layer thickness, FC, PWP, BD), crop (phenology , maximum LAI, root depth, specific leaf area, growth, nitrogen parameters (defining crop N demand and root uptake), harvest index , and salinity tolerance) , and management(date of planting, date, rate and method of fertilizer and water application, tillage operations, and residue management) were collected. The soil parameters required for models were estimated at sowing of the crop using standard procedures. For parameterization of CropSyst, the heat sums for different phenological stage were estimated from the base temperature, cutoff temperature and daily mean temperature. For calibration of models data from the first year study was considered. To determine model performance, we compared simulated and measured green area index, crop economic yields, above ground biomass yield, and N uptake using CC, RMSE, and index of agreement.

RESULTS

The EY (economic yield) and ABY (above ground biomass yield) varied considerably amongst studied crops. Amongst kharif crops, the EY varied from 1946 kg/ha to 2212 kg/ha, and ABY varied from 5844 kg/ha to 8077 kg/ha. Averaged across years, cotton recorded 32% higher EY and 29% higher ABY than that of clusterbean. The cost of cultivation (CC) of crops varied from Rs. 24386/ha to Rs. 43118/ha. Averaged across years the cultivation of cotton incurred highest cost (Rs. 41799/ha) than clusterbean (Rs. 24105/ha). The cotton incurred 73% higher CC compared to clusterbean. The higher labor, irrigation, and seed costs for cotton compared to clusterbean was responsible for higher CC of cotton. The clusterbean had higher NR (Rs. 138566/ha) than cotton (Rs. 72002/ha). The cotton recorded 1.9 times higher profit than clusterbean. Averaged across both the years, the mean amount of irrigation water applied were higher for cotton (402 mm) than clusterbean (92 mm) . Averaged across the years, the WP_{TWY} for cotton and clusterbean were 0.31, 0.45 kg/m^3, respectively. Thus considering WP_{TWY}, the clusterbean was 1.4-times more water productive than clusterbean. The water productivity of total water applied measured in terms of return (WP_{TWR}) were Rs. 10.9 and 36.4/$m^3$for cotton and, clusterbean. Thus considering WP_{TWR}, the clusterbean was 3.3-times more water productive than clusterbean. Calibrated results for yields

Table 1. Indices of agreement between simulated and measured yields and nitrogen uptake of crops in IGNP Stage - I.

Crop/ Parameter	Calibration						Validation					
	Obs	Pre	RMSE	RRMSE	CC	IoA	Obs	Pre	RMSE	RRMSE	CC	IoA
Cotton												
EY	1946	1891	130	6.7	0.89	0.92	2212	2275	84.3	3.81	0.86	0.84
ABY	7359	7274	366	4.9	0.94	0.96	8077	8750	700.2	8.67	0.88	0.51
NU	78.05	80.1	5	6.5	0.84	0.89	77.0	86.0	11.2	14.62	0.87	0.45
Clusterbean												
EY	1530	1532	119	7.8	0.85	0.92	1612	1558	95.5	5.93	0.74	0.81
ABY	5844	5913	369	6.3	0.91	0.95	6089	5927	388.4	6.38	0.73	0.81
NU	76.2	75.1	8	11.0	0.79	0.81	70	75	6.2	8.90	0.75	0.60

and N uptake for different crops are presented in Table 1. CropSyst simulated economic and above ground biomass yield of crops satisfactorily. Amongst the studied crops it simulated both economic and ABY better for cotton and clusterbean. Among the studied parameters, model simulated yields better than N uptake.

CONCLUSION

The clusterbean had greater profit and water productivity than Bt-cotton in IGNP Stage –I. The Cropsyst model predicted yield, nitrogen uptake satisfactorily.

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Sowing method as an effective climate resilient technology in soybean cultivation

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Farmers of Sheopur district of Madhya Pradesh have been growing soybean in Kharif season. The productivity of soybean in this district is very low as compared to state and national productivity due to multiple factors. Improper crop establishment method i.e. flat bed sowing and broadcasting is an important reason for low productivity in the district. Sowing methods have a major influence on aeration, moisture and temperature of soil which in turn affect the yield and quality of crop. Therefore, there is need to standardize sowing method for the cultivation of soybean in the Sheopur district. Broadcasting and flat bed sowing methods are very popular among farmers in the district because of easy availability of flat bad sowing seed drills and lake of awareness among the farmers about other methods of soybean sowing. The crop sown in flat bed, suffers from water logging condition during intensive rainfall and moisture stress condition during prolong dry spells due to erratic nature of rainfall. Keeping above consideration in view an On Farm Trail was conducted during Kharif season of 2015 at eight locations of the district (farmers' field) to validate, refine and popularize the technology developed at Directorate of soybean Research, Indore for sowing of soybean crop. The experiment comprised four treatment viz. broadcast sowing (Farmers practice) flat bed seed drill sowing (Farmers practice), ridge and furrow sowing and broad bad and furrow sowing (BBF). Highest yield of soybean was recorded under ridge and furrow sowing (1.60 t/ha) followed by broad bad and furrow (1.6 t/ha), flat bad seed drill sowing (1.34 t/ha) and broadcasting (1.18 t/ha). As per findings of present study, ridge and furrow and BBF method of sowing for soybean may be advocated in the district. It may be helpful to avoid prolonged dry spell and water logging condition occurred by the erratic nature of monsoon.

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Contingent crop practices under aberrant monsoon condition of *Malwa* region

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To mitigate drought, succeeding crops *Viz.,* mustard, blackgram, horsegram, toria *etc.,* may be grown on residual moisture to increase productivity and rain water use efficiency. Alternate sustainable cropping systems under rainfed situations, crop diversification with low water demanding short duration crops may be the best option to mitigate drought and enhanced the productivity of rainfed soybean ecosystem. Some practice like spraying of chemicals and use of mulches in commonly grown crops (soybean, maize, horse gram, black gram) may help in better productivity and rain water use efficiency in dryland conditions and give maximum return to farmers. The experiment was conducted to evaluate performance of various crops to combat aberrant monsoon conditions, and evaluate the economic viability of different treatments

METHDOLOGY

A field experiment was conducted during *Kharif* 2012 at Indore, on medium black soil, having 7.88 pH, 0.49% organic carbon, 232 kg/ha available nitrogen, 10.2 kg/ha available phosphorus and 540 kg/ha available potassium. The experiment was conducted in split-plot design replicated 3 times, keeping 4 crop in main-plots and 3 chemical sprays, one polythene mulch and control in sub-plots. The crop treatments were Soybean, Maize, Blackgram and Horsegram. All the crops were grown as per the recommended package of practices. The rainfall of 920.8 mm in 35 days was received mostly during rainy-season cropping period.

RESULTS

Result reveled that, contingent crops practices under aberrant monsoon condition of *Malwa* region, to combat the abi-

Table 1. Seed yield; net return and B: C ratio of different crops as influenced by different treatments under aberrant monsoon condition of *Malwa* region.

Main and Sub plottreatments	Black Gram (JU- 86)	Maize (HQPM-1)	Soybean (JS 95-60)	Horse Gram (HG 563)	Mean
			Crop seed yield (kg/ha)		
T1-Spray of VAM-C 50 % SL @ 3.75 l/ha	462	1870	2365	667	1341
T2-Spray of potassium Solution @ 2%	433	1643	2148	640	1216
T3-Spray of thiourea @ 250 g/ha	450	1767	2098	658	1243
T4-Polythine mulch	419	1548	2331	614	1228
T5-Control	400	1500	1817	597	1079
CD (P=0.05)		Main (42.5), Sub (30.3) and Int. M x S (60.7)			
			Net Return (./ha)		
T1-Spray of VAM-C 50 % SL @ 3.75 l/ha	8497	16185	56452	16667	24450
T2-Spray of potasium Solution @ 2%	7312	13000	49944	15598	21464
T3-Spray of thiourea @ 250 g/ha	8000	14741	48437	16328	21876
T4-Polythene mulch	6762	11667	55421	14550	22100
T5-Control	6011	11000	40024	13894	17732
CD (P=0.05)		Main (923), Sub (860) and Int. M x S (1720)			
			B: C Ratio		
T1-Spray of VAM-C 50 % SL @ 3.75 l/ha	1.85	2.62	4.89	2.67	3.01
T2-Spray of potassium Solution @ 2%	1.73	2.30	4.44	2.56	2.76
T3-Spray of thiourea @ 250 g/ha	1.80	2.47	4.34	2.63	2.81
T4-Polythene mulch	1.68	2.17	4.82	2.46	2.78
T5-Control	1.60	2.10	3.76	2.39	2.46
CD (P=0.05)		Main (0.07), Sub (0.06) and Int. M x S (0.12)			

otic stress the effect of spraying of VAM-C 50 % SL @ 3.75 l /ha; potassium Solution @ 2%; thio-urea @ 250 g /ha at the reproductive stage of the crop were study on four crops *viz.,* black gram, maize, soybean, and horsegram. The spraying of VAM-C 50 % SL @ 3.75 l /ha recorded the significant high seed yield /ha of Soybean 2365 kg, Maize 1870 kg, Blackgram 462 kg and Horsegram 667 kg as compared to the without spray *i.e.,* control. Data presented in table 1 showed that the significantly higher seed yield 2365 kg /ha, net return Rs. 56452, B: C ratio 4.89 recorded by soybean with T1-spray of VAM-C 50 % SL @ 3.75 l/ha but found at par with T4 - Polythene mulch as received 2331 kg /ha, net return Rs. 554421 with B: C ratio 4.82 as compared to control 1817 kg /ha, Rs. net return 40024 , B: C ratio 3.75,respectively.The significant response of treatments on maize crop was also observed as indicated that highest seed yield 1870 kg /ha recorded with T1- Spray of VAM-C 50 % SL @ 3.75 l/ha followed by T3-Spray of thio-urea @ 250 g/ha 1767 kg /ha and T2-Spray of potassium Solution @ 2% 1643 kg /ha.

CONCLUSION

Considering the production and net return**,** soybean crop with foliar spray of VAM-C @ 375 ml/ha, thiourea @ 0.05% and Potassium solution @ 2% was proved most promising and remunerative.

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Crop weather relationship of aerobic rice (*Oryza sativa*)

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Rice plays an important role as staple food throughout Asia and parts of Africa and any negative consequences of climate change on rice production would put at risk the fragile food supply stability of these regions. Rice cultivation is a water intensive enterprise. However, lowland rice fields have relatively high water requirements and their sustainability is threatened by increasing water shortages (Bouman and Tuong, 2001). Aerobic rice system is a new way of growing rice that needs less water than low land rice. It is grown like an upland crop in soil that is not puddled, non-flooded or saturated. It is a sustainable rice production methodology for immediate future to address water scarcity and environmental safety arising due to global warming. Hence, this study is oriented towards establishing the crop weather relationship of aerobic rice with regard to crop stress along with ways and means to mitigate the climate stress.

METHODOLOGY

The experiment on aerobic rice was conducted at Karaikal during *Rabi* season (September 2014 –February 2015) with different sowing window. Karaikal is situated at 10°55' N latitude and 79°49' E longitude with an altitude of 4 meters above Mean Sea Level (MSL). The region comes under Eleventh Agro Climatic Zones of India and is classified as "PC_2 Coastal Deltaic Alluvial Plains Zone" under fifteen All India Agroclimatic Zonal Classification. Karaikal enjoys a tropical climate and receives a normal rainfall of 1397 mm in a year with mean maximum and minimum temperature of 35.4°C and 25.6°C respectively. The treatment combination comprised of four dates of sowing at weekly interval [September 12th (D_1), September 20th (D_2), September 27th (D_3) and October 4th (D_4) and three seed hardening techniques [one per cent KCl (H_1), water (H_2) and control (H_3)]. The treatments were evaluated in factorial concept of RBD and replicated thrice. Rice variety chosen for the study was ADT (R) 46. The major phenological stages of rice *viz.,* Seedling, Vegetative, Reproductive and Maturity stages were identified from the treatment when 50 per cent of the population exhibited the condition. The direct weather parameters like Maximum Temperature, Minimum Temperature, Evaporation, Soil Temperature, Rainfall and Sunshine Hours were recorded at various phenological stages of the respective treatments, to study their influence on grain yield.

RESULTS

The findings from the present investigation revealed that early sown crops treated with one per cent KCl grew taller throughout the crop growth phase. Similarly the LAI was also higher for the crops sown earlier especially on 12th September treated with one per cent KCl or plain water throughout the phenophases. It was also observed that late sown crop especially D$_3$ (27th September) and D$_4$ (4th October) without seed hardening did not result with higher dry matter production (DMP) almost in all the phases of investigation. It was observed that crop raised on 12th September resulted in increased grain yield (Table 1) of 58 per cent higher over the crop raised on October 4th. The crops that were raised on 4th October was exposed to higher RH (93.78%) coupled with low temperature of 28.12^{o}C which induces the spikelet sterility and increased the number of ill-filled grains. It was noted that on an average 15 Kg/ha of grain yield decreased per day due to delay in sowing from September 12th to October 4th. The derived weather parameters *viz.,* GDD, RTD, RHD, HTU, PTU and HUE also contributed significantly in a positive manner to the rice grain yield.

Table 1. Effect of date of sowing and seed hardening on mean grain yield (kg/ha), straw yield (kg/ha) and harvest index (%) of aerobic rice

Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index (%)
Date of Sowing (D)			
D$_1$: 12th September	3972	10459	28
D$_2$: 20th September	3190	7941	29
D$_3$: 27th September	2010	5736	26
D$_4$: 4th October	1685	4605	27
S Ed	152.4	881.4	2.3
CD (p=0.05)	316.1	1827.9	4.8
Seed Hardening (H)			
H$_1$: Hardening with one per cent KCl	2821	6887	29
H$_2$: Hardening with Water	2898	8065	26
H$_3$: Without hardening	2423	6604	27
S Ed	132.0	763.3	2.0
CD (P=0.05)	273.8	NS	NS
Interaction (D×H)			
S Ed	264.0	1526.6	4.0
CD (P=0.05)	NS	NS	NS

CONCLUSION

From this study, it was proved that the early crop of rice achieved the nearly potential yield and the sowing window optimized for aerobic rice during *Rabi* season was September 12th. One per cent KCl hardened treatments was effective during the initial stages of crop growth but not continued to the later stages, this is because the treatments had not undergone the water stress condition owing to the optimum rainfall in the later stages.

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Weather in relation to yield of different rice (*Oryza sativa*) varieties under climatic condition of *Konkan* in Maharashtra state

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Rice based agriculture is the largest source of livelihood of majority of rural mass in *Konkan,* which lies along the Arabian seacoast at the extreme western part of the Indian peninsula. The rice crop is adopted to a greater range of climatic conditions, As such, cultivated lands ranges from coastal lowlands, floodplains and deltas to forested hills and mountains. Among the wet season crops in *Konkan*, rice alone occupies an area about 3.83 lakh hectares with production of 10.59 lakh tonnes and per hectare yield of 2.76 tonnes (Anonymous, 2013[a]). However, variations in rice productivity are governed by seasonal and spatial differences in climatic factors and their degree of influence on a particular phenophase of rice crop. In *Konkan* region of Maharashtra about 80 per cent of rice crop is a low land, spreading over a 40-60 km in width and stretching to a length of 700 km all along the west-coast. But the yields are highly variable due to aberration in weather like late onset of monsoon, heavy continuous rains, intermittent dry spell and heavy rains at the time of harvesting, etc.

METHODOLOGY

A field experiment was conducted during rainy season of 2013 and 2014 at Agronomy Department Farm, College of

Agriculture, Dr. B.S.K.K.V., Dapoli. The climate is sub-tropical which is characterized by warm and humid atmosphere. The experiment was conducted in lateritic soil of *Konkan* and laid in split plot design with three main plot treatments consisting sowing times and nine sub plot treatments having varieties.Rice were sown at different sowing time as per treatments and transplanted after 21‘ DAS ‘of respective sowing time, Weather data during the crop growing season were collected from meteorological laboratory, AICRPM, Dapoli, located 50 m away from experimental field.

RESULTS

Weather effect: The weather parameters during *Kharif* season of 2013 and 2014 were critically studied. Maximum temperature, minimum temperature as well as sunshine hours were at higher side during *Kharif* season of 2014 than 2013, however, regarding the relative humidity, rainfall and number of rainy days, it were higher in the year of 2013 than 2014.Weather data clearly showed that comparatively much higher sunshine hours were recorded during 2014 than 2013. This might have resulted in the optimum growth of crop during 2014 and resulted into production of more sink. Whereas in the year of 2013 comparatively less shine hours exhibited more competition for sunshine and resulted in more vegetative growth. On the other hand, crop experienced more rainfall and more number of rainy days in the most of crop growing period of rice during the year of 2013 as compared to 2014. Predominantly more rainfall during the flowering and maturity stage of most of the varieties were experienced in the year of 2013, which resulted the washing out of pollens and subsequently poor grain filling (more number of chaffy grains) in most of the varieties. *Effect of sowing time:* Data showed that the sowing during 23rd meteorological week recorded significantly higher grain yield /ha as compared to 25th meteorological week and found statistically at par with sowing during 24th meteorological week sowing during both the years of study, whereas in pooled data, sowing during 23rd meteorological week recorded significantly more grain yield over rest of the sowing times. The mean increase in grain yield due to sowing during 23rd meteorological week over sowing during 24th and 25th meteorological week was to the tune of 7.65 and 21.98 per cent respectively. The increased yield contributes might be due to result of optimum growth and development parameters associated with 23rd meteorological week, which associated with favourable weather condition. However, higher straw yield was recorded by the sowing during 23rd meteorological week and was at par with the 24th meteorological week sowing but found to be significantly superior over the 25th meteorological week sowing during both the years of study. Whereas in the pooled data, the sowing during 23rd meteorological week proved its significant superiority over remaining sowing times in terms of straw yield /ha. Magnitude of increase in mean straw yield under the 23rd meteorological week sowing over 24th and 25th meteorological week sowing was to the tune of 5.67 and 16.72 per cent, respectively. This might be due to increased morphological characters observed in the 23rd meteorological week sowing. The foregone discussion suggests that second year environmental condition was much better for grain production than first year which was good for vegetative growth. Delay in sowing significantly reduced the grain and straw yield but it was more pronounced in second year. The production of above ground biomass a straw yield was more in first year and grain yield in second year. Maximum straw yield (5.42 t/ha) was obtained during first year where as highest grain yield (4.84 t/ha) was recorded in second year at early date of seeding. *Effect of varieties:* Short duration hybrid Sahyari-4 was remunerative and produced significantly the highest grain yield than rest of the varieties and followed by medium duration Jaya within level of significance. The hybrid Sahydari-4 significantly out yielded all the varieties during both the years and in the pooled mean and produced the grain yield of 5.25, 5.67 and 5.46 t/ha respectively, which was higher than the other tested varieties. The mean increase in the grain yield of the short duration hybrid Sahyadri-4 over medium duration Jaya, short duration Karjat-7, long duration Swarna and Karjat-2, short duration Karjat-3, medium duration Palghar-1 and Karjat-5 and short duration Ratnagiri-24 was to the tune of 3.00, 11.92, 13.31, 14.55, 19.67, 23.87, 30.13 and 43.15 per cent, respectively. Hybrid Sahyadri-4 and conventional variety Jaya performed better due to more conversion of photosynthates into economic produce, which resulted in higher yield contributing characters in the respective varieties. Medium duration variety Karjat-5 produced significantly higher straw yield during both the years and in the pooled data to the tune of 6.60, 6.32 and 6.46 t/ha respectively, in comparison to the other tested varieties. The increase in the mean straw yield under medium duration variety Karjat-5 over the short duration Sahyadri-4, late duration Swarna, medium duration Jaya, late duration Karjat-2, early duration Karjat-7 and Karjat-3, medium duration Palghar-1 and early duration Ratnagiri-24 was to the tune of 13.10, 15.19, 17.84, 19.63, 28.98, 30.15, 30.86 and 39.55 per cent, respectively. This was due to the increased morphological characters *viz*., plant height and dry matter production hill^{-1} observed in the Karjat-5.

CONCLUSION

It can be concluded that *Kharif* rice in *Konkan* be sown during 23rd meteorological week with hybrid Sahyadri-4 or conventional variety Jaya, so as to obtained higher yield and economic returns due to congenial environment associated.

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Effect of sowing dates and plant spacing on yield, nutrient uptake and economics of sweet corn under lateritic soils

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The cultivation of rainy season maize in south konkan coastal zone is impossible and difficult due to natural vagaries of the monsoon season and restricted sunshine hours for photosynthesis. Similarly, the heavy rainfall in konkan disturb the plant initially and may not results into mature plant due to washing out of pollens with the heavy rains upto September. These coupled with fluctuation in the moisture content of soil reduces the yield. Its potential can, however, be exploited during the winter season owing to favourable climate, better water management and less attack of pests and diseases. Next to sowing time, another factor of almost equal importance is plant density (planting geometry), because maize crop is less capable of adjustment to thinner stand than other members of grass family. Plant density has been recognized as a factor determining the degree of competition between plants; yield per unit area is the product of yield per plant and number of plants per unit area. Finding the optimum plant densities that produce the maximum yield per unit area under the given environmental conditions is the major concern of the Agronomist. Inadequate as well as high plant population leads to low productivity with poor quality. The cultivation of sweet corn in winter is advantageous to farmers due to increasing tourism in konkan. Hence an experiment was conducted to exploit the possibility of growing sweet corn during winter in Konkan region of Maharashtra.

METHODOLOGY

The experiment was conducted at Agronomy farm, college of Agriculture, Dr. B.S. Konkan Krishi Vidyapeeth, Dapoli (Ratnagiri) in Maharashtra during the winter seasons of 2007-08 and 2008-09 in split plot design with 3 replications. The soil was sandy clay loam, slightly acidic in reaction (pH 6.52), high in available nitrogen (196.69 kg /ha), low in available phosphorus (17.12 kg /ha) and K (204.54 kg /ha). The main plot treatments consisted of 6 sowing dates in alternate meteorological week 45th MW, (5 -11November), 47th MW, (19–25 November), 49th MW, (03 – 09 December) 51st MW, (17–23 December), 1st MW (01– 07 January) and 3rd MW, (15 – 21 January), while the sub-plot treatments consisted to 3 plant spacings (60 cm x 20 cm, 60 cm x 40 cm and 60 cm x 60 cm).

Table 1. Effect of the sowing dates and plant spacing on yield, nutrient uptake and economics of sweet corn (mean of 2007-08 and 2008-09)

Treatment	Cob yield (t/ha)	Green fodder yield (t/ha)	Net returns (Rs/ha)	B : C ratio	Nitrogen uptake (kg/ha)	Phosphorus uptake (kg/ha)	Potassium uptake (kg/ha)
Sowing dates							
45th MW	19.9	25.6	1,01,120	2.61	260.30	32.49	105.85
47th MW	18.8	23.1	87,754	2.47	222.38	26.67	90.46
49th MW	17.1	21.4	82,040	2.41	195.25	24.11	79.97
51st MW	15.5	20.5	56,106	2.08	173.32	21.54	72.18
1st MW	13.7	19.2	47,675	1.94	148.32	18.26	62.01
3rd MW	12.4	18.2	28,549	1.63	129.19	15.99	53.68
CD (P=0.05)	0.43	0.35	-	-	8.26	1.188	2.28
Plant spacing (cmx cm)							
60 × 20	20.8	27.5	85,040	2.31	238.95	26.86	89.71
60 × 40	16.9	21.9	62,915	2.13	198.79	25.02	83.64
60 × 60	11.0	14.8	53,668	2.13	126.65	17.64	58.71
CD (P=0.05)	0.12	0.15	-	-	2.51	0.56	1.36
Interactions							
SXD	NS	NS			NS	NS	NS

The sweet corn variety 'Sugar 75' was dibbled as per the spacing treatments in a gross plot size of 4.8 m X 4.2 m area. The 12 kg, 6 kg and 4 kg/ha seed was required for 60 cm x 20cm, 60 cm x 40 cm and 60 cm x 60 cm spacing, respectively. The recommended dose of fertilizer for sweet corn is 225, 60 and 60 NPK kg /ha. The entire quantity of P_2O_5 and K_2O along with one-third N was applied as basal at the time of sowing. Remaining quantity of N was top-dressed in 2 equal splits, at knee stage and tasseling stages. Well decomposed FYM 10 tonnes /ha was incorporated in to the soil 10 day before sowing. The total nutrient uptake was calculated on the basis of per cent dry matter accumulation multiplied by nutrient content in different plant parts.

RESULTS

The maximum mean cob yield and green fodder yield were recorded when sweet corn was sown on 45th MW, (5 -11 November), followed by 47th MW (19 – 25 November). Delayed in sowing, yields were reduced significantly and sowing of 3rd MW recorded significantly low green cob and fodder yield. Higher the green cob and fodder yield resulted into significant increase in the dry matter content of different plant parts ultimately showed the higher nutrient uptake with the crop sown on 45th MW over the subsequent delayed sowing. These results are in line with the results obtained by Sutaliya and Singh (2005). Economics of sweet corn cultivation shows that crop sown on 45th MW gave the maximum net returns and benefit : cost ratio (2.61), followed by 47th MW. Higher monetary returns in above sowing dates as compared to others were attributed to more sweet corn cob and fodder yields. Further, the economic values were decreased under subsequent delayed sowing dates. These results are in agreement with those reported by Karthikeyan and Balasubramaniyan (2006). The planting geometry significantly influenced the cob and green fodder yields. Sowing of sweet corn with 60 cm x 20 cm (D_1) spacing recorded the highest cob yield and it was significantly higher over its subsequent spacings. Similarly, spacing of 60 cm x 40 cm produced significantly higher cob yield over 60 cm x 60 cm spacing. Similar trend was observed in case of green fodder yield. Higher yields under plant spacing of 60 cm x 20 cm significantly increased yield was mainly owing to maximum number of marketable cobs compared with those of 60 cm x 40 cm and 60 cm x 60 cm. Similarly, higher nitrogen, phosphorus and potassium uptake was obtained with plant spacing of 60 cm x 20 cm than the wider plant spacing of 60 cm x 40 cm and 60 cm x 60 cm. Green cob yield directly contributed to the net profit. The plant spacing of 60 cm x 20 cm gave the highest net profit of Rs. 85040 /ha and benefit: cost ratio of 2.31 due to maximum cob and green fodder yield than the others spacings.

CONCLUSION

Sweet corn sown in 45th meteorological week (5 – 11 November) gave maximum mean cob yield with maximum values of nutrient uptake and net returns than the subsequent delayed sowing. The plant spacing of 60 cm x 20 cm recorded higher nutrient uptake and maximum net returns over the wider spacing of 60 cm x 40 cm .

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Climate change and water productivity of wheat – A review of effects and management strategies

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Large weather fluctuations experienced during recent years are exerting tremendous pressure on water resources. The period from 1983 to 2012 has been observed as the warmest 30-year period of the last 1400 years in the Northern hemisphere. The globally averaged combined land and ocean surface temperature data depict a warming of 0.85°C over the period 1880 to 2012 (IPCC, 2014). These climatic changes are likely to have adverse impact on crop water requirements and water productivity. With the increase in temperature, the PET demand and hence the crop water requirement will increase. Increase in evapotranspiration due to global warming can put tremendous pressure on already over-stressed water resources over different regions. All these climatic changes have adverse impacts on the evapotranspiration and water productivity of wheat. Wheat is the world's third most widely grown crop. It is an important cereal crop of India, ranking second after rice in area and production. India is second largest producer of wheat after China with about 12% share in global food production. It meets 61% of protein requirement in India. The global warming scenarios are resulting in increasing water demand and decreasing productivity. Huntington (2005) reported that climate change might change the rate of evaporation, which will lead to variation in water availability and ground water recharge. Kingra and Kukal (2013) also reported that increase in mean air temperature by 1^{o}C during the growing period of wheat increases its water requirement by 45 mm. Thus, the impacts of climate change on agriculture and water resources have emerged as an important issue for scientists as well as policy makers.

METHODOLOGY

The relevant literature was collected from different journals, reports and review papers of national and international status. Besides this, websites were consulted/ visited for relevant literature to be incorporated in the study. Major findings emerged from the review have been discussed.

RESULTS

Due to climatic fluctuations, water demand is increasing, which will have negative impact on water productivity of wheat. IPCC (2014) has also predicted rise in surface temperature from 3.7 to 4.8 ˆC and in the levels of atmospheric CO_2 from 500 to 1000 ppm by the end of the 21st century. Under such conditions, different agronomic management options such as bed planting, irrigation management, conservation tillage, appropriate sowing time, mulch application etc. need to be adopted to improve water productivity of wheat. Zero tillage helps to decrease water losses during fallow periods and thus increases water productivity (Chi *et al.,* 2016). Proper irrigation scheduling can increase the canopy light interception and leads to more conversion of solar energy into dry matter (Ping and Zhu, 2012). By adjusting sowing dates, wheat can be protected from terminal heat stress. Mulch application helps to maintain optimum soil temperature and moisture for proper crop growth (Chakraborty *et al.,* 2008). Bed planting of wheat also reduces evapotranspiration and increases yield, thus increasing water productivity (Kingra and Mahey, 2013).

CONCLUSION

Climate change can have severe implications on water requirement and water productivity of wheat. Adaptations such as improved water management, planting patterns and tillage practices will be beneficial to check negative impacts of climate change on crop and water productivity. Thus, adoption of agronomic management options for managing water requirement and sustaining water productivity of wheat under limiting water and changing climatic scenarios is the need of the hour.

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Effect of planting dates on growth and yield of pre-seasonal sugarcane (Var. CoM 0265) under climate change situation

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Global warming and climate variation may have influenced the planting time, crop productivity and sugar recovery percentage (Duli and Li, 2015). Also many predicted negative impacts like climate induced biotic and abiotic stresses, deterioration of soil and water resources, shift in weed species, pest and diseases patterns, cane quality deterioration, etc. ring the alarm bells and attract immediate research initiatives for studying the impact as well as for developing strategies to overcome them (Bhaskaran and Nair, 2014). The preseasonal sugarcane planting is recommended during 15 October to 15 November for Maharashtra. The farmers of Maharashtra have started planting the sugarcane as per their convenience to get the higher prices from sugar factories. Unseasonal planting may affect the productivity of sugarcane. Since last few years it was observed that there is reduction in crop productivity and sugar recovery percentage, despite many important recommendations. Therefore, the experiment was planned with the objectives to find out the optimum planting dates of preseasonal sugarcane and to correlate meteorological parameters with phenological stage in sugarcane.

METHODOLOGY

Field experiment was conducted during 2011-12 to 2013-14 at Central Sugarcane Research Station, Padegaon, Satara, Maharashtra. The experiment was laid out in randomized block design with three replication and nine treatments comprises of nine planting dates of preseasonal sugarcane in different meteorological week with fifteen days intervals viz., 42nd MW (15.10), 44th MW(01.11), 46th MW(15.11), 48th MW(01.12), 50th MW(15.12), 1st MW(01.01), 3rd MW(15.01), 5th MW(01.02) and 7th MW(15.02). The sugarcane variety CoM 0265 was planted as per the treatments with 120 cm row spacing in gross and net polt size 10.0m X 7.20m and 8.00m X 4.80m, respectively. The two eye budded setts were planted at 15-20 cm distance. The crop was fertilized with the recommended fertilizer dose 340 kg N /ha, 170 kg P_2O_5 /ha and 170 kg K /ha. The nitrogen was applied in 4 splits at planting (10%), tillering (40%), grand growth stage (10 %) and earthing up (40 %). Phosphorus and Potassium were applied in 2 splits at planting (50 %) and earthing up (50 %). The soil of the experimental site was medium black. The daily weather data of the crop season during three years was considered for correlation study.

RESULTS

Among the different growth parameters recorded in Table 1 significantly the higher germination percentage (74%), tillering ratio (1.70), millable cane height (290.67 cm), cane

Table 1. Growth and yield attributes, yield, quality parameters of sugarcane and economics as affected by various treatments (pooled data).

Treatments	Cane yield (t /ha)	CCS yield (t /ha)	Weight/cane (kg)	Brix (c)	Net Return (₹)	B:C ratio
Planting in 42nd MW	171.15	25.01	1.60	21.27	314983	2.78
Planting in 44th MW	169.02	24.35	1.59	21.07	310229	2.75
Planting in 46th MW	165.64	23.32	1.58	20.75	302346	2.69
Planting in 48th MW	163.32	23.08	1.56	20.63	297116	2.66
Planting in 50th MW	150.22	20.44	1.50	20.29	264904	2.38
Planting in 1st MW	146.54	19.80	1.49	19.98	256270	2.32
Planting in 3rd MW	143.38	19.19	1.49	19.83	248937	2.26
Planting in 5th MW	140.62	18.64	1.51	19.22	242606	2.22
Planting in 7th MW	138.41	17.87	1.50	18.57	237651	2.18
CD (P=0.05)	19.84	2.95	NS	0.91		

girth (11.46 cm), number of internodes per cane (29.67), and number of millable cane (106865) observed under planting of sugarcane in 42nd MW (T_1). However, it was found at par with the treatment T_2, T_3, and T_4. The weight per cane (kg) was found to be non significant due to different treatments under study. The data presented in Table 1 revealed that, significantly the higher cane and CCS yield of sugarcane was recorded when it was planted in 42nd MW (171.15 t /ha and 25.01 t /ha) However, it was at par with planting in 44th MW (169.02 t /ha and 24.35 t /ha), planting in 46th MW (165.64 t /ha and 23.32 t /ha), and planting in 48th MW (163.32 t /ha and 23.08 t /ha). The per cent reduction in cane and CCS yield over 42nd MW were 12.23% and 18.26%, 14.38% and 20.82%, 16.23% and 23.27%, 17.84% and 25.46% and 19.13% and 28.54% in treatment 50th MW, 1st MW, 3rd MW, 5th MW and 7th MW, respectively. The data on quality parameters revealed that, significantly the highest Brix (21.27), Sucrose (20.44%), Purity (96.86%) and CCS (14.61%) were observed under planting in 42nd MW. However, it was at par with the treatment planting 44th MW, planting in 46th MW and planting in 48th MW. The increased cane and CCS yield might be due to increased contribution of growth and yield attributes. The higher net returns (314983 /ha) and B: C ratio (2.78) was obtained in treatment of planting in 42nd MW followed by planting of sugarcane in 44th MW, 46th MW and 48th MW.

CONCLUSION

Under the changing climatic condition planting of pre-seasonal sugarcane (CoM 0265) was to be found suitable from 42nd MW to 48th MW (i.e. 15 October to 30 November) for higher CCS yield without reduction in cane yield in medium to deep black soils of Western Maharashtra.

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Weather based multiple regression model for girdle beetle (*Obereopsis brevis* Gahan) on soybean

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Soybean (*Glycine max*) is facing problems with some biotic stresses recently and which is resulted in low production and productivity. In Maharashtra state particularly in Marathwada region, 19 species have been identified of insect pest attacking on this crop (Mundhe, 1982). Among these pests girdle beetle is major insect causing more damage to the soybean crop. Population dynamics of any pest depends on certain set of optimum weather conditions and crop growth stages. Thus, the studies on population dynamics of girdle beetle on soybean was conducted which is helping to forewarning of pest attack and ultimately it is useful to pest management.

METHODOLOGY

The present investigation was undertaken at Department of Agril. Meteorology, VNMKV, Parbhani to study the correlation and regression of population dynamics of Girdle beetle on soybean and weather. The observations of pest incidence on soybean and weather prevailed during kharif season (2002-2013) were collected. The data of pest incidence during 2002 to 2013 years for Girdle beetle were collected from AICRP on Soybean. One meter row length area was marked from the plot for pest observation. Labeling with date of all the girdle infested plants showing typical cutoff symptoms was done at weekly interval and observation of number of total plants and girdle affected plants were counted and this data was converted into percent plant infestation. Weekly weather data during the same years was collected from Department of Agril. Meteorology, VNMKV, Parbhani. Meteorological daily data was converted into weekly averages. Thus obtained data during *Kharif* 2002-2013 were analyzed and correlation coefficient worked out.-

RESULTS

Perusal of data (Table 1) revealed that peak population infestation was observed in 38th MW (57.57 %) in the year 2013. Pest Population above Economic threshold level (ETL) *i.e.* 10 % was recorded during the year 2008 and 2011 to 2013. Among the study period it was found that miner pest (girdle beetle) became a major pest and infestation was found above ETL level in only four years. It might be due to prevailed congenial weather condition for growth and development of girdle beetle. While, it was observed that the negative correlation of girdle beetle incidence was found during the wet weather condition (i.e. more rainfall, RH-I and RH-II) and more maximum temperature and minimum temperature as well as cloudy condition (i.e. low BSS) and positive correlation during dry condition (i.e. low rainfall), ranging low Tmin, RH-I, RH-II and more BSS (Table 2). Related observations were recorded by Kujur (2011) reported that peak activity of girdle beetle was noticed during the second week of September. Whereas, Singh *et al*. (2013) reported that the infestation of girdle beetle started in first week of August in the years 2007 and 2008. Multiple regression model was developed with weather parameters. The models developed from this analysis are given below.

$Y = 141.03 + 4.2109X_1 - 0.6906X_2 + 0.0081X_3$ ($R^2 = 0.97$)

Where, X_1 = Tmin, X_2 = RH II, X_3 = BSS and R^2 = Regression coefficient.

Year wise multiple regression analysis was worked out and validated with observed girdle infestation for each year. Pest incidence data of present meteorological week and mean weather data of previous four meteorological weeks was taken for analysis. As grub is damaging stage of the pest and lifecycle duration is 24 to 30 days hence, weather parameters averages of last 4 meteorological weeks were used. All equations were validated with each MW for every year and best fit equation was found for the year 2002 and it is used for calculating the error and per cent error in between observed and predicted values (Table 3). The correlation coefficient (R^2) was 0.97 and result was found significant and it provided forewarning of the pest before one week.

Table 3. Observed and predicted Girdle beetle population during 2013 in Parbhani Maharashtra

MW	Observed value	Predicted value	Error	Error %
32	18.18	27.46	09.28	51.00
33	25.00	29.47	04.47	17.88
34	32.57	47.41	14.84	45.55
35	49.24	57.30	08.06	16.36
36	53.03	57.39	04.87	09.05
37	56.81	53.39	00.58	01.02
38	57.57	53.28	-4.29	07.45
39	00.00	9.41	9.41	00.00

Table 1. Population dynamics of Girdle beetle in soybean at Parbhani (2002-2013)

M.W.	Girdle beetle (% infestation)											
	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
32	0.0	00.1	0	0	0	2.35	6.10	0.0	1.13	0.83	8.33	18.18
33	0.0	0.3	0	0	0	3.35	2.80	0.0	3.16	1.94	15.00	25
34	0.0	0.41	0	1.2	0	2.30	4.20	2.78	5.94	4.85	30.00	32.57
35	1.10	0.4	0	2.2	0	2.30	12.80	1.67	7.47	10.67	46.66	49.24
36	1.20	0.3	0	0	0	1.57	11.32	4.44	7.57	24.27	50.00	53.03
37	1.12	0.4	2.2	0	1.2	2.75	7.93	5.56	8.24	28.15	51.66	56.81
38	2.20	0	1.7	0	1.5	2.69	5.40	4.44	9.17	31.06	51.66	57.57
39	2.40	0	1.2	0	4.26	0	3.46	2.78	8.24	34.95	53.33	0.0

Table 2. Simple correlation between weather parameters and Girdle beetle during 2002-2013

Year	Weather Parameter					
	RF (mm)	Tmax (°C)	Tmin (°C)	RH-I (%)	RH-II (%)	BSS (hrs)
2002	-0.398	0.320	-0.923**	0.074	-0.670*	0.281
2003	-0.550	-0.625	-0.287	-0.904**	-0.049	-0.196
2004	-0.112	0.655	-0.500	-0.415	-0.267	0.784**
2006	-0.657*	0.558	-0.346	-0.608	-0.711*	0.900**
2009	0.632*	-0.765**	0.233	0.362	0.637*	-0.798**
2010	-0.779**	-0.323	-0.332	0.855**	-0.204	-0.690*
2012	0.076	0.759	-0.585	0.566	0.231	-0.814**
2013	-0.532	-0.861**	0.828**	0.732*	0.643*	0.100

CONCLUSION

Pest Population above Economic threshold level (ETL) *i.e.* 10 % was recorded during the year 2008 and 2011 to 2013. Population dynamics of girdle beetle showed either positive or negative association independently or coupled with one or more parameters, it might be due to non-availability of micro-climatic weather of particular experimental plots. Though the results obtained from multiple regressions model was found significant; it needs to be improving for accurate prediction and wide adoptability.

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Thermal requirement and yield of pigeon pea (*Cajanus cajan* (L.) Millsp.) genotypes sown at different dates under Marathwada (MS) condition

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Pigeon pea, a major pulse crop, is grown usually under rainfed environments across semi-arid Tropics (SAT). In such areas of uncertainty, intra and inter annual variability in weather causes substantial fluctuation in pigeon pea productivity. Reaumur was the first to suggest in 1735 that duration of particular stages of growth was directly related to temperature and this duration for particular species could be predicted using the sum of daily air temperature (Wang, 1960). The experiment was aimed to study the effect of sowing time on thermal requirement and yield of pigeon pea.

METHODOLOGY

A field experiment was conducted on experimental farm of Dept. of Agricultural Meteorology, VNMKV, Parbhani during *kharif* season of 2015-2016 under rainfed condition in factorial randomized bock design with five sowing dates (*i.e.* 25th, 26th, 27th, 28th and 29th MW) and three genotypes (*viz.* BDN-711, BSMR-736 and BSMR-853) with three replications.The growing degree days (GDD) was worked out for different phenophases by considering the base temperature of 10.0 ^{o}C (Patel *et al.*2000). HUE (kg/ha ^{o}C/day) was computed by using following formula (Kumar *et al*., 2008).

RESULTS

The different sowing dates have marked influence on growing degree days (GDD) and it was observed that mean GDD at emergence to branching (P_1), branching to floral bud initiation(P_2), floral bud initiation to 50 % flowering(P_3), 50 % flowering to 50 % pod formation(P_4) and 50 % pod formation to physiological maturity (P_5) was 483, 986, 273, 217 and 279 ^{o}C day, respectively (Table 1). Among all the sowing dates, the total GDD accumulated from emergence to physiological maturity ranged between 2078 to 2811 ^{o}C day. The significantly highest GDD was found with 25, 26 and 27th MW at different phenophases and total accumulated GDD was found significantly highest in 25th MW (2811 ^{o}C day) sowing and lowest in 29th MW sowing (2078 ^{o}C day). However, the trend showed that, with delay in sowing date, decreasing total accumulated GDD to attain physiological maturity. Similar results were reported by Patel *et al.* (2000). Total GDD was accumulated significantly higher by BSMR-736 (2262 ^{o}C day) over the rest of genotypes (BDN-711 and BSMR-853) and lowest in BDN-711 (2198 ^{o}C day). The mean HUE was observed 0.82 and among the sowing dates, significantly highest (0.87 kg/ha ^{o}C/day) was observed in 27th MW sowing and at par with 25th MW and 29th MW sowing (Table1). While, lower HUE (0.71 kg/ha ^{o}C/day) was observed in 26th MW sowing. Significantly highest HUE (0.86 kg/ha ^{o}C/day) was observed in BSMR-853 over rest of genotypes (BSMR-736 and BDN-711) and lowest (0.78 kg/ha ^{o}C/

Table 1. Effect of dates of sowing and genotypes on GDD, HUE, seed and biological yield of pigeon pea

Treatment	GDD (°C day)						HUE (kg/ha °C/day)	Seed Yield (kg/ha)	Biological Yield (kg/ha)
	P_1	P_2	P_3	P_4	P_5	Total			
Sowing dates									
25 MW	508	1496	317	228	262	2811	0.87	397	2466
26 MW	463	847	274	226	299	2109	0.71	375	1513
27 MW	521	808	268	228	282	2106	0.87	418	1850
28 MW	496	864	256	199	272	2087	0.79	382	1652
29 MW	428	915	249	203	283	2078	0.85	411	1767
CD (P=0.05)	55.70	44.98	22.48	19.83	NS	-	0.05	20.83	160.12
Genotypes									
BDN-711	470	950	246	231	301	2198	0.81	414	1798
BSMR-736	494	1002	285	218	263	2262	0.78	399	1789
BSMR-853	485	1005	287	203	274	2254	0.86	375	1962
CD (P=0.05)	NS	34.8	17.4	15.3	NS	-	0.04	16.1	124
Interaction									
CD (P=0.05)	NS	NS	38.94	NS	NS	-	NS	NS	NS
G. Mean	483	986	273	217	279	-	0.82	396	1850

P_1- Emergence to branching ; P_2- Branching to floral bud initiation; P_3- floral bud initiation to 50% flowering; P_4- 50 % Flowering to 50% pod formation; P_5- 50% Pod formation to physiological maturity

day) in BSMR-736. It may be due to the varietal characters and genotypic differences to take different time of GDD accumulation and differences in production of dry matter. This result is in conformity with the Singh *et al*. (2016). Significantly highest seed yield (418 kg/ha) was recorded with 27th MW sowing and lowest (375 k/ha) in 26th MW sowing over rest of the treatments; at par with 25th and 29th MW sowing dates. Among three genotypes, highest seed yield (414 kg/ha) was observed with genotype BDN-711 and lowest (375 kg/ha) with BSMR-853 The BDN-711 genotype recorded significantly superior yield over all other varieties and it was found at par with BSMR-736. It may be due to its varietal characteristics, to give response and to produce more grain yield under same weather condition prevailed. These results are in agreement with reported in past by Singh *et al.* (2016).

CONCLUSION

Total accumulated GDD was recorded highest in 25th MW sowing and lowest in 29th MW; while it was accumulated highest by BSMR-736 and lowest by BDN-711 genotypes. The uniform pattern of highest GDD was not observed with either one sowing date or with one variety. Whereas, highest total HUE was accumulated by 27th MW sowing and lowest by 26th MW and highest by BSMR-853 and lowest by BSMR-736. Highest seed and biological yield observed in 27th MW sowing and 25th MW sowing respectively.

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Climate resilience in Bundelkhand agriculture through soil moisture conservation and crop diversification

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The average annual precipitation ranges between 700 to 1000 mm with 80-90% of it being received during July to mid-September. The region faced a chronic drought during 2003-2010 and unseasonal rainfall in *Rabi* 2014. The soils are mixture of black, red and yellow soils. The soils are medium to low in fertility with low organic matter content and poor water holding capacity that limits the fodder and food productivity. Therefore, as a practice light soils are sown during *kharif* and heavy soils are left fellow for cultivation during *Rabi* season. However in medium to heavy soils cropping intensity and diversity can be improved through adoption of suitable crop species in conjunction with moisture conservation strategy. Keeping in view the above points on station experiment was conducted to evaluate the performance of different crops species in *kharif* season for climate resilience.

METHODOLOGY

The treatments consisted of eight crop species viz., c1 (fodder sorghum), c2 fodder cowpea, c3 black gram- shekhar-3, c4 maize, c5 black gram-azad-2, c6 sesamum t-78, c7 sesamum- jts-8 and c8 groundnut; and three moisture conservation methods: m1 (deep summer ploughing + mulching with locally available biomass + weed @ 5 tonne fresh material), m2 (lifesaving irrigation) m3 (farmers practices). The productivity of crops was worked out in terms of fodder equivalent yield received. The packages of practices were followed for cultivation. The experiment was laid out in split plot design allocating crop species in the main plots and moisture conservation methods in subplots with three replications.

RESULTS

The performance of the crops was evaluated by converting the economic yield in fodder equivalent yield, as they differed in terms of economic output. The data presented in table 1. Indicates that groundnut proved most productive, remunerative (net return Rs. 94635/ ha) as well as recorded maximum RWUE (1.13kg/ha/mm) followed by sorghum. The Maize proved least productive as the rainfall was scarce and season faced a long dry spell during SMW 34-37 and 39-40 SMW, which coincided with leaf development, silk emergence, browning and early grain development stage leading to drastic reduction in the yield.

Table 1. Fodder eq. yield, Gross returns and rain water use efficiency of different crops

	Fodder eq. yield (t/ha)	Gross returns (Rs/ha)	(kg/ha/mm)
C1	40.19[b]	60288[b]	0.72
C2	30.83[c]	46247[c]	0.55
C3	25.27[d]	37912[d]	0.45
C4	10.02[f]	15030[g]	0.18
C5	21.26[f]	31897[f]	0.38
C6	20.63[f]	30947[f]	0.37
C7	22.88[e]	34331[e]	0.41
C8	63.09[a]	94635[a]	1.13
Mean	29.27	43911	0.52
M1	29.31[b]	43970[b]	0.52
M2	30.46[a]	45696[a]	0.54
M3	28.04[c]	42066[c]	0.50
Mean	29.27	43911	0.52

CONCLUSION

The groundnut proved most productive, and efficient in terms of rain water use efficiency under semi-arid region of Bundelkhand.

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Development of climate resilient maize-based cropping systems for mountain ecosystems under organic management

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Arable land in Sikkim is about 1.09 lakh ha, which is 16% of the total geographical area of the state. The net cultivable area is approximately 79,000 ha. Agriculture is mainly rainfed (89%) and practiced on slopy terrain. The slopy lands are 3-4 times less efficient than the plains in meeting the caloric and protein needs of their populations. Farmers of the state leave their land fallow during the *Rabi* season due to negligible and very less rainfall which is not able to support crop cultivation. Currently, sustaining crop productivity under decreasing water availability and shrinking land resources is becoming major challenge in mountain ecosystems (Babu *et al.,* 2014). Productivity of rainfed mono-cropping system of Sikkim is very low and it is a high risk economic activity. It is assumed that the present and future demand of food can be met through intensive crop production with increase in productivity per unit area and time especially under rainfed ecosystems of the region (Babu *et al.,* 2016). Therefore, there is need to intensify existing maize-fallow system by inclusion of more number of crops per unit area. But, the intensified production systems require increased use of production inputs. Therefore, selection of appropriate, vital crops and nutrients management practices in maize–based cropping system is necessary to harness maximum returns and enhancing flexibility of cropping under limited moisture supply without considerable modification in farming operations. In view of the limited scope for horizontal expansion to augment food production, the alternative is to proceed with vertical growth by increasing the productivity per unit of available land. Farmers practice mono cropping of maize in the state due to which the cropping intensity of Sikkim is very low (118%) as compared to the national average of about 140%. Hence, an attempt has been made to increase the cropping intensityup to 300% and per unit land and water productivity, besides judicious uses of natural resources in rainfed ecosystem through intensification of maize-based cropping sequences with the inclusion of leguminous crop.

METHODOLOGY

Fixed plot field experiment was initiated during 2014 at the research farm of ICAR Research Complex for NEH Region, Sikkim Centre, Tadong situated at latitude 27^{o}32' N and longitude 88^{o}60' E, at an altitude of 1300 amsl. The soil is clay loam in texture and initial content of pH, organic carbon, available N, P and K was 5.8, 21.8 g/kg, 265.4 kg/ha, 27.60 kg/ha and 212.8 kg/ha, respectively. Three cropping sequences *viz*., CS_1- maize-fallow (FP), $CS\text{-}_2$- maize-urd bean (*pahenlo dal*)-buckwheat and CS_3- maize-urd bean (*pahenlo dal*)-mustard were imposed in main plot and four organic sources of nutrients *viz.,* control (farmers' practices); 50% FYM + 25% VC + 25% MC + biofertilizers; 50% MC + 25%FYM + 25%VC + biofertilizers and 25%FYM + 25%MC + 25%VC + 25%PM+ biofertilizers in subplots with three replications. The crops were grown under rainfed conditions with the recommended organic cultivation practices. Properly decomposed organic manures were applied and incorporated in the soil at the time of last tilling before the sowing of crops. Observations on yields were recorded as per the standard procedures. System production efficiency (SPE) and relative production efficiency (RPE) were calculated as per the equations suggested by Babu *et al.* (2016) and apparent water use productivity (AWUP) was calculated as per the formula given below.

AWUP (kg/ha) = [Equivalent yield of a system (kg/ha)]/ Total quantity of water used in ha of land in cm.

RESULTS

In general, intensified cropping systems were more productive over the farmer's practices (maize-fallow) of the region (Table 1). While comparing the total productivity of intensified cropping systems, maximum system production efficiency (28.34 kg/ha/day) was recorded with maize-*Pahenlo dal* (green seeded urd bean)-buckwheat. Crop yield, duration and sale price of the produce greatly influenced the overall return and PE (production efficiency) of various systems (Mukherjee, 2010) and resulted in higher production efficiency. Similarly, relative production efficiency (RPE) *i.e.*, the capacity of the system for production in relation to existing system was maximum (190.4%) with maize-green seeded urd bean--buckwheat system followed by maize-urd bean-toria

Table 1. System production efficiency (SPE), relative production efficiency (RPE), apparent water use productivity (AWUP) and water equivalent of maize grain under diverse cropping system, nutrient and moisture management practices in Sikkim Himalayas

Treatment	SPE (kg/ha/day)	RPE (%)	AWUP (kg/ha-cm)	Water (l/kg) equivalent of maize grain
Cropping system				
Maize-fallow	9.76	00	117.6	859.4
Maize-urdbean –buckwheat	28.34	190.4	341.4	296.0
Maize-urdbean- toria	27.20	178.7	327.6	308.5
SEm±	0.09	–	1.1	2.1
CD (P=0.05)	0.27	–	3.3	6.2
Organic N sources substitution				
Farmers Practice	18.37	00	221.3	573.5
50% FYM + 25%MC + 25%VC + BF	22.08	20.1	265.9	474.5
50%MC + 25%FYM + 25%VC + BF	22.73	23.7	273.8	460.5
25%FYM + 25%MC + 25%VC + 25%PM + BF	23.89	30.0	287.8	443.3
SEm±	0.08	–	0.9	2.5
LSD (*P=0.05*)	0.19	–	2.3	6.2
Moisture conservation practices				
Without mulching	21.53	–	259.4	490.5
With mulching	22.00	–	265.0	485.4
SEm±	0.04	–	0.4	0.5
CD (P=0.05)	0.09	–	1.0	1.1

FYM: Farmyard Manure, MC: Mixed Compost, VC: Vermicompost, PM: Poultry manure and BF: Biofertilizers

sequence. With regard to apparent water use productivity (AWUP) and water requirement (l) per kg of maize grain equivalent, maize-urd bean-buckwheat system showed its superiority over the others and resulted in the lowest amount of water requirement for kg grain production (296 liter of water/kg of maize grain equivalent yield). Among the organic sources of nutrients, substitution of organic nutrients in 25%FYM + 25%MC + 25%VC + 25%PM+BF in combination resulted in maximum system production efficiency, relative production efficiency and required the least amount of water per kg grain production of maize in system mode. During winter season, moisture conservation by mulching resulted in higher system production efficiency, AWUP and required lower amount of water for kg grain production as compared to no mulching.

CONCLUSION

It may be concluded cultivation of maize-*Pahenlo dal*-buckwheat along with substitution of organic nutrients in 25%FYM + 25%MC + 25%VC + 25%PM + BF combination and mulching with crop residue during winter months under rainfed ecosystems of Sikkim Himalayas may enhance the water and crop productivity. Therefore, it is recommended that growers can utilize this technology under rainfed conditions for sustaining their livelihood security especially in the mid hills of Sikkim Himalayas.

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Crop weather interaction studies in damask rose (*Rosa damascena*) in the Western Himalaya

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Weather parameters *viz.,* temperature and sunlight are the major limiting factors for higher crop productivity. Crop-weather interaction studies in aromatic crops are very meager and need particular attention to ensure higher recovery of essential oil yield and composition of particular compounds. Damask rose (*Rosa damascena* Mill.) is one of the most important commercial aromatic crop commonly grown for rose essential oil, concrete, absolute and rose water. Rose essential oil is most expensive because of its low content and non-availability of synthetic alternative. Rose essential oil is a mixture of different compounds, among them geraniol, citronellol and nerol are the most important that have several applications in cosmetic and perfumery industry (Verma *et al.,* 2011). Temperature is one of the most important environmental factor which affects phenology and yield of plant (Pal *et al.,* 2013). A field study was conducted to ascertain the role of meteorological parameters in *R. damascena* varieties. Agro-meteorological indices *viz*., relative temperature disparity (RTD), growing degree days (GDD), heliothermal units (HTU) and photothermal units (PTU) were calculated. A literature studies revealed that less work has been done on the crop-weather interaction studies in damask rose. Therefore, present study was undertaken to assess crop weather interaction studies in *R. damascena* in the western Himalayas.

METHODOLOGY

To perceive the thermal impact on different phenophases and productivity of damask rose oil, field experiment was carried out during 2014-2015 at the experimental farm of CSIR-Institute of Himalayan Bioresource Technology (IHBT), Palampur (1325 m amsl, 32º06´05"N, 76º34´10"E), India. The soil of experimental area is clay loam in texture, acidic in reaction (pH 5.7), high in organic carbon (1.0 %), medium in available N (278.4 kg/ha), available P (17.2 kg/ha) and available K (275.4 kg/ha). The experiment was laid out as per split plot design taking two varieties of damask rose *viz*., Himroz and Jwala in main plot and five pruning time (October 30, November 15, November 30, December 15 and December 30) in sub-plots. The experiment was replicated four times. Standard agricultural practices were followed during the crop growth season. Data on weather parameters *viz*., maximum and minimum temperature, relative humidity, evaporation, bright sunshine hours, day length and rainfall for the crop season was recorded at meteorological observatory of the CSK Himachal Pradesh Agricultural University, Palampur, HP. Data on phenological stages after pruning *viz*., days taken to leaf bud initiation, days taken to flower bud initiation, days taken to flower initiation, days taken to 100% flowering, flower yield/plant and plant parameters *viz*., essential oil content and essential oil composition were recorded. Weather variables *viz*., accumulated RTD, GDD, PTU and HTU from pruning to flower initiation were calculated using standard formulas. For calculation of GDD, base temperature was taken as 10^{o}C.

RESULTS

During the crop growing season the maximum and minimum temperature was within the range of 8.5 to 28^{o}C and 1.5 to 14.5^{o}C, respectively. Agrometeorological indices indicate the differential behaviour of environment. Temperature indices *viz.*, accumulated RTD, GDD, HTU and PTU during the crop growing season of *R. damascena* are presented in Table 1. Data revealed that for date of pruning to flower initiation different values of GDD, PTU and RTD were accumulated. Early pruned plants (October 30) of both the varieties of*R. damascena* accumulated higher value of GDD(1299 and1323^{o}C days),PTU (14727 and 15057^{o}C day h), HTU (9110 and 9281^{o}C day h) and RTD (16005 and 16119 %) as compared to late pruned plants (December 30).Similar findings were observed by Mote *et al.,*2015 and Kumar *et al.,* 2010 for rice and wild marigold. The values of GDD, RTD,HTU and PTU reduced as the pruning delayed for both Himroz and Jwala varieties (Table 1). The results obtained from the correlation studies (Table 2) indicated that accumu-

Table 1. Agrometeorological indices during the crop growing season of *R. damascena*

Treatment	ARTD(%)	AGDD (°C days)	APTU (°C day h)	AHTU (°C day h)	Day length (h)	BSS (h)
Pruning time			Himroz			
October 30	16005	1299	14727	9110	1866	1101
November 15	14576	1086	12334	7544	1655	959
November 30	13125	969	11170	6518	1514	838
December 15	11545	864	10163	5608	1376	722
December 30	9591	786	9330	5054	1212	617
			Jwala			
October 30	16119	1323	15057	9281	1894	1114
November 15	14625	1099	12514	7638	1669	966
November 30	13174	982	11350	6598	1527	844
December 15	11662	888	10482	5706	1403	730
December 30	9703	813	9691	5201	1239	628

ARTD, Accumulated Relative Temperature Disparity; AGDD, Accumulated Growing Degree Days; APTU, Accumulated Photo Thermal Unit; AHTU, Accumulated Helio Thermal Unit.

Table 2. Correlation coefficients of agro-meteorological indices with different parameters of *R.damascena*

Parameters	ARTD (%)	AGDD (°C days)	APTU (°C day h)	AHTU (°C day h)	Day length (h)	BSS (h)
Flowers/plant	0.232	0.192	0.185	0.203	0.194	0.252
Weight of flower/plant (gm)	0.427	0.354	0.345	0.382	0.375	0.449
CCI	0.589	0.470	0.458	0.409	0.564	0.445
Number of branches	0.531	0.525	0.519	0.538	0.514	0.570
Oil Compounds (%)						
Citronellol	0.824*	0.784*	0.778*	0.807*	0.080	0.072
Nerol	-0.351	-0.380	-0.376	-0.371	0.236	0.241
Geraniol	-0.182	-0.212	-0.208	-0.191	0.348	0.351

lated RTD, GDD, PTU and HTU positively correlated with yield attributes *viz.*, number of flowers/plant, weight of flower/plant, Chlorophyll Content Index (CCI) and number of branches. Day length and bright sunshine hours also showed positive correlation with yield attributes. Essential oil compound citronellol was significantly correlated with different agrometeorological indices. Geraniol and nerol were negatively correlated with weather indices. However, day length and BSS showed positive correlations with these compounds. This suggests that temperature, day length and sunshine hours play a vital role in damask rose productivity and quality.

CONCLUSION

Weather variables influenced the accumulation of plant parameters of *R. damascena.* Temperature, day length and sunshine hours play an important role in determining the productivity of *R. damascena*. It is therefore, concluded that the weather variables had a definite bearing on growth and quality of rose essential oil. The response of damask rose crop to different thermal regimes, suggests that under the mid hills of western Himalayas, damask rose should be pruned during December 15 to 30.

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Performance of quality protein maize under different planting dates to provide fodder during winter lean period

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Maize (*Zea mays* L) is one of the most versatile and diversify crop, having wider adaptability in diverse ecologies and multi-uses. The existing normal maize varieties are deficient in certain essential amino acids particularly lysine, tryptophan and threonine. The biological value of normal maize is 40% compared to that of QPM, which is 80 and only 37% of normal maize protein intake is utilized compared to 74% of the same amount of high-quality maize protein (Panda *et al.,* 2014). The QPM, in general, contains 55% more tryptophan, 30% more lysine and 38% less leucine than that of normal maize. This genetic manipulation for nutritional fortification of maize may affect the green fodder quality. With this hypothesis, the present study was undertaken to study the performance of different cultivators of QPM maize and normal green fodder for evaluating their nutritional and fodder production capacity during winter lean periods at different planting windows.

METHODOLOGY

The experiment was conducted at FRMC, NDRI, Karnal, Haryana. The experiment was laid out in split plot design with four sowing times 15th August, 5th September, 25th September and 15th October in main plots and five maize cultivars HQPM-1, HQPM-4, HM-10, African tall and J-1006 in sub-plots during post rainy season of 2014 and 2015. The soil of the experimental field was clay loam in texture and low in available N, P, Zn and high in available K. The crop was sown for experiment from 15th August to 15th October in both the years using seed rate at 60 kg ha^{-1} with spacing of 30 cm x 10 cm. The recommended (120 kg N and 60 kg P_2O_5 /ha) dose of fertilizers were applied, of which full dose of P and half N were applied at sowing time and remaining half nitrogen at 30 days after sowing. The crop was harvested at the age of 65-70 days for green fodder purpose when the tip of tassel has emerged in more than 50 % of the field and DM %, Green fodder and dry matter yield were recorded.

RESULTS

Green fodder and dry matter yield significantly influenced by both sowing time and cultivars (Table 1). August 15th sown

Table 1. Effects of different cultivars and planting windows on dry matter content, green fodder and dry matter yield of fodder maize.

Treatment	Dry matter content (%)		Green Fodder Yield (t/ha)		Dry Matter Yield (t/ha)	
	2014	2015	2014	2015	2014	2015
Sowing time						
D1 (15 Aug)	21.30	21.44	53.49	56.17	11.39	12.03
D2 (05 Sept)	21.18	21.32	50.58	53.11	10.72	11.32
D3 (25 Sept)	20.56	20.70	45.42	47.69	9.33	9.87
D4 (15 Oct)	19.12	19.25	7.95	9.15	1.52	1.76
CD (P=0.05)	0.23	1.00	4.86	5.11	1.07	1.21
Variety						
Africam Tall	20.60	20.74	42.00	44.27	8.77	9.31
J-1006	20.50	20.64	39.44	41.61	8.29	8.80
HQPM-1	20.47	20.61	40.38	42.59	8.40	8.92
HQPM-4	20.43	20.57	40.40	42.64	8.45	8.96
HM -10	20.69	20.83	34.59	36.54	7.29	7.74
CD (P=0.05)	NS	NS	2.97	3.14	0.59	0.63

crop recorded maximum green fodder yield (53.49 and 56.17 t/ha) and dry matter yield (11.39 and 12.03 t/ha) during 2014 and 2015, respectively. The performance in terms of both green fodder and dry matter yield observed with 15th August sowing was at par with September 5th sowing, however further delay in sowing led to significant reduction in green fodder and dry matter yield. October 15th sowed drastic reduction in yield during both the year of experimentation. Early sowing on 15th August and 5th September resulted in greater plant height and other growth parameters, which ultimately resulted in increased green fodder as well as dry matter yield. Growth and development of Maize are strongly dependent on temperature. Maize develops faster when temperatures are warmer and more slowly when temperatures are cooler. Growing degree day's requirement of maize for tip of tassel to emerge i.e. flowering initiation is 1135 (Nielsen, 2012). During both the years of study Growing degree day's requirements are satisfied only up to the sowing of 5th September and delayed sowing results in laser availability of growing degree day and hence the significant lower growth and fodder yield.

CONCLUSION

Green fodders of QPM varieties have potential to be included in ruminant feeding similar to normal fodder maize varieties during winter lean periods.

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Effect of sowing date on barley yellow dwarf virus (BYDV) severity in different wheat cultivars

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Barley yellow dwarf virus (BYDV) is considered as the most important viral disease of cereal crops in several Asian countries including Iran. Yield loss caused by BYDV infection is reported to be varied depending on the used cultivar, virus strain, time of infection, and environmental conditions. In wheat, yield losses due to BYDV infection have been reported to be as high as 40-50% (Herbert *et al*., 1999, Riedell *et al*., 1999).In cereal crops, planting date and variety selection is considered important tasks for wheat producers. Our main objective in the present study was to investigate the effect of planting date on incidence of BYDV in different wheat cultivars.

METHODOLOGY

Field studies were conducted to determine the effect of planting date on naturally occurring barley yellow dwarf virus (BYDV) incidence in different wheat genotypes. The experimental design was a split-plot arrangement in a randomized complete block with three replications. Eight seeding dates (SD) at one month intervals were assigned to main plots. Fourteen cultivars (Twelve bread wheat, one durum wheat and one triticale cultivar) were subplots that randomized within each main plot. Visual assessments of typical BYDV symptoms was observed and scored based on the proportion of infected plants and the severity of the symptoms in the plot on a 0–5 Scale (Niks *et al*., 2004).

RESULTS

The wheat genotypes showed different level of BYDV infection in different sowing dates. There was a high correlation between the growth habit and the level of BYDV severity. In general, spring wheat cultivars showed more BYDV infection than the winter cultivars. Most of the susceptible cultivars showed their highest level of infection in the first sowing date. Our results demonstrated the role of planting date in the level of BYDV infection and can be used to recommend modifying the sowing dates as a means to escape the disease in the BYDV hot spot regions.

CONCLUSION

Barley yellow dwarf virus is a disease complex. Sowing date and overlapping between the growing period of different cereal crops that are host to the pathogen and aphid vectors are important part of the integrated BYDV managements programs.

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Reflected PAR on growth and yield of spring-summer mungbean (*Vigna radiata*) sown under different dates

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The interaction between radiation and crop canopy is complicated. The complication arises due to certain part of incident radiation reflected to the environment which is termed as albedo. The reflection of radiation from crop canopy is a protective mechanism as it offloads the heat received by the crop. The nature of canopy reflectance may be used to predict the maturity of underground portion of the plant (Carley *et al*., 2008). Productivity of pulses is regulated by temperature and radiation environment. Informations on the effect of this reflected radiation by mungbean is lacking. The present study aims to illustrate the pattern of reflection by mungbean crop under different dates of sowing as well as its impact on LAI, plant height and seed yield of the mungbean crop.

METHODOLOGY

A field experiment was carried out during spring-summer season of 2011 and 2012 at the District Seed Farm (22°56´ N Lat and 88°32´E Long, 9.75 m above mean sea level) Bidhan Chandra Krishi Viswavidyalaya, Kalyani, West Bengal. The experimental site falls under tropical sub-humid climate. The soil was sandy loam in texture with almost neutral pH (7.1). The experiment was laid out in split-plot design where four (15^{th} February, 25^{th} February, 7^{th} March, 17^{th} March) dates of sowing were allotted as the main plot treatment and the five (IPM-2-3, *Samrat,* Pant Mung-5, *Sonali* and *Meha*) varieties were in the sub-plot treatment with three replications. The plot size was 5m×6m. The reflected Photosynthetically Active Radiation (RPAR) was measured from the crop canopy with the help of line quantum sensor (APOGEE Logan UT, Model number MQ301) at the different phenophases (branch initiation, bud emergence, 100% flowering and pod emergence) of mungbean crop diurnally (8.00, 12.00 and 16.00 h). The plant height and LAI were measured at the respective stages. The impact of reflectivity on seed yield was also estimated through step-wise multiple regressions and the relationship study was done by SPSS 7.5 software, (SPSS 7.5 copyright, 1997 by SPSS Inc., USA Base 7.5 Application guide).

RESULTS

The mean reflected PAR during spring-summer season declined gradually from branch initiation to pod emergence under different dates of sowing (except D_1) (Table 1). The PAR reflectivity significantly declined with the increment of height; the reflected PAR was the exponential function of crop

Table 1. Mean reflected PAR (%) during growth phases in mungbean sown under different dates in spring-summer season (mean over two years and varieties)

Treatments	Branch initiation	Bud emergence	100% flowering	Pod emergence
D_1 (15th February)	7.2	6.3	5.4	5.7
D_2 (25th February)	7.1	6.0	5.6	5.1
D_3 (7th March)	6.8	6.1	5.9	5.2
D_4 (17th March)	7.1	6.4	5.1	5.2

Table 2. Impact of reflected PAR recorded at different growth phases on seed yield of spring-summer mungbean under different dates of sowing

Dates of sowing	Regression Equations
D_1(15th February)	Yield = 6306.644 - 0.603 $RPAR^*_{Branch\ initiation}$ + 0.317 $RPAR_{Bud\ emergence}$ – 0.018 $RPAR_{100\%\ flowering}$ – 0.761 $RPAR^*_{Pod\ emergence}$ R^2 = 0.927 Adj R^2 = 0.869 $SE_{(Est.)}$ = 168.430
D_2(25th February)	Yield = 1699.956 - 0.708 $RPAR^{**}_{Branch\ initiation}$ + 0.528 $RPAR^{**}_{Bud\ emergence}$ – 0.099 $RPAR_{100\%\ flowering}$ – 0.552 $RPAR^{**}_{Pod\ emergence}$ R^2 = 0.990 Adj R^2 = 0.981 $SE_{(Est)}$ = 42.558
D_3(7th March)	Yield = 3520.544 + 0.302 $RPAR_{Branch\ initiation}$ - 0.336 $RPAR_{Bud\ emergence}$ – 0.067 $RPAR_{100\%\ flowering}$ – 0.717 $RPAR_{Pod\ emergence}$ R^2 = 0.921 Adj R^2 = 0.857 $SE_{(Est)}$ = 104.426
D_4(17th March)	Yield = 2823.489 - 0.896 $RPAR^{**}_{Branch\ initiation}$ - 0.161 $RPAR_{Bud\ emergence}$ – 0.120 $RPAR_{100\%\ flowering}$ + 0.041 $RPAR_{Pod\ emergence}$ R^2 = 0.935 Adj R^2 = 0.884 $SE_{(Est)}$ = 53.850

Note: **- Significant at 1% level; *- Significant at 5% level; RPAR – Reflected PAR; $SE_{(Est)}$ – Standard Error of the Estimate

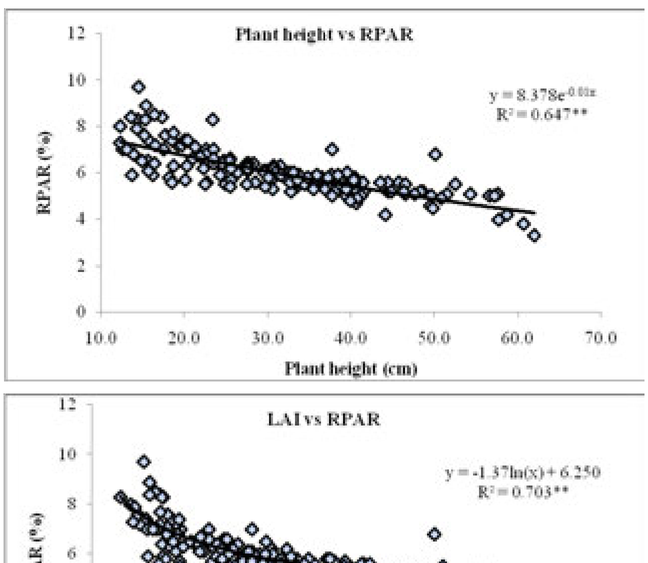

Fig. 1. Relationship between reflected PAR and growth parameters (plant height and LAI) of mungbean crop during spring-summer season

height and about 64.7% variation in PAR reflectivity were explained through crop height (Fig. 1). The reflected PAR decreased logarithmically with the increment of LAI during spring summer season; 70.3% variation in reflected PAR may be assigned to the variation in LAI. Reflected PAR in different growth phases significantly explained the grain yield in mungbean. During spring-summer season reflected PAR at branch initiation and pod emergence had significantly negative impact on seed yield under D_1 and D_2 sowing (Table 2), whereas the reflected PAR at bud emergence had a positive and significant effect on seed yield under D_2 sowing. Under D_3 sowing, the reflected PAR had no significant effect on seed yield, whereas it had a significant negative impact on the seed yield at branch initiation phenophase of the D_4 sown crop.

CONCLUSION

It has been showed that the branch initiation phase was the most sensitive phenophase where higher reflectivity by the crop will reduce the seed yield significantly. It has been concluded that by measuring reflective PAR growth parameter and crop yield may be assessed.

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Influence of microclimate on soybean (*Glycine max*) – sweet corn (*Zea mays Saccharata*) cropping system under land configuration and nutrient management

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Soybean-sweet corn cropping sequence is a new cropping sequence just introduced in the farmers community because In the era of shrinking resource base of land, water and energy, resource use efficiency has become an important issue for considering the suitability of a cropping system (Yadav, 2005). Land configuration plays an important role in conservation of maximum water in the soil. Chittaranjan (1981) stated that land configuration is the mechanical measure for better *in situ* moisture conservation as the soil profile acts as reservoir for moisture storage and this facility needs to be exploited to the maximum extent. The nutritional study particularly with respect of levels of potassium on soybean crop in meager and also the study of nutrient management as well as the effect of land configuration on both soybean and sweet corn is meager. Hence the present investigation has been undertaken to study the "Effect of microclimate on land configuration in soybean- maize (sweet corn) crop sequence"

METHODOLOGY

The field experiment was conducted at integrated farming system research project farm, M.P. K. V. Rahuri during *kharif* and *rabi* seasons of 2011-12 and 2012-13. The experimental crop of soybean received 311mm rain in 23 rainy days and 308 mm rains in 21 rainy days, respectively, during first and second year of the experiment. The six irrigations were provided to sweet corn at an 15-18 days interval, irrigation water was applied equally to all the plots of sweet corn irrespective to the land configurations and fertilizers applied. The experiment was comprised of a total of 10 treatment combinations during *kharif* soybean crop involving 2 land configuration and 5 potassium levels *Viz*. O kg K_2O,12.50 kg K_2O, 25 kg K_2O, 37.50 kg K_2O, 50 kg K_2O + GRDF (50:75:00 N:P:K/ ha + 10 t/ha FYM + *Rhizobium* + PSB) is common to all treatment and total 30 treatment combinations during *rabi* sweet corn crop involving 2 land configuration and 5 potassium levels to preceding soybean (*kharif*) and 3 fertilizer levels to sweet corn *Viz.*75 %RDF (90:30:45 kg NPK/ha), 100 % RDF (120:40: 60 kg NPK/ha), 125 % RDF (150:50:75 kg NPK/ha). During *rabi* season full dose of P and K will be applied as basal and N will be applied as three equal splits to sweet corn i.e. 1/3rd at planting, 1/3rd at 30 DAS and remaining 1/3rd at 45 DAS. These treatment combinations were replicated thrice under split plot design in permanent fixed layout for both the years. The photo synthetically active radiation (PAR) was measured daily between 11.00 am to 1.00 pm with the line quantum sensor (Li-cor make) LI191SA. The observations were recorded across the rows. The incident PAR (PARo) was measured 30 cm above the canopy by Line Quantum Sensor facing towards sky. The transmitted PAR (TPAR) was measured by placing the line quantum sensor at ground level facing upwards. Reflected PAR by soil (RPARs) was measured at 15 to 30 cm above the ground by facing line quantum sensor towards soil. The reflected PAR by canopy + soil (RPARc) was measured by holding line quantum sensor 30 cm above the canopy facing towards canopy. The absorbed Photosynthetically Active Radiation (APAR) was calculated using the formula given by Gallo and Daughtry (1986).The Infra Red Gas Analyzer (IRGA) LI-COR make LI 6400XT is an open system, which means that measurement of photosynthesis is based on the differences in CO_2 and H_2O in an air stream that is flowing through the leaf cuvette. Physiological parameters *viz.* rate of photosynthesis (µ mol co_2 m/s) were measured using portable photosynthesis system LI-COR 6400XT (LI- COR, Lincoln, NE, USA) at an interval of 15 days from 30 days after sowing. The observations were recorded on the five randomly selected tagged plants on the upper, lower and middle leaves and then mean value was considered. The observations were recorded between 10-11am at every time.

RESULTS

The planting methods was not influenced significantly on any parameter of microclimate but the ridges and furrow planting method recorded highest values of absorbed photo synthetically active radiation (APAR) 646.20 µ mol/m^2/s, light use efficiency 1.68 g/MJ and CO_2 concentration 383.295 ì mol/ m^2/ s at 60 DAS, photosynthetic rate 27.64 ì mol/ m^2/ s, stomatal conductance 0.98 mol H_2O mol/ m^2/ s and at 75 DAS, stomatal resistance minimum 9.83 and leaf temperature 34.69 ^{O}C at harvest among all the growth stages of soybean crop. This might be due to non-stress soil moisture situation experienced by crop resulted plant absorb adequate moisture and the cells become turgid, stomata remains open for more exit of H_2O and entry of CO_2. Because of more absorption of

Table 1. Different microclimate parameters as influenced periodically by different treatments of soybean

Treatments	Absorbed PAR (μ mol/m^2/s) 60 DAS	Light use efficiency (g/MJ) 60 DAS	Photosynthetic rate (μ mol/ m^2/ s) 75 DAS	Stomatal conductance (mol H_2O/m ^{2}/s) 75 DAS	Stomatal resistanc (mol H_2O/m ^{2}/s) At harvest	CO_2 concentration (μ mol/ m^2/ s) 60 DAS	Leaf temperature (^OC) At harvest
Main plot treatment (Land configuration)							
L_1 : Flat bed	640.50	1.65	27.27	0.96	11.14	381.79	34.90
L_2 : Ridges and furrow	646.20	1.68	27.64	0.98	9.83	383.29	34.69
SEm±	2.605	0.07	0.29	0.03	0.34	1.31	0.12
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS
Sub plot treatment (Potassium levels)							
K_1 : O kg/ha (control)	615.50	1.47	25.56	0.85	13.04	376.70	35.97
K_2 : 12.50 kg/ha	626.67	1.59	26.32	0.92	11.07	380.41	35.34
K_3 : 25 kg/ha	640.58	1.64	27.55	0.98	10.47	381.96	34.80
K_4 : 37.50 kg/ha	660.33	1.77	28.51	1.03	9.46	385.32	34.12
K_5 : 50 kg/ha	673.66	1.84	29.35	1.07	8.4	388.31	33.75
SEm±	7.44	0.06	0.72	0.04	0.77	1.82	0.30
CD (P=0.05)	22.30	0.19	2.15	0.11	2.30	5.45	0.91
Interactions							
L x K	NS	NS	NS	NS	NS	NS	NS
General mean	643.35	1.665	27.45	0.97	10.485	382.545	34.8

Table 2. Different microclimate parameters as influenced periodically by different treatments of sweet corn

Treatments	APAR (μ mol/m^2/s) 60 DAS	Light use efficiency (g/MJ) 60 DAS	Photosynthetic rate (μ mol/ m^2/ s) 60 DAS	Stomatal conductance (mol H_2O/m ^{2}/ s) 30 DAS	Stomatal resistance (mol H_2O/m ^{2}/ s) At harvest	CO_2 concentration (μ mol/ m^2/ s) 30 DAS	Leaf temperature (^OC) 30 DAS
Main plot treatment (Land configuration)							
L_1 : Flat bed	670.90	1.35	35.66	0.45	12.66	377.21	35.15
L_2 : Ridges and furrow	677.43	1.385	37.85	0.55	9.83	378.15	35.03
SEm ±	0.66	0.007	0.16	0.004	0.295	1.31	0.075
CD (P=0.05)	NS	NS	0.97	0.025	NS	NS	NS
Sub plot treatment (Potassium levels)							
K_1 : O kg/ha (control)	652.50	1.355	34.79	0.45	18.96	372.41	35.43
K_2 : 12.50 kg/ha	665.75	1.36	36.12	0.48	12.19	374.23	35.31
K_3 : 25 kg/ha	673.75	1.36	36.84	0.51	10.20	377.51	35.31
K_4 : 37.50 kg/ha	683.08	1.37	37.51	0.52	8.52	381.02	34.92
K_5 : 50 kg/ha	695.75	1.385	38.51	0.56	6.36	383.22	34.47
SEm±	2.32	0.015	0.51	0.012	0.67	1.645	0.115
CD (P=0.05)	6.97	NS	1.56	0.038	2.02	4.955	0.36
Sub-Sub plot treatment (Fertilizer levels)							
F_1 : 75 % RDF	631.10	1.355	34.39	0.43	13.1	375.28	35.55
F_2 : 100 % RDF	683.30	1.355	37.18	0.53	10.82	378.12	34.95
F_3 : 125 % RDF	708.10	1.39	38.70	0.55	9.82	379.64	34.77
SEm±	2.047	0.012	0.48	0.008	0.745	1.13	0.095
CD (P=0.05)	5.85	NS	1.38	0.0230	2.14	NS	0.28
Interactions							
L × K	NS	NS	NS	NS	NS	NS	NS
L × F	NS	NS	NS	NS	NS	NS	NS
F × K	NS	NS	NS	NS	NS	NS	NS
L × K × F	NS	NS	NS	NS	NS	NS	NS
General mean	751.25	1.37	36.93	0.51	10.49	377.93	35.055

water, the uptake of nutrients by crop was also increased which favoured the luxurious crop growth reflected in increase the crop canopy thereby more interception of PAR which accelerates the rate of photosynthesis. Similar results were reported by Lawlor and Mitchell (2006) and Turner *et al.* (2010). Different potassium levels was influenced significantly on all the microclimate parameters potassium level @ 50 kg/ha recorded significantly highest absorbed photo synthetically active radiation (APAR) 673.66 μ mol/ m^2/ s, light use efficiency 1.84 g/MJ and CO_2 concentration 388.31 μ mol/ m^2/s at 60 DAS, photosynthetic rate 29. μ mol/m^2/s, stomatal conductance 1.07 mol H_2O m^2/s at 75 DAS, stomatal resistance minimum 8.4 mol H_2O m ^{2}/ s and leaf temperature minimum 33.75^{O}C at harvest but it was at par with potassium level @ 37. 50 kg/ha among all the growth stages of soybean crop. In sweet corn, planting methods significantly not influenced on any parameter of microclimate except photosynthetic rate and stomatal conductance. The ridges and furrow planting method recorded significantly highest value of photosynthetic rate 37.85 μ mol/ m^2/ s and stomatal conductance 0.55 mol H_2O m^2/ s among all the growth stages of sweet corn. Fertilizer levels was significantly influenced at all the stages of crop growth except light use efficiency and CO_2 concentration. Significantly highest absorbed photo synthetically active radiation (APAR) 708.10 μ mol/ m^2/ s, photosynthetic rate 38.70 μ mol/m^2/s at 60 DAS as well as stomatal conductance 0.55 mol H_2O / m^2/ s and leaf temperature minimum 34.77 ^{O}C at 30 DAS and stomatal resistance minimum 9.82 mol H_2O / m^2/ s at harvest was observed among all the growth stages during the investigation of two years data. Nitrogen and other nutrients in plant cell owing to plants luxurious growth and thereby more light interception reflected in maximum absorbed PAR. Stomata remained open to meet evapotranspirational demand owing to higher stomatal conductance reflected in maximum absorption of CO_2 for photosynthesis and finally resulted in more dry matter production and green cob yield as well as green fodder yield of sweet corn.

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Impact of improved technologies in agriculture to mitigate the effect of climate change in NICRA village

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Agriculture plays a key role in overall economic and social wellbeing of India. In recent years, with the growing recognition of the possibility of global climate change, an increasing emphasis on world food security in general and its regional impacts in particular have come to forefront of the scientific community. Crop growth, development, water use and yield under normal conditions are largely determined by weather during the growing season. Even with minor deviations from the normal weather, the efficiency of applied inputs affected extremely and food production is seriously impaired. Pathak *et a*l. (2003) concluded that the negative trends in solar radiation and an increase in minimum temperature, resulting in declining trends of potential yields of rice and wheat in the Indo-Gangetic plains of India. Productivity of some of the important cropping systems has either become static or shown a decline in some locations. Recent trends of a decline or stagnation in the yield of rice-wheat cropping system in Indo-Gangetic plain and north western India have raised serious concern about the regions food supply (Aggarwal *et al*., 2000;). To make Indian agriculture more adaptable in this adverse situation ICAR has started a project “National Initiative On Climate resilient Agriculture” project in 100 village of India through KVK. Under this project KVK Gorakhpur selected a flood prone village Jhangha block Khorabar for demonstrating the developed technologies to cope up with anticipated climate change impacts.

METHODOLOGY

KVK Belipar Gorakhpur (U.P.) is implementing NICRA project in Jhangha village of Khorabar block of Gorakhpur since 2010. A team of KVK scientists conducted house hold survey and group discussion with farmers to find out the major constraints of low productivity and technology gap. The village has 12 hemlets (Tolas) with a population of 6478 having 1354 farm families. Important characteristics of the village is that 170 ha cultivated land suffered due to flood every year and rest suffered due to moisture scarcity during *kharif*. About 170 hectare area during kharif did not planted due to fear of flood or water stagnation from few inches to 5 feet or more. Most of the farmers are marginal and don't have capacity to use of recommended dose of balanced fertilizer. Most of the soil in village is low in organic carbon ranging between 0.2to 0.3 per cent. About 44 percent land of the village under sandy loam category hence heavy dose of fertilizer and more irrigation is required to produce average yield of crops. For demonstration of the improved technology group of farmers were selected voluntarily for particular technology i.e. 20 farmers were selected for demonstration on effect of green manuring through Sesbania and green gram variety HUM 16. The seed was provided by KVK to compare with the farmer practice; 20 farmers considered for demonstration on wheat residue retention (harvested by combine) with advised to incorporate wheat residue with 45 kg urea in half acre and rest half with their practice (burning of residue); For deep water and submerged area seed of rice variety Jalnidhi and Swarna sub 1 was provided for sowing, and 20 farmers were selected for direct seeded rice and zero till wheat.

RESULTS

Temperature recorded showed that in last few years there has been a rapid alteration and unexpected changes in the climate. The average temperature is 25.68°C, but during the summer months the maximum temperature shoots up to 31.95°C; whereas the minimum is above 19.57°C. The city receives an annual average rainfall of about 1200 mm. During the last decade Gorakhpur has experienced significant ups and downs in temperature as well as rainfall. Since the year 2003, there has been a continual change in the annual maximum and minimum temperatures. There has been a 9.51 percent increase in the maximum temperature during 2003-2008 and after that showing a decreasing trend; whereas, on the other end, the annual minimum temperature has been recorded a decreasing trend. In 2002, it was 19.63°C which has now dropped to 18.25° C. Incorporation of wheat residue increase the rice yield on an average 0.16 t/ha over farmers have burnt their residue in field. Green manuring through sesbania yielded 19 and 17.5t/ha green matter which incorporated in the field resulted increase in rice yield by 0.32 and 0.33 t/ha during 2011 and 2012, respectively over farmer practice (no GM of sesbania) Fig 2. In Rice – wheat cropping system green gram yielded 0.96 t/ha seed with increase in fallowed crop rice yield by 0.18 t/ha during 2011 while in 2012 green gram seed yield was 0.87 t/ha with increase in rice yield by 0.25 t/ha. It was also observed that these practices increased the wheat yield by 0.11, 0.25 and 0.27 t/ha over the farmers practice (residue burning) during 2011-12 (Fig.3). Deep water rice variety Jalnidhi yielded 3.03 and 3.24 t / ha with a net return of Rs. 12224 and 18689/ ha during 2011 and 2012, respectively, in those field where farmers never received rice yield. Introduction of submergence tolerant variety Swarna sub- 1 recorded higher yield than BPT 5204 but difference was not makeable may be due to less submergence of crop during this year. Wheat variety DBW 17 recorded

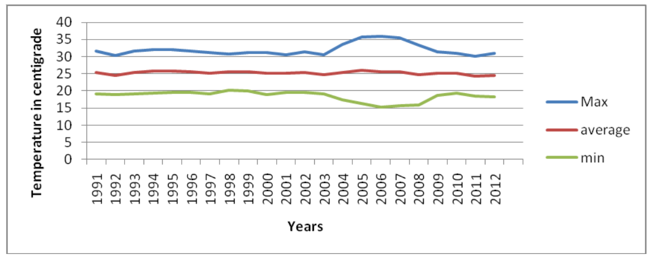

Fig. 1. Change in mean yearly temperature at Gorakhpur

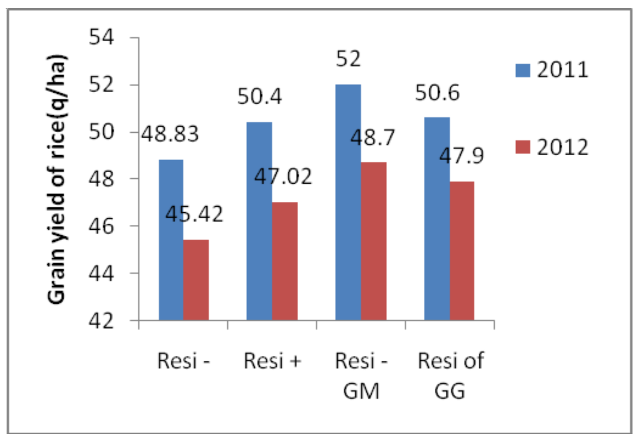

Fig. 2. Effect of residue management/GM on rice yield

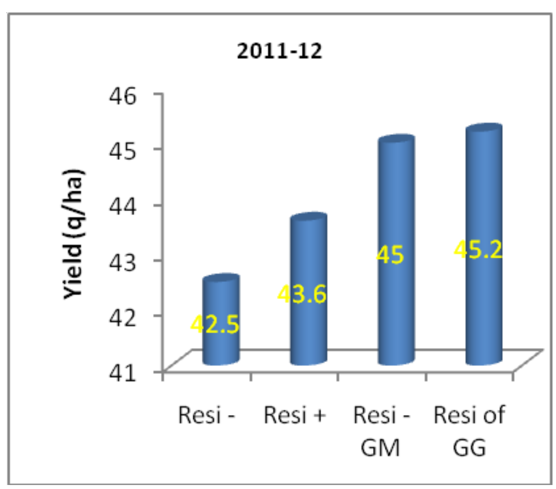

Fig. 3. Effect of residue management/GM on wheat yield

11.2 percent higher yield than established variety PBW 343. Advancement of sowing date(3rd Nov.) increased the wheat yield by 7.74 and 6.19 percent higher yield than farmer practice, respectively, in 2011-12 and 2012-13 (Sowing during 3rd week of November 18th Nov.). Direct seeding of rice gave 4.62 and 12.68 percent higher yield over transplanted rice in 2011 and 2012, respectively. Higher net return and B:C ratio was also recorded with direct seeded rice. Higher yield in DSR may be due to establishment of rice crop before flood and better return due to reduction of Rs. 4870/ha (mean of 2 years) in cost of cultivation over transplanted rice. Wheat sown with zero till technology recorded 4.35 and 12.89 percent higher yield over wheat sown with conventional tillage practice. Higher net return and B: C ratio was also recorded with zero till wheat (Tomar *et al*., 2007).

CONCLUSION

On the basis of above findings it may be concluded that under the agro climatic condition of the Jhangha village use of improved technologies DSR, ZT and proper variety according to situation can mitigate the adverse effect of climate change on agriculture.

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Climate change and its effect on maize and groundnut

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Climatic variability, together with increase in atmospheric carbon dioxide (CO_2) and temperature do have a lot of implications on agriculture sector. According to Intergovernmental Panel on Climate Change (IPCC), it is defined as "Change in climate over time, either due to natural variability or as a result of human activity". This concentration is estimated to reach levels of 421-936 ppm by the end of 21st century. For the past decade (2004-2013), on an average annual atmospheric CO_2 increase was 2.1 ppm per year and an average for the prior decade (1994-2003) was 1.9 ppm per year (Anon, 2016). Maize (*Zea mays* L.) is popularly known as "Queen of cereals" because of its higher yield potential among the cereals. Peanut or Groundnut (*Arachis hypogaea* L.) is one of the major oilseed crop grown in subtropical and tropical regions of the world. Legumes can supply nitrogen *via* symbiotic nitrogen fixation, expected to respond relatively more to a rise in CO_2 and increased temperature. Keeping these views in mind, the present investigation was undertaken with an objective to study the effect of elevated levels of CO_2 and temperature on yield of maize and groundnut.

METHODOLOGY

An experiment was conducted in Open Top Chambers (OTC's) at Main Agricultural Research Station, University of Agricultural Research Station, Raichur during *kharif* and *rabi* seasons of 2015. Two maize genotypes *i.e.* CP-818 and Hema and two groundnut genotypes TMV-2 and K-9 genotypes were evaluated for two CO_2 levels (ambient CO_2 and elevated CO_2 @ 550 ppm) along with combinations of temperature (ambient temperature and elevated temperature @ + 2° C). Results of the experiments were analyzed through two factor-CRD design with 5 replications. Yield parameters of maize *viz.* grain yield /plant, stover yield /plant, seeds/cob and test weight were recorded and analyzed. Similarly yield parameters of groundnut *viz.* number of pods /plant, pod yield /plant, shelling (%) and test weight were recorded and analyzed.

RESULTS

The eCO_2 and Temperature significantly influenced on yield of maize genotypes. Significantly higher seeds /cob (528.5), test weight (31.07 g), grain yield /plant (101.37 g)

Table 1. Yield parameters of maize genotypes as influenced by elevated CO_2 and temperature in OTC's during *Kharif* 2015

Treatment	Seeds per cob			Test weight			Grain yield per plant		
	G_1	G_2	Mean	G_1	G_2	Mean	G_1	G_2	Mean
T_1	478.6	578.4	528.5	30.1	32.0	31.1	106.0	130.3	118.1
T_2	437.2	545.0	491.1	27.1	33.0	30.0	102.8	128.8	115.8
T_3	416.8	531.8	474.3	27.0	28.4	27.7	90.7	118.9	104.8
T_4	458.8	509.4	484.1	26.0	29.5	27.7	92.9	118.9	105.9
T_5	410.2	430.6	420.4	25.8	26.1	26.0	87.6	115.1	101.4
Mean	440.3	519.0		27.2	29.8		96.0	122.4	
	SEm±	CD (P=0.01)	CD (P=0.05)	SEm±	CD (P=0.01)	CD (P=0.05)	SEm±	CD (P=0.01)	CD(P=0.05)
Factor T	14.49	55.4	41.4	0.7	2.7	2.0	3.1	11.7	8.72
Factor G	9.17	35.1	26.2	0.4	1.7	1.3	1.9	7.4	5.52
TxG	20.50	NS	NS	1.00	NS	NS	4.3	NS	NS

T_1- eCO_2 (550 ppm) + aTemperature, T_2- eCO_2 (550 ppm) + eTemperature(2° C rise), T_3- aCO_2 + eTemperature(2°C rise), T_4- Control OTC. T_5- Control plot.- Maize: G_1- Hema, G_2- CP-818, Groundnut: G_1- TMV-2, G_2- K-9 Factor T- Climate variables effect, Factor G- Genotypic effect

and stover yield (413 g) was recorded under (T_1) *i.e.* eCO_2 @ 550 ppm with ambient temperature. Whereas, plants under grown under open plot (T_5) recorded lower yield and yield components. Between the maize genotypes CP-818 recorded higher seeds/ cob (519.0), test weight (29.8 g), grain yield/ plant (122.4 g) and stover yield (403 g) as compared to Hema. Yield and yield attributes of groundnut genotypes are significantly influenced by different concentrations of CO_2 and eTemperature. Plants grown under eCO_2 with a temperature (T_1) recorded significantly higher Number of pods/ plant (39.6), test weight (45.5), shelling per cent (74.4) and pod yield/ plant (41.3) as compared to rest of treatments. Between the genotypes K-9 recorded higher Number of pods/plant (33.9), test weight (41.6), shelling per cent (72.1) and pod yield/plant (35.8).

CONCLUSION

The tested crops (C_3 and C_4) were shown significant variation with respect to yield and yield components. However, C_3 plant (Groundnut) shown results under elevated CO_2 conditions, whereas both crops shown inferior results under elevated temperature conditions. Among the genotypes in both crops some have performed well under changing climatic scenario. In case of maize CP-818 performed well as compared to Hema and in case of groundnut K-9 performed well as compared TMV-2.

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Climate variability and its impact on planting dates of rice in southern Kerala

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Climate variability is one of the factors contributing the fragility of rice production systems in Kerala. Analysis conducted on the temporal variation in rainfall has indicated a declining in trend rainfall and the number of rainy days during the month of June and an increasing trend in October. The diurnal temperature variation has narrowed significantly during the months of April and May mainly due to the increasing trend in minimum temperature recorded during these months. The decreasing trend of rainfall in June could be attributed to the decline in rainfall during the 23rd and 24th standard weeks, which mark the beginning of the South West monsoon and cropping season. Hence one of the adaptation strategies suggested is the possibility of altering the plant dates of rice, especially during the first crop season. A study was conducted for 2 years to assess the phenological impact of change in planting dates on rice based on GDD during the first crop season in southern Kerala.

METHODOLOGY

Rainfall data of thirty years (1984–2013) recorded at the Regional Agricultural Station (Southern Zone), Vellayani, Kerala were analyzed. As a primary step the statistical parameters of mean, standard deviation and coefficient of variation were computed for each month. The monthly data were pooled over the months in a season and parameters for seasonal rainfall and rainy days were also computed. The trend of rainfall and rainy days over the years (N=30) was estimated using linear regression models and the significance of their coefficients tested. Field experiments were conducted to assess the effect of planting dates on the crop duration and yield of first crop season rice. The field experiment was laid out in randomized block design with 5 planting dates (15th May, 01st June, 15th June, 01st July, 15th July) replicated thrice. Apart from the phenological and yield observations, the Accumulated Growing Degree Days (GDD) was also calculated as per Nuttonson (1955). GDD = Ó [(Tx + Tn) / 2 - Base temperature] where, Tx=Daily maximum temperature Tn=Daily minimum temperature

RESULTS

The trend analysis of rainfall and rainy days showed that the rains in June exhibited a strong declining trend both in terms of quantity and number of rainy days. This strongly points towards a possibility of shift in cropping season and varieties. Varieties with shorter duration may become a norm for the first crop season commencing in May-June so as to ensure timeliness of the second crop during the second crop season. The predominant decline in rainfall during the month of June has been reported by Krishna kumar *et al*. (2009). A preliminary analysis of the standard week wise rainfall of the South West monsoon (Table 1) showed that the decreasing trend of rainfall in June could be attributed to the decline in rainfall during the 23rd and 24th standard weeks, which mark the beginning of the South West monsoon. The decline was also observed to be very sharp during 2004-‘13, the percentage deviations from normal being –60.2 per cent and –36.2%

Table 1. Weekly distribution of rainfall (mm) during South West monsoon season

Std. week	1984–88	1989–93	1994–98	1999–03	2004–08	2009–13	Normal rainfall (mm)
23	53.7	196.22	57.64	101.90	35.40	32.30	88.97
24	66.4	68.34	77.12	56.04	39.20	38.11	61.43
25	51.18	60.30	41.60	48.54	108.12	52.77	61.95
26	44.60	50.70	49.34	25.44	20.40	43.22	38.10
27	21.58	97.62	26.76	36.34	80.50	43.26	52.56
28	34.18	31.08	29.82	42.72	38.20	34.21	35.20
29	34.46	57.86	40.58	27.88	73.74	50.22	46.90
30	3.16	35.44	53.52	24.78	49.54	30.67	33.29
31	41.70	66.52	55.90	36.16	42.68	40.26	48.63
32	76.62	12.68	14.18	26.60	33.54	31.22	32.72
33	48.96	23.04	43.84	23.88	20.68	23.43	32.08
34	21.48	4.64	36.78	63.86	7.08	15.89	26.77
35	19.50	17.88	33.42	8.38	68.54	21.89	29.54
36	24.96	16.40	41.70	3.28	76.60	11.26	32.59
37	14.14	18.42	36.90	8.04	70.64	31.65	29.63
38	41.46	24.08	68.88	61.54	59.72	60.11	51.14
39	35.54	32.62	59.50	66.80	32.86	48.96	45.46

Table 2. Effect of date of planting on GDD (^oC) of first crop season rice (mean over 2 years)

Growth stages	Date of planting				
	15th May	01st June	15th June	01st July	15th July
Sowing to Transplanting	478	460	417	402	403
Transplanting to Tillering	206	544	624	162	221
Tillering to PI	728	461	347	987	932
PI to Booting	285	158	131	161	154
Booting to Heading	109	65	87	84	49
Heading to 50% flowering	49	48	104	103	50
Flowering to Ripening	267	309	177	116	223
Ripening to Harvest	215	222	217	239	154
Total GDD	2336	2266	2103	2255	2186

Table 3. Effect of date of planting on yield and harvest index of first crop rice (pooled mean over 2 years)

Treatment	Grain yield (t/ha)	Straw yield (t/ha)	Harvest Index
15 May	5.09	6.22	0.45
01 June	4.80	6.63	0.42
15 June	3.14	4.91	0.39
01 July	2.87	4.13	0.41
15 July	3.06	4.59	0.40
SE m (±)	0.331	0.236	0.004
CD (0.05)	1.057	1.264	0.127

during the 23rd and 24th standard weeks respectively.

The data on the effect of date of planting on Growing Degree Days (GDD) during the first crop season are presented in Table 2. The GDD accumulated was highest (2336°C) when planted on 15th May followed by 01st June planting (2266°C). The least GDD was recorded by the crop planted on 15th June. Irrespective of the date of planting the period from tillering to panicle initiation (PI) accumulated more GDD. However, this was not reflected in the final yield of the crop at all planting dates. Crop duration was observed to be maximum (140 days) for the Virippu crop planted on 15th May followed by 01st June (137 days). The crop duration progressively decreased when the date of planting advanced to 15th July and thereafter the duration increased. Crop duration was observed to have a direct bearing on the crop yield. But the longer crop duration supported by late planting contributed towards higher straw yield rather than grain yield. The perusal of data in Table 3 showed that planting on 15th May resulted in significantly higher grain yield, straw yield and harvest index.

CONCLUSION

The results of the present investigation revealed that early planting of rice was more advantageous for the crop to combat the vagaries of monsoon encountered as a part of climate variability, compared to the late planting in vogue in southern Kerala. Further, early planting during the second fortnight of May also resulted in higher grain yield and straw yield with a better harvest index.

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Impact Assessment of *El Nino* on wheat production in Punjab

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Climatic change and *El Nino* events are resulting in large scale rainfall variability with significant impact on Indian food grain production. *El Nino* Southern Oscillation (ENSO) is one of the strongest signals in short term climate variability. The *El Nino* is a warming of the surface water of the tropical eastern Pacific from South America Coast to the international date and normally occurs around Christmas and usually lasts for a few weeks to a few months. In general, it is believed that the *El Nino* event would result in below normal rainfall during southwest monsoon and loss of food grains production of the country. In view of this, a research investigation was conducted on assessment of impact of *El Nino* episodes on wheat productivity in Punjab state.

METHODOLOGY

The Oceanic Nino Index (ONI) has become the de-facto standard that NOAA uses for identifying *El Niño* (warm) and *La Niña* (cool) events in the tropical Pacific. It is the running 3-month mean SST anomaly for the Niño 3.4 region (5°N-5°S, 120°-170°C). Events are defined as 5 consecutive overlapping 3-month periods at or above the +0.5° anomaly for warm (*El Niño*) events and at or below the -0.5 anomaly for cold (*La Niña*) events. The threshold is further broken down into Weak (with a 0.5 to 0.9 SST anomaly), Moderate (1.0 to 1.4), Strong (1.5 to 1.9) and Very Strong (≥ 2.0) events (Jan, 2016). At least 3 consecutive overlapping 3-month periods. In the light of above, the present study attempted to find out the effect of *El Nino* on rainfall pattern at district level as well as implications of different categories of warm episodes on wheat Production in the State. The long-term wheat yield data for different locations of Punjab was collected from statistical abstracts of Punjab and different websites. The variability of wheat yield w.r.t. *ENSO* was assessed.

RESULTS

The data on *El Nino* from the year 1951-53 to 2015-16 showed that the weak *El Nino* years were 1951-52,1952-53,1953-54, 1958-59, 1968-69,1969-70, 1976-77, 1977-78, 1979-80, 1994-95, 2004-05, 2006-07; the moderate *El Nino* years were 1963-64, 1986-87,1987-88, 1991-92, 2002-03, 2009-10 and 1957-58,1965-66,1972-73 & 1982-83, 1997-98, 2015-16 were strong and very strong years, respectively. Spatial-temporal effect of *El Nino* episodes was investigated on wheat productivity at different locations in Punjab. The analysis revealed that strong *El Nino* episodes had adverse effect on wheat productivity at all locations in the state. Strong *El Nino* episodes of 1997-98 led to considerable decrease in wheat productivity, whereas during weak *El Nino* years of 1999-00 and 2011-12, significant increase in wheat productivity has been observed at all the locations. Thus, the effect of climatic changes and *El Nino* episodes cannot be ruled out in the years to come.

CONCLUSION

The study clearly indicates that climatic changes and *El Nino* episodes in the coming years also can have large fluctuations in wheat productivity in the region.

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Canopy temperature and leaf growth of lentil (*Lens culinaris*) in the lower Gangetic plains of West Bengal

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Canopy temperature (CT) is an indicator of the plant water status and the water stress experienced by the plant. CT thus affects the physiological processes and growth of the crop. Radiation environment, temperature, humidity and wind profile affects the CT of a particular crop (Ajayi and Olufayo, 2004). When the crop is sown on different dates, the CT varies owing to varying growing environments. The canopy volume differs among the varieties of the same crop. Canopy volume remarkably influences the radiation interception, which is the most crucial determinant of CT. Dearth of useful information in this aspect needs to be addressed. With this background, a two year experiment was conducted to study the diurnal variation in CT of lentil varieties sown on different dates.

METHODOLOGY

A two year experiment was conducted on lentil at the District Seed Farm, B.C.K.V, W.B. (Lat $22^0 56'$ N; long $88^0 32'$ E), during 2013-14 and 2014-15 *Rabi* seasons. The crop was planted on four dates of sowing (DOS) (D_1-31st October, D_2 – 7th November, D_3 – 14h November, D_4 – 21st November). The experiment was laid out in a strip plot design in a plot size of 15 m^2 with the DOS in the vertical strip and five varieties (V_1- HUL 57, V_2 – WBL 77, V_3 – KLS 218, V_4 – WBL 58, V_5 – B 256) in the horizontal strip with three replications. CT was measured throughout the growth period with the help of Infra-Red Tele-Thermometer (AG 42, Telatemp). The observations were recorded diurnally from 45 days after emergence (DAE) to 105 DAE at 15 days interval, but the mean values are presented for brevity. Pearson's correlation coefficients (r) for CT and leaf weight were computed.

RESULTS

On 45 DAE, the mean CT ranged from 21.9 to 25.0 °C in the first year and 22.4 to 25.0 °C in the second year (Table 1). In the first year experiment, all the DOS except D_4 recorded a rise in CT on 75 DAE. The first three DOS experienced higher relative humidity during this period which reduced the transpirational cooling and increased the CT. In the second year, only D_1 sowing showed similar trend and the remaining DOS experienced a dip in CT on 75 DAE. The D_4 sown crop recorded a steep rise in CT on 90 and 105 DAE in both the

Table 1. Canopy temperature (°C) of lentil varieties under different dates of sowing

DOS	Varieties	2012-13						2013-14					
		45 DAE	60 DAE	75 DAE	90 DAE	105 DAE	Mean	45 DAE	60 DAE	75 DAE	90 DAE	105 DAE	Mean
D_1	V_1	22.1	21.7	24.1	22.3	27.1	23.5	23.4	24.4	25.3	22.9	23.0	23.8
	V_2	21.8	21.8	23.4	22.6	26.3	23.2	23.0	22.9	25.6	22.1	23.2	23.4
	V_3	22.3	21.2	23.4	22.3	27.8	23.4	25.8	23.4	25.9	23.0	22.6	24.1
	V_4	22.6	22.0	24.6	23.1	29.1	24.3	26.7	25.3	26.6	23.4	23.7	25.1
	V_5	20.6	20.9	23.0	22.0	25.8	22.5	22.7	22.4	24.9	21.6	21.9	22.7
Mean	21.9	21.5	23.7	22.5	27.2		24.3	23.7	25.7	22.6	22.9		
D_2	V_1	22.7	21.4	23.0	21.7	25.9	22.9	22.3	24.2	21.3	21.7	28.0	23.5
	V_2	23.8	22.4	24.0	23.1	27.9	24.2	23.2	24.8	22.8	22.4	28.7	24.4
	V_3	24.3	23.0	24.3	23.9	28.4	24.8	23.4	25.3	23.3	23.0	29.2	24.8
	V_4	23.3	22.1	23.3	22.7	27.4	23.8	23.0	25.1	23.0	22.2	28.9	24.4
	V_5	23.1	22.3	23.6	22.2	26.4	23.5	22.9	24.6	22.0	21.9	28.3	23.9
Mean	23.4	22.2	23.6	22.7	27.2		23.0	24.8	22.5	22.2	28.6		
D_3	V_1	23.7	22.4	23.9	22.9	27.9	24.2	22.9	24.9	23.3	23.3	27.6	24.4
	V_2	23.6	23.2	24.2	22.8	26.2	24.0	22.3	25.1	22.3	22.6	27.9	24.0
	V_3	23.3	22.2	24.7	22.4	26.0	23.7	22.2	24.4	23.1	22.3	28.1	24.0
	V_4	22.9	21.9	23.2	22.2	25.8	23.2	21.4	23.9	21.6	22.0	27.2	23.2
	V_5	24.6	23.4	25.4	23.1	28.7	25.0	23.2	25.3	24.4	23.6	28.7	25.0
Mean	23.6	22.6	24.3	22.7	26.9		22.4	24.7	22.9	22.8	27.9		
D_4	V_1	25.8	26.7	23.7	26.8	33.6	27.3	25.4	24.0	22.3	32.6	31.6	27.2
	V_2	25.1	26.2	23.1	26.1	32.7	26.6	25.3	23.1	21.9	31.2	31.0	26.5
	V_3	24.8	26.4	22.9	25.7	31.6	26.3	24.8	22.3	21.6	29.4	30.8	25.8
	V_4	24.9	26.2	23.3	26.1	32.0	26.5	25.1	23.8	21.3	30.1	31.2	26.3
	V_5	24.3	26.0	22.7	25.3	29.8	25.6	24.6	21.8	21.1	28.8	30.4	25.3
Mean	25.0	26.3	23.1	26.0	31.9		25.0	23.0	21.6	30.4	31.0		

Table 2. Pearson's correlation coefficient between canopy temperature and leaf biomass of lentil

DOS	2012-13	2013-14	Varieties	2012-13	2013-14
D1	0.78	-0.56	V1	0.71	0.8585
D2	0.68	0.49	V2	0.69	0.8329
D3	0.58	0.54	V3	0.74	0.7784
D4	0.61	0.83	V4	0.75	0.7218
			V5	0.74	0.8098

years. The crop sown under this DOS reached its 90 and 105 DAE in end of February and early March, respectively. The atmospheric temperature begins to rise in the lower Gangetic Plains of West Bengal during this time. The CT gradually increased with delayed planting in the first year of experiment irrespective of dates of observations and varieties. No such definite trend could be ascertained in the second year. The second year registered marginally higher CT than the first year except few aberrations. In case of D_1 sowing, the magnitudes of temperature rise in the second year were 2.4 °C, 2.2 °C, 2.0 °C and 0.1 °C for 45, 60, 75 and DAE respectively (Parya *et al.,* 2010). When the sowing was delayed, the variety V_1 recorded the highest CT in both the year of experiment. The CT was highest in V_3 and V_4 under D_1 and D_2 sowings respectively in both the years. CT was positively correlated to leaf biomass (Table 2). The relationship remained insignificant. The r values ranged from 0.58 to 0.78 and -0.56 to 0.83 for DOS in the first and second year of experiment respectively. The same ranged from 0.69 to 0.75 and 0.72 to 0.81 for varieties in the first and second year of experiment respectively. CT was negatively correlated to leaf biomass under D_1 sowing in the second year. The late heavy October rains coupled with high CT during the early and mid-growth phases led to poor crop stand, which eventually lowered leaf biomass production for this DOS.

CONCLUSION

CT varied with the year of experiment and the second year registered higher CT. Variety V_1 under delayed sowing recorded the highest CT. CT is positively correlated to leaf biomass production.

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Effect of various cultivation techniques on greenhouse gas emission under rice-wheat cropping system in the perspective of climate change

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Rice (*Oryza sativa* L.)–wheat (*Triticum aestivum* L.) cropping system is the most intensively cultivated cropping system of the Indo-Gangetic plains (IGP) that plays a foremost role in the food security of south Asia. The conventional practice of rice and wheat cultivation in this region is input (e.g. energy, water, fertilizer etc.) intensive and subsequently a source of GHG emission. It has been projected that the annual demand for rice and wheat is expected to grow between 2% and 2.5% until 2020. Conventional cultivation techniques put forward threats against enhanced sustainable productivity and decreased green-house gas (GHG) emission. Adoption of various GHG mitigation technologies in this crop rotation needs to be evaluated. Keeping this in view, a field experiment was carried out to evaluate the feasibility of different management practices for emission rates and energy use efficiency from rice-wheat cropping system.

METHODOLOGY

Rice variety 'Rajendra Suwasini' was sown in mid of June and transplanted in mid of July. Rice was planted in three different methods viz. system of rice intensification (SRI) (M1), transplanted puddle rice (TPR) and direct seeded rice (DSR) and the seed rate was 5, 50 and 30 kg/ha. Rice under SRI system was planted in 25 x 25 cm spacing, whereas 20 x 15 cm spacing was given in transplanted rice. Manual sowing of DSR was carried out with the spacing of 20 cm, in the plot. A recommended dose of fertilizers 100 kg N + 40 kg P_2O_5 + 20 kg K_2O/ha was applied. Wheat variety 'HD-2967' was sown manually in the mid of November through hand plough with row to row distance 22 cm using seed rate of 100 kg/ha. Under zero tillage condition, seeds were sown with the help of hand tyne only, in the 30% rice residue retaining condition of the field. Recommended dose of fertilizers (RDF) for wheat was 120 kg N + 80 kg P_2O_5 + 60 kg K_2O/ha. The greenhouse gases i.e. CH_4, N_2O and CO_2 were collected from both rice and wheat field through Pyrex glass gas chamber. At each sampling date, GHG samples were collected at 0, 30 and 120 minutes interval from each plot within 8.00 AM - 11.00 AM.

RESULTS

The highest rice grain yield was obtained under system of rice intensification (SRI) among the rice planting methods (Figure 1). Although, direct seeded rice (DSR) did not perform well under system, but zero tilled wheat yielded higher (4.70 t/ha) than the conventional wheat (3.49 t/ha). Thus the system productivity was highest in DSR followed by zero till wheat (9.13 t/ha), as compared to the conventional rice and wheat crop. Sole mineral fertilization possesses the yield that eventually increased the rice equivalent yield (REY) by 6.16% over integrated fertilization. However, inclusion of green manure had significantly increased the rice yield by 4.32% over sole mineral fertiliser application that ultimately increased system productivity (REY) (Figure 1). The cumulative emission of GHGs was significantly with the cultivation techniques as well as cropping seasons. Application of sole mineral fertiliser emits highest N_2O may be substrate availability for the processes driving the soil N_2O emissions (Xia et al., 2014), as compared to the combined application of

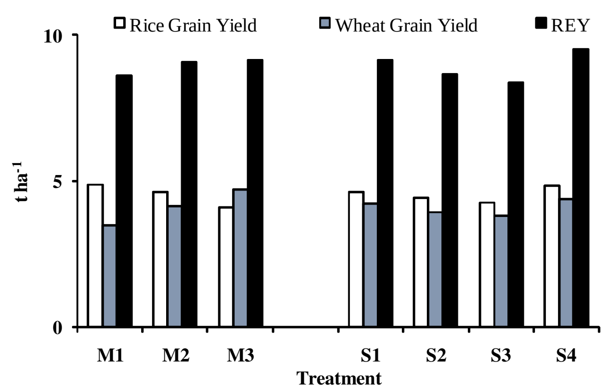

Fig. 1. Effect of cultivation techniques on rice and wheat grain yield and rice equivalent yield

Treatment: M_1: Conventional tillage, M_2: Conventional tillage +30% residue incorporation, M_3: Zero tillage +30% residue retention; S_1: 100% inorganic, S_2: 75% inorganic+ 25% organic, S_3: 50% inorganic+ 50% organic, S_4: 100% inorganic + Green manuring.

Table 1. Effect of cultivation techniques on cumulative green house gas emission in rice-wheat cropping season

Treatment	CH_4-C emission (Kg/ha)		N_2O-N emission (Kg/ha)		GWP (Kg $CO_{2\,eq}$ /ha)		GHGI (Kg $CO_{2\,eq}$/kg grain yield)	
	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat
Main Plot								
System of rice intensification - Conventional wheat	470.99b	3.71b	0.50b	8.69a	16608b	9457a	3.41b	2.71a
Transplanted rice - Conventional wheat + 30% rice residue incorporation	596.48a	5.67a	0.27c	6.03b	20526a	7736b	4.42a	1.88b
Direct seeded rice – Zero Till Wheat + 30% residue retention	223.02c	1.59c	0.77a	4.01c	8829c	4150c	2.15c	0.88c
Sub plot								
100% Inorganic fertilizer	386.69b	2.95d	0.59a	7.89a	13784a	8390a	2.98b	1.99a
75% Inorganic fertilizer + 25% Organic fertilizer	443.17a	3.86b	0.47b	5.49c	15627a	6471a	3.52a	1.64a
50% Inorganic fertilizer + 50% Organic fertilizer	471.82a	4.39a	0.44b	5.10c	16629a	6408a	3.90a	1.67a
100% Inorganic fertilizer + green manuring	418.07b	3.33c	0.54a	6.57b	14810a	7258a	3.07ab	1.65a

Different letters within the same column indicate significant differences in variable means among treatments over the seasons based on the Tukey's HSD mean separation test ($P<0.05$).

mineral fertilizer and organics. There were significant differences of the total global warming potential (GWP) of emitted methane (CH_4), carbon dioxide (CO_2) and nitrous oxide (N_2O) across all treatments, ranging from 4150 to 20526 kg CO2eq/ha in whole cropping seasons.

CONCLUSION

It is concluded that wider adoption of resource conservation practices such as direct seeded rice followed by zero till wheat with residue retention is a long run economically viable and ecologically sound options for conserving natural resources, higher productivity and profitability.

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Elevated temperature and carbon dioxide concentration effect on forage cowpea productivity in few locations of India

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Climatic changes and variability can affect the yields of different crops through their direct as well as indirect effects such as weather induced changes in incidence of insect-pests thus there are a major threat to food security in many regions of the developing world (Rai *et al*., 2014, Mohanty *et al.*, 2015). The cowpea (*Vigna unguiculata* L. Walp.) is an annual herbaceous legume cultivated for its edible seeds or for fodder and grown as intercrop with forage cereals like sorghum, maize and pearl millet in all growing region of India. The fresh fodder has 15-20 % CP content and being legume it fixes nitrogen in the soil which makes more suitable for rainfed marginal lands. In this context, CROPGRO- model was calibrated and validated for forage cowpea and this was employed for assessing the impact of climate forage cowpea production in semi-arid regions of India.

METHODOLOGY

Field experiments were conducted during 2010 and 2011 during rainy seasons at Central Research Farm ($25^0 27'$N, $78^0 37'$E; 240m above mean sea level), Jhansi, Uttar Pradesh, India to calibrate and validate CROPGRO-Cowpea model for forage cowpea varieties (four varieties i.e BL-1, BL-2, Kohinoor and EC-4216) under different environment condition (three date of sowing). Statistical test were performed between observed and simulated TDM (dry biomass at anthesis) and GY (Grain yield) to evaluate the model. The calibrated and validated model was used to assessing the effect of elevated temperature (1-4 ^{o}C) and CO2 (660ppm) on forage cowpea yield in location of India

RESULTS

Validation of the model revealed that model simulated GY(y = 1.0405x + 0.4206;R^2 = 83% Bias=36.1 kg/ha, RMSE=117.2 kg/ha) and TDM (y =1.2377x - 1098.2;R^2 = 70%; Bias: 144.6 kg/ha; RMSE:636.7 kg/ha) reasonably well under different environmental condition. Also, the high r^2> 0.71 values indicate good agreement between observed and simulated values of anthesis, grain yield, total dry biomass and Leaf area Index. Dry biomass increased by 67 % and 58% with elevated CO_2 and increased in temperature (4^{o}C) at Jhansi and Raipur respectively. Grain yield was negatively impacted and reduction was found to be 15 and 65% from its normal productivity for elevated temperature of 2 and 3 ^{o}C respectively. However, increased in temperature up to 4 ^{o}C grain yield was increased by 20% under elevated CO_2 condition, thus it indicates that CO_2 is able to cancel out the negative impact of temperature at Raipur. Similarly at Palampur, a high rainfall area (1400mm) GY was negatively impacted for elevated temperature (1-4^{o}C) under present day CO_2 (390ppm) condition. However, elevated CO_2 is able to cancel out the negative impact of temperature up to 2^{o}C and grain yield was higher by 7 to 25%. At Hisar, a low annual rainfall (470mm) region, positive response in dry biomass was noticed for both short (BL-1) and long duration variety (BL-2) in response to change in temperature between -4 to 2 ^{o}C. The dry biomass increases in the range of 12 to 47% and 5.6 to 33.8% for BL-1 and BL-2, respectively. However, further in crease in temperature above 2^{o}C is detrimental and reduction in dry biomass ranged from 15.3 to 40.1% for 3 and 4 ^{o}C, respectively for long duration variety. However, Grain yield decreases with increase in temperature after 1^{o}C under elevated CO_2 condition. Also, dry biomass at anthesis was positively impacted with elevated temperature and elevated CO_2 (660 ppm) and increased was ranged 15 to 5% for 1 to 4 ^{o}C, respectively, which indicates that negative effect of elevated temperatures is compensated by positive effect of CO_2. In general, increasing temperature had negative and decreasing temperature had positive impact on dry biomass of forage cowpea.

CONCLUSION

Forage Grain yield would be greatly affected due to changing climate and is expected to go down under future warmer climatic condition. However, Dry biomass and grain yield would increased under thermal stress 1-4 ^{o}C and 1 -2 ^{o}C at Jhansi and respectively. Such simulation studies can guide us in determining the effect of climate change and variability and changes on productivity of forage cowpea and can be used for crop yield forecasting and further policy planning by government.

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Changes in seed yield and oil content of sunflower (*Helianthus annus* L.) hybrids in relation to sowing date

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The seed yield, oil content and oil yield are complex quantitative traits, determined by genetic and environmental factors, along with interaction between them. The oil yields per plants the result of the number of seeds per capitulum, 100-seed weight and oil content. These components are determined by genetic factors, but they can be modified by environmental and growth conditions. In order to maximize the use of natural resources, the appropriate sowing date is very important since it ensures good seed germination, as well as the timely appearance of seedlings and the optimum development of the root system. It also allows superposing the critical periods for oil yield and its components with the moment of the growth season where more environmental resources are available. The objective of this study was to evaluate the effects of hybrids, sowing time and the interactions of these factors on spring sunflower seed yield, oil content and oil yield under Punjab conditions.

METHODOLOGY

The experiment was conducted during spring seasons of 2014 and 2015 at Research Farm of Department of Plant Breeding and Genetics, PAU, Ludhiana (30°56' N, 75°52' E, and 247 m above msl). The soil of the experimental site was loamy sand in texture with normal pH (7.4), low organic carbon (0.26%), medium available phosphorus (27.4 kg/ha) and low available potassium (152.0 kg/ha). The experiment was laid out in split plot design in three replication with four sowing dates (30 January, 10 February, 20 February and 2 March) in main plot and two sunflower hybrids (PSH 1962 and PSH 996) in sub-plot treatments. The oil content in the sunflower seeds was estimated by non-destructive method using nuclear magnetic resonance spectroscope

RESULTS

The pooled data on seed yield, oil content and oil yield is presented in Table 1. The results revealed that there was decline in seed yield with the delay on sowing. The crop planted on 31^{st}January gave maximum seed yield (2652 kg/ha) which was statistically at par with 10^{th} February planted crop (2316 kg/ha) and significantly higher than 20^{th} February and 2^{nd} March planted crop. This decrease in seed yield with delayed sowing might be due to higher temperature prevailing during the time coinciding with seed development which may also adversely affect pollination and fertilization resulting in poor seed setting. Among the hybrids, PSH 1962 (2292 kg/ha) significantly out yielded PSH 996 (2092 kg/ha) which might be due genotypic potential. The data on oil content showed that there was general decline in oil content with delayed sowing. The seed oil content of PSH 1962 was significantly higher (39.5%) as compared to PSH (36.5%). The oil yield followed the same trend as seed yield.

Table 1. Seed yield, oil content and oil yield of sunflower hybrids under different sowing dates at PAU, Ludhiana (Pooled data of 2014 & 2015)

Date of sowing	Seed yield (kg/ha)		
	PSH 1962	PSH 996	Mean
31^{st} January	2823	2480	2652
10^{th} February	2414	2218	2316
20^{th} February	2225	2046	2136
2^{nd} March	1707	1623	1665
CD (P=0.05)	DOS: 455; Hybrid: 89; Interaction: NS		
Date of sowing	Oil content (%)		
	PSH 1962	PSH 996	Mean
31^{st} January	40.5	37.7	39.1
10^{th} February	39.3	38.1	38.7
20^{th} February	39.9	36.6	38.3
2^{nd} March	38.3	33.5	35.9
CD (P=0.05)	DOS: 1.89; Hybrid: 0.85; Interaction: 1.69		
Date of sowing	Oil yield (kg/ha)		
	PSH 1962	PSH 996	Mean
31^{st} January	934	1145	1040
10^{th} February	845	945	895
20^{th} February	751	886	818
2^{nd} March	542	650	596
CD (P=0.05)	DOS: 168; Hybrid: 40; Interaction: NS		

CONCLUSION

From the results of the study, it can be concluded that delay in sowing of spring sunflower results in significant decline in seed yield, oil content and oil yield and there was higher genetic potential for seed and oil yield in PSH 1962 hybrid over PSH 996.

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Adapting wheat for climate change under different crop growing environment and irrigation conditions

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Normal sowing of wheat has longer growth duration which consequently provides an opportunity to accumulate more biomass as compared to late sowing and henceforth manifested in higher grain and biological yield (Singh and Pal, 2003). Whereas in case of delayed sowing, the wheat crop is exposed to sub-optimal temperature at establishment and su-pra-optimal temperature at reproductive phases that lead to forced maturity and reduction in grain yield (Sardana *et al.*, 1999). Influence of temperature on phenology and yield of crop plants can be studied under field condition through accumulated heat units system (Bishnoi *et al.*, 1995). The grain and biological yield heat use efficiency differed significantly and is found more in case of irrigated compared to rainfed condition. Keeping this in view, an attempt was made to know the adaptability for climate change of wheat in terms of heat unit requirement and heat use efficiency in different sowing windows and irrigation conditions.

METHODOLOGY

Field experiments were conducted during rabi (winter) 2010-2011 and 2011-2012 at the experimental farm of Bihar Agricultural University, Sabour, India (25^0 24’ N, latitude and 87^0 04’E, longitude at a height of 37 m above the mean sea level) with wheat (*Triticum. aestivum,* L.). The climate is sub-tropical humid with warm summer and dry winter. The soil is sandy loam in texture, neutral in reaction, low in available nitrogen, and medium in phosphorous and medium in available potassium. The experiment was laid out in split plot design with date of sowing as the main plot and irrigation levels as sub plot factors, replicated three times. The net plot size was 5.0 x 2.0 m. The experiment was sown for nine dates of sowing- 15 November, 22 November, 29 November, 06 December (normal sowing date in the region) and 13 December, 20 December, 27 December, 03 January, 10 January (late sowing date in the region). The cultivars used for the study were K-9107 as normal sowing date variety for 15 November to 06 December and DBW-14 as late sowing date variety for 13 December to 10 January. Crop was fertilized as per recom-

Table 1. Effect of sowing time and irrigation on grain yield (t/ha) (pooled data of two years)

Irrigation at	Sowing Date									
	Nov 15	Nov 22	Nov 29	Dec 6	Dec 13	Dec 20	Dec 27	Jan 3	Jan 10	Mean
CRI	3.88	3.72	3.60	3.32	3.38	3.13	2.93	2.48	2.61	3.23
CRI & Flowering	4.50	4.33	3.95	3.87	3.65	3.43	3.20	2.78	2.83	3.62
CRI, Boot & Milking	4.80	4.65	4.30	4.18	4.12	3.67	3.40	3.00	2.92	3.89
CRI, Tillering, Boot & Milking	5.15	4.83	4.53	4.43	4.35	4.10	3.72	3.22	3.11	4.16
Mean	4.58	4.38	4.09	3.95	3.87	3.58	3.31	2.87	2.87	
			Sowing date			*Irrigation*			*Interaction*	
SEm ±			0.017				0.015		0.047	
CD (P= 0.05)			0.053			0.045			NS	

Table 2. Effect of sowing time and irrigation on growing degree days (GDD), heliothermal unit (HTU) and heat use efficiency (HUE) at different phenophases (pooled data of two years)

Treatment	GDD (^{0}C day)		HTU (^{0}C day)		HUE (Kg ^{0}C/day)	
	Ear emergence	Maturity	Ear emergence	Maturity	Biomass	Grain
Sowing dates						
Nov 15	1075.4	1738.9	5746.6	12333.6	5.45	2.62
Nov 22	1045.8	1725.0	5698.6	11973.5	5.26	2.45
Nov 29	1012.1	1706.4	5563.1	11650.5	5.05	2.36
Dec 6	996.8	1693.2	5468.1	11288.8	4.98	2.20
Dec 13	981.9	1675.8	5384.6	10975.8	4.81	2.13
Dec 20	966.1	1661.5	5247.0	10733.8	4.32	2.04
Dec 27	942.3	1646.2	5110.2	10525.3	4.27	1.81
Jan 3	932.0	1633.3	5054.0	10326.3	4.22	1.75
Jan 10	914.0	1606.0	4942.6	10102.9	4.05	1.70
SEm±	5.14	6.27	21.7	139.6	0.07	0.04
CD (P= 0.05)	15.4	18.8	65.3	418	0.15	0.09
Irrigation at						
CRI	995.4	1585.0	5036.4	11129.6	4.46	1.97
CRI & flowering	1092.4	1634.6	5508.4	11585.7	4.61	2.17
CRI, boot & milking	1109.9	1683.9	5703.9	12037.8	4.84	2.31
CRI, tillering, boot & milking	1144.5	1739.3	5929.8	12576.0	4.94	2.41
SEm±	5.08	5.6	37.7	40.47	0.05	0.03
CD (P= 0.05)	NS	15.9*	NS	114.7*	0.04*	0.02*

mended contained in package of practices. Growing degree days (GDD)/heat unit requirement, heliothermal units (HTU), photothermal units (PTU) and heat use efficiency (HUE) were computed at different phenophases. The base temperature of 4.5 ^{0}C was used for computation of GDD on daily basis.

Growing degree days (GDD) (^{0}C day) = Σ {(Tmax+ Tmin)/2}-$T_{b\ (base\ temperature)}$

Accumulated HTU (^{0}C day hr) = Σ (GDD x Duration of sunshine hours)

Heat use efficiency (kg/ha/ ^{0}C day) = Biomass or yield (kg /ha) / GDD

RESULTS

The crop sown on November 15 recorded the highest grain yield which was due to higher yield attributes, GDD and HTU (Table 1). The higher value of yield in case of early sowing over delayed ones could be attributed to availability of optimum environmental conditions for growth and development of crop which might enhance accumulation of photosynthates from source to sink. The detrimental effect of heat at later stage of crop development and ear emergence stage in delayed sowing had adverse effect on grain yield. Under different irrigation treatments, the highest grain yield was recorded in four irrigation (at CRI, tillering, boot & milking stage) applied crop which was significantly higher than less no. of irrigated crop at different phenophases. The growing degree days (GDD) or heat unit requirement ranged from 914.0 to 1075.4 across the sowing dates for ear emergence stage and 1606.0 to 1738.9 across different no. of irrigation at different phenophases for maturity stage (Table 2). Similarly consumption of heliothermal unit (HTU) and heat use efficiency as compared to other date of sowing was significantly higher for November 15 sown crop and with four no. of irrigation.

CONCLUSION

Timely sown crop at November 15 and with four no. of irrigation at CRI, tillering, boot and milking stage recorded significantly higher grain and biomass yield. It also took maximum GDD, HTU and showed highest heat use efficiency which is adaptable to climatic changed scenario.

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Climate resilient forage based production systems for sustainability of rainfed agriculture in Central India

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Out of an estimated 140.3 m ha net cultivated area; 79.44 m ha (57%) is rainfed, and contributing 44% of the total food grain production which is prone to climate uncertainties and risks. During recent past, perennial based rainfed forage production systems are also influenced by climatic variability. In recent years change in climatic situations has greater impact on sustainability of fodder and food crops in the system. To mitigate the effect of climate change, climate resilient forage production systems should be evaluated with efficient utilization of available natural resources and to improve the production and productivity of forage crops under rainfed situation. A field study was initiated in the year 2012 to enhance the productivity and sustainability of perennial forage based systems in changing vulnerabilities through integration of different practices.

METHODOLOGY

A field experiment was started during 2012 at the Central Research Farm of ICAR-Indian Grassland and Fodder Research Institute, Jhansi in central India. The experiment estab-

Table 1. System productivity (total green fodder equivalent yield) and economics as influenced cropping system and moisture conservation

Treatment	Fodder equivalent yield (t/ha/year)	Net Returns (INR/ha)	B:C Ratio
Cropping systems(CS)			
CS1: TSH* + *Leucaena* + (Sorghum + Pigeonpea)	76	72014	1.74
CS2: TSH + *Leucaena* + (Sorghum + Cowpea - Chickpea)	87	80971	1.66
CS3: TSH+*Leucaena* + (Sorghum + Cowpea - Barley)	91	86644	1.74
CS4: TSH +*Desmanthus* + (Sorghum + Pigeonpea)	72	67834	1.68
CS5: TSH+*Desmanthus* + (Sorghum + Cowpea - Chickpea)	80	71864	1.50
CS6: TSH + *Desmanthus* + (Sorghum + Cowpea - Barley)	84	77196	1.59
CS7: TSH + *Sesbania* + (Sorghum + Pigeonpea)	78	76148	1.84
CS8: TSH + *Sesbania* + (Sorghum + Cowpea - Chickpea)	95	93323	1.91
CS9: TSH + *Sesbania* + (Sorghum + Cowpea - Barley)	99	99358	2.00
SEM±	4.37	6772	0.151
CD (P=0.05)	12.76	19766	NS
Resource conservation practices (RC)			
RC1: Rainfed (control)	78	71012	1.56
RC2: Life saving irrigation*	89	86723	1.86
RC3: *In-situ*moisture conservation (CA based practices)**	87	84049	1.80
SEM±	2.42	4029	0.090
CD (P=0.05)	8.39	NS	NS

*TSH- Trispecific hybrid

lished and maintained under broad and furrow system, *Pennisetum* tri-specific Hybrid (*Pennisetum purpureum* × *P. squamulatum* × *P. glaucum*) and forage bush legumes were planted on broad bed and seasonal fodder and food crops are grown in furrows in their respective season. The same systems were also maintained under flat system for comparative study. Field experiment was conducted in strip plot design with four replications, nine cropping systems as main plots, in which three bush forage legumes (Sesbania/Subabul/Desmanthes) + Pennisetum Trispecific Hybrid (TSH) on broad bed in combination with sorghum+cowpea (*kharif*)- chickpea (*rabi*), sorghum + cowpea (*kharif*)- barley (*rabi*) and sorghum + pigeonpea in their respective furrows. Moisture conservation practices followed were allotted to sub plots viz., Rainfed (control), Lifesaving irrigation (One pre-sowing irrigation (Rabi) + other irrigation as per theoretical calculation i.e. 30% of total rainfall-ET losses) and *In-situ* moisture conservation (CA based practices like integration of residue retention (stubble height 15 cm) + mulching (green weed biomass + litter fall). The soil was clay loam in texture, medium in organic carbon (0.52 % in 0-15 cm soil depth and 0.39 % in 15-30 cm soil depth) and available phosphorus (20.81 kg/ha), low in available nitrogen (242.8 kg/ha) and high in available potassium (275.5 kg/ha) and neutral in reaction (7.04). The experiment was started with imposition of the treatments as per approved programme (9 cropping systems x 3 resource conservation techniques).

RESULTS

TSH+ Sesbania + (Sorghum + Cowpea - barley) and TSH+ Sesbania + (Sorghum + Cowpea - chickpea) cropping system produced highest forage equivalent yield of 99 and 95 t/ha/year (Table 1). Among resource conservation practices life saving irrigation and in-situ moisture conservation (Conservation agriculture based practices) produced highest forage equivalent yield (89 and 87 t/ha/year) compared to rainfed (78 t/ha/year) during 2015-16 cropping season. On an average of2-3 % more moisture recorded in life saving irrigation and in-situ moisture conservation plots at soil depth of 0-15 cm compared with rainfed treatment. Highest net returns (Rs. 99358) and B:C ratio (2.00 was recorded with TSH+ Sesbania + (Sorghum + Cowpea - barley) cropping system. Ridge and furrow system of sowing and application of green weed biomass mulch improved the soil moisture conservation considerably and sorghum yield by 24.1%. Perennial grass and forage legume on permanent beds have deeper and better developed root system and therefore better access to sub-surface water and nutrients. These add in withdrawing nutrients in large volumes from soil and recycle it by means of leaf litter fall which helps in maintaining soil fertility. Moreover, in arid and semi-arid areas this system helps in insurance against climate extremes. During dry season these perennial supplements some fodder when there is acute shortage and also explore the residual soil moisture and nutrients beyond the reach of annual crops and produce extra dry matter yield.

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Developing portfolios of climate smart agriculture practices for a rice-wheat cropping system in Western Indo-Gangetic plains of South Asia

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Future food security to keep pace with growing population and in the face of increasing scarcity of resources (water, labour and energy), higher cost of production, diminishing factor productivity, deteriorating soil health shrinking land with emerging concerns of climate change will be a much more challenging task than ever before (Agarwal, 2008; Jat *et al.* 2016). In India, as rice- wheat system of Indo-Gangetic Plains (IGP) is the foundation to national food security; its sustainability in face of multiple challenges including climate change will be crucial not only for the farmers but also for the country's economic development as well. Climate Smart Agriculture (CSA)which basically deals with improving adaptive capacity, ensuring food security while reducing the environmental foot prints has been found one of the key strategic options to deal with the challenges of food security under climatic externalities, improve farm income and sustain natural resources. There are several practices and services; the climate smart agriculture practices (CSAPs) which help adapting to climate risks of varying degree under diverse production systems and ecologies. However, there exists significant interaction of these CSAPs under different production ecologies and farmer circumstances. Moreover, the CSAPs in isolation may or may not work effectively due to their interactions with other factors. But, layering of various CSAPs may have synergies and lead to multiplier effects of these practices together compared to that in isolation. We therefore conducted a participatory strategic research on developing and validating portfolios of climate smart agriculture practices in a rice-wheat rotation of western Indo-Gangetic plains to provide options and strategies for sustaining RW system and ensure food security in the face of climate change.

METHODOLOGY

A participatory strategic research was conducted at farmers' fields in three different climates smart villages *viz.*Birnarayana, Anjanthali and Chandsam and of Karnal, Haryana, India under CIMMYT-CCAFS program. This area is characterized by low rainfall (700 mm) and temperature extremes of 0-4°C in January and 41-45°C in June. Sixscenarios consisting of varying degree of layering of climate smart agriculture practices (CSAPs) i.e. Farmers' practice; FP (S1), Improved FP with low Intensity of adaptive measure (S2), Improved FP with high intensity of adaptive measure (S3), Climate Smart Agriculture (CSA) with low-intensity of adaptive measure (S4), CSA with medium intensity (S5) and CSA with high intensity of adaptive measure (S6) were evaluated. These scenarios basically consisted of 8 factors which plays critical role in improving adaptive capacity i.e. i) Tillage: In S1 and S2, six tillage operations were done, whereas in S3 and S4 only three operations were done. Zero till (ZT) was practiced in S4, S5 and S6 for wheat and in S5, S6 for rice; ii)Crop establishment: In S1 and S2, transplanted rice followed by conventional wheat. In S3 DSR (direct seeded rice) was followed by rotary till drill wheat. In S4, S5 and S6ZT, the crops were planted under ZT using Happy seeder; iii) Precision land-levelling: Practiced in S4, S5 and S6; iv)Cultivars: For rice, Pusa-44 was cultivated in S1, S2 and S3 and PR-114 in S4, S5 and S6 followed by wheat PBW-343 was cultivated in S1, S2 and HD-2967 in S3,S4,S5 and S6 scenarios; v) Crop residues (CRs) management: Straw removed in FP. However, in other scenarios anchored residue of wheat (1.5-2 t/ha) and full (100%) residues of ricewas recycled; vi) Water management: State recommendation (SR) were followed in S1 to S4, while in S5 and S6 irrigation water was applied based on soil metric potential using tensiometer; vii) Nutrient management: Farmers fertilizer practice was used in S1, S2 whereas in S3, SR practice was followed. In S4- SR using N source as neem coated urea (NCU); S5- SR wherein N application was guided by Green-Seeker sensor and was applied using NCU; S6-Site-Specific Nutrient Management (SSNM) using Nutrient Expert (NE) decision support tool wherein N rates were guided by Green-Seeker sensor and applied through NCU; viii) Information & Communication Technology for weather information to take real time decisions on farming operations and ix)Index based crop insurance were followed in S5 and S6. Each scenario was rep-

Table 1. Grain yield of rice, wheat and RW system under different scenarios during 2014-15 and 2015-16

Scenarios	Grain yield (t/ha)					
	2014-15			2015-16		
	Rice	Wheat	RW System	Rice	Wheat	RW System
S1	6.59 A	4.70 D	11.29 C	6.73 B	5.19 E	11.92 D
S2	6.59 A	4.65 D	11.24 C	6.88 B	5.30 D	12.18 CD
S3	6.52 A	5.31 C	11.83 B	6.7 B	5.44 C	12.14 CD
S4	6.55 A	5.44 BC	11.98 AB	6.71 B	5.70 B	12.41 BC
S5	6.60 A	5.52 B	12.12 AB	6.84 B	5.80 A	12.64 B
S6	6.64 A	5.66 A	12.30 A	7.14 A	5.87 A	13.01 A

Within a column followed by the same letter are not different at 0.05% level using Fischer protected LSD test

licated thrice in production scale plots in a randomized complete block design

RESULTS

Result of 2-year participatory strategic research showed that in first year that different scenarios of CSAPs had no effect on rice yield (Table 1). However, wheat yield under layering of various CSAPs in scenarios 6, 5, 4 and 3 was increased by 20.4, 17.4, 15.7 and 12.9%, respectively compares to that of scenario- 1 (farmers practice). Highest system productivity in year 1 was recorded with layering of all CSAPs (scenario 6); an increase of 8.9% over scenario 1.The continuous high and unusual rains (Figure 1) at grain filling stage of wheat during 2014-15 (year-1) which led to yield losses of varying degree under varied levels of adaptation measures in different scenarios with maximum being under farmers practice (scenario 1) and lowest under scenario 6 layered with all CSAPs. . Synthesis of large number of published research by Wright *et al*., 2014 and Jat *et al*. 2016 across South Asia and Latin America also revealed that improved management practices have high adaptive capacity to combat climatic adversities in agriculture. During second year of study, almost similar rice grain yield was recorded among different management scenarios except scenario 6 (improved management layers) which fetched significantly higher yield over rest of the scenario (Table 1). Alike year 1, significant yield differences in wheat yield were observed but the magnitude of gains under scenarios layered with CSAPs was lower compared to year 1. The respective yield increase in scenarios 6, 5, 4 and 3 was recorded at 13.1, 11.75, 9.83 and 4.82% compared to scenario 1. This increase was 30-40% lower compared to year 1 due to relatively better growing season indicating that CSAPs perform good in risk free seasons but do much better in risk prone seasons due to high adaptive capacity.

CONCLUSION

Climate smart agriculture practices portfolios helps in minimizing adverse effects of climatic risks due to improved adaptive capacity and reduce the magnitude of crop losses under the situations of climate related risks. The results of our study revealed that CSAPs are good under risk free situations but are better in risk prone condition and hence provide potential opportunities for sustaining RW systems under the scenario of projected climate risks.

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Phenological development and yield of wheat (*Triticum aestivum*) cultivars in relation to argometeorological indices under different sowing windows

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Growing degree days (GDD) and photo-thermal units (PTU) are good estimators of wheat growth stages (Pal *et al.*, 1996). Though accumulation of growing degree days and photo thermal units for each developmental stage is relatively constant and independent of sowing date, crop variety may modify it considerably (Phadnawis and Saini, 1992). In most crop based systems (Soybean-wheat, Rice-wheat) sowing of wheat crop is often delayed which enforces to face high temperature during its later stages leading to force maturity and low productivity. Hence, it becomes imperative to have knowledge of exact duration of phenological stages in a particular crop-growing environment and their impact on yield of a particular crop. Therefore, an experiment was planned to determine the phenology and heat unit requirement of promising wheat cultivars under different sowing windows and irrigation schedules in Jabalpur conditions.

METHODOLOGY

A field experiment was conducted during *rabi*season of2014-15 at the Research farm, Jawaharlal Nehru KrishiVishwaVidyalaya, Jabalpur (M.P.). The soil classified as a Vertisol which was medium in organic carbon (0.59%), low in N (276.11 kg/ha), medium in P (17.47 kg/ha) and high in K (311.14 kg/ha) with neutral pH (7.3). The experiment was laid out in split plot design with three replication and 18 treatment combinations consist of 3 sowing windows, 2 cultivars and 3 irrigation schedules. The main plot consists3 sowingwindows (27 November, 12 December, and 27 December), two cultivars ('GW 366' and 'MP 1202'), while 3 irrigation schedules (CRI+FL, CRI+FL+ML, CRI + LJ + FL + ML) were imposed in sub plots. The crop was raised by following the recommended package of practices of the region. Irrigation schedule was followed as per the treatments keeping 60 mm depth of irrigation. However, a shallow come-up irrigation was given immediately after sowing of the wheat crop to all the treatments. Meteorological data was recorded from Agro-meteorological observatory of Department of Physics and Agrometeorology, JNKVV, Jabalpur to estimate various thermal indices.

RESULTS

The wheat cv. 'GW 366' took longer time to attain the various phenological phases and growing degree days (1485.9^{0}Cday). The differential behaviours to heat unit requirements and days required to reach the various phenological phases could be ascribed solely to its genetic makeup. The irrigation schedules had marginal variation in accumulation of GDD at various phenophases, but there was uniform requirement of growing degree days at maturity. Data showed that the highest helio-thermal units 11395.6 ^{0}C day were required for maturity when crop was sown on 27 November while the lowest in delayed sowing (10810.6^{0}C day hours). Wheat cv.'GW 366' (11141.7^{0}C day hours) required highest HTU to attain

Table 1. Yield and heat use efficiency (HUE) of wheat cultivars sown under different environments and irrigation schedules

Treatment	Yield (t/ha)		HUE(kg/ha/^{0}C day)	
	Grain	Straw	Grain yield basis	Biological yield basis
Sowing date				
27 November	4.85	6.99	3.33	8.17
12 December	4.01	6.79	2.96	7.97
27 December	3.43	6.45	2.69	7.77
CD (P=0.05)	0.146	0.557	-	-
Variety				
'GW 366'	4.23	6.87	3.06	8.08
'MP 1202'	3.96	6.62	2.93	7.86
CD (P=0.05)	0.119	0.455	-	-
Irrigation schedule				
CRI + FL	3.92	6.53	2.88	7.73
CRI + FL +ML	4.09	6.77	2.99	7.98
CRI + LJ + FL +ML	4.28	6.93	3.11	8.19
CD (P=0.05)	0.146	0.557	-	

the maturity as compared to 'MP1202' (10945.0 ^{0}C day hours). The highest heat use efficiency for dry matter was 8.17 kg/ha/^{0}C days as well as for grain yield was3.33 kg/ha/^{0}C days under 27 November sown crop (Table 1).Wheat cv. 'GW 366' registered maximum accumulated GDD (1485.9 ^{0}C day) than cv. 'MP 1202' (1477.6 ^{0}C day) and hence HUE for grain yield (3.06 kg/ha/^{0}C days) was highest in the former treatment. Irrigation scheduled at four critical stages recorded highest HUE for dry matter (3.11 kg/ha/^{0}C days) as well as grain yield (8.19 kg/ha/^{0}C days) over rest of the treatments (Table 1).The crop sown on 27 November recorded the highest grain (4.85 t/ha) and straw yield (6.99 t/ha) which was statistically on par with 12 December sowing, but significantly superior to the late sown wheat (27 December). The reduction in grain and straw yield among early and late sown wheat was 29.3 % and 7.75%, respectively. The highest grain yield was produced by cv. 'GW 366' (4.23 t/ha) as compared to 'MP 1202' (3.96 t/ha), whereas, the straw yield was not differed significantly.

CONCLUSION

From the present investigation it can be concluded that to maximize agrometeorological indices (GDD, PTU, HTU and HUE) in cultivar 'GW 366', it can be sown earlier (27 November) with four irrigations at most critical stages for obtaining higher yield.

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Effect of elevated CO_2 and temperature on quality of maize (*Zea mays*) and groundnut (*Arachis hypogaea*)

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The impact of climate change on Indian agriculture is expected to be adverse, and Karnataka is considered one of the most vulnerable states. Human emissions of greenhouse gases have grown so swiftly over the past decade that they're following the worst case scenario of the Intergovernmental Panel on Climate Change. Annually humanity is now emitting more than 10 gigatons of carbon (in the form of 40 gigatons of CO_2). The atmospheric CO_2 concentration is nearing 400 parts per million, its highest level in millions of years. Because CO_2 lasts so long in the atmosphere, even if no more were emitted, the existing gas would cause temperatures to rise by a further 0.5 degrees Celsius (to about 1.5 degrees above the preindustrial average). Understanding the change in atmospheric CO_2 and temperature on quality aspects of important crops is need of the hour (IPCC, 2013). Hence the present study is conducted with the objective to study the quality aspects of maize and groundnut under elevated CO_2 and temperature conditions.

METHODOLOGY

An experiment was conducted in Open Top Chambers (OTC's) at Main Agricultural Research Station, University of Agricultural Research Station, Raichur during *kharif* and *rabi* seasons of 2015. Two maize genotypes i.e. CP-818 and Hema and two groundnut genotypes TMV-2 and K-9 genotypes were evaluated for two CO_2 levels (ambient CO_2 and elevated CO_2 @ 550 ppm) along with combinations of temperature (ambient temperature and elevated temperature @ + 2° C). Results of the experiments were analysed through two factor-CRD design with 5 replications. Quality parameters of maize viz. oil, protein and starch content were analysed at NMR Unit of MARS, Raichur. Similarly for groundnut oil, protein and fatty acid profile was done at IIOR, Hyderabad.

RESULTS

Among the various combinations of CO_{2-} levels and temperature variations, maize and groundnut plants grown under

Table 1. Crude protein (%), Oil (%) and starch (%) content in maize and groundnut genotypes as influenced by elevated CO_2 and temperature in open top chambers during *Kharif* and *rabi* seasons of 2015

Treatments	Maize									Groundnut					
	Crude Protein (%)			Oil (%)			Starch (%)			Protein content (%)			Oil content (%)		
	G_1	G_2	Mean	G_1	G_2	Mean	G_1	G_2	Mean	G_1	G_2	Mean	G_1	G_2	Mean
T_1	9.1	8.5	8.8	7.0	6.4	6.7	69.8	70.6	70.2	20.46	19.96	20.21	47.68	51.11	49.40
T_2	8.2	8.0	8.1	6.7	6.3	6.5	70.6	70.8	70.7	19.56	20.10	19.83	42.50	46.03	44.26
T_3	8.8	8.5	8.7	6.5	6.2	6.4	70.7	70.6	70.6	20.10	20.30	20.20	41.98	43.94	42.96
T_4	10.9	8.6	9.8	6.8	6.5	6.6	71.3	71.4	71.3	22.30	22.81	22.56	44.05	47.02	45.53
T_5	8.8	8.4	8.6	6.7	6.5	6.6	71.1	71.5	71.3	21.46	22.10	21.78	43.49	46.16	44.82
Mean	9.2	8.4		6.7	6.4		70.7	71.0		20.78	21.05		43.94	46.85	
	SEm±	CD (P=0.05)	CD (P=0.05)	SEm±	CD (P=0.05)	CD (P=0.05)	SEm±	CD (P=0.05)	CD (P=0.05)	SEm±	CD (P=0.05)	CD (P=0.05)	SEm±	CD (P=0.05)	CD (P=0.05)
Factor T	0.11	0.4	0.3	0.08	NS	0.2	0.9	NS	NS	0.24	0.93	0.69	0.51	1.96	1.46
Factor G	0.07	0.3	0.2	0.05	0.2	0.2	0.5	NS	NS	0.15	NS	NS	0.32	1.24	0.92
T*G	0.15	0.6	0.4	0.11	NS	NS	1.2	NS	NS	0.34	NS	NS	0.72	NS	NS

T_1- eCO_2 (550 ppm) + aTemperature, T_2- eCO $_2$(550 ppm) + eTemperature(2°C rise), T_3- aCO_2 + eTemperature (2°C rise),T_4- Reference OTC. T_5- Control plot. Maize: G_1- Hema, G_2- CP-818, Groundnut: G_1- TMV-2, G_2- K-9 Factor T- Climate variables effect, Factor G- Genotypic effect

ambient CO_2 and ambient temperature recorded significantly higher crude protein (9.8 and 22.6%, respectively) than rest of the treatments. However, plants grown under elevated CO_2 @ 550 ppm with elevated temperature (+2 °C rise) recorded significantly lower crude protein (8.1 and 19.8%, respectively). It was also noticed that a strong relationship exists between relative effects of elevated CO_2 as compared to ambient CO_2 on grain N and grain yield. Maize and groundnut plants grown under elevated CO_2 @ 550 ppm and ambient temperature recorded significantly higher oil content (9.8 and 49.4%, respectively) than rest of the treatments. However, plants grown under ambient CO_2 with elevated temperature (2 °C rise) recorded significantly lower oil content (8.1 and 43.0%, respectively). Among the maize genotypes, Hema recorded significantly higher oil content (9.2%) as compared to CP-818 (6.7%). Between the groundnut genotypes, K-9 has recorded significantly higher grain oil content (46.9%) as compared to genotype TMV-2 (44.0%). However, interactive effect between genotypes with change in CO_2 levels and temperature variations on grain oil content of both the crops are found to be non significant. Oils are primarily made up of fatty acids. Since fatty acids are mainly composed of carbon compounds this might have lead to increase in little increase in oil content of the groundnut. Non-significant difference was observed among the genotypes, CO_2 concentration and temperature variations (Table 1). But the highest starch content was recorded in ambient carbon dioxide with ambient temperature treatments i.e. T_4 (71.3%) and T_5 (71.3%) treatments, respectively. Least starch content of grain was recorded in elevated CO_2 @ 550 ppm with ambient temperature T_1 (70.2%). Between the genotypes, Hema recorded lower starch content (70.7%) than CP-818 genotype (71%). The fatty acid profile of groundnut genotype as influenced by elevated CO_2 and temperature in open top chambers reveals that, highest oleic acid (18.78%) noticed with TMV-2 inT4 (Reference plot) and lowest (10.82%) was recorded with same variety in T2 (eCO $_{2\,@}$550 ppm with e Temperature@+2°C). Whereas highest linoleic acid (56.61) was recorded with K-9 in T-3 (ambient CO_2 with elevated temperature of +2°C) and lowest (43.77 %) was recorded with TMV-2variety in T4 (Reference plot). Among the genotypes, K-9 has recorded higher palmitic, stearic, linoleic and behenic acids, whereas TMV-2 has recorded higher oleic archidic and elicosaenic acids irrespective of variations in CO_2 and temperature.

CONCLUSION

The study revealed that among the tested crops (C_3 and C_4) were shown significant variation with respect to quality aspects. However, C_3 plant (Groundnut) shown results under elevated CO_2 conditions, where as both crops shown inferior results under elevated temperature conditions. Among the genotypes in both crops some have performed well under changing climatic scenario. In case of maize CP-818 performed well as compared to Hema and in case of groundnut K-9 performed well as compared TMV-2.

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Impact of climate change on potato productivity in Madhya Pradesh

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Potato is a popular temperate crop and is largely grown during winter season in India. However, due to global climate change, the availability of suitable growing period is likely to be impacted, probably leading to decline in potato productivity. Compared to the baseline scenario of 2000, potato season in India in 2020 is likely to be warmer by 0.78 to 1.18 ºC and in 2055, by 2.41 to 3.16 ºC under A1FI scenario. During the same period, the CO_2 concentration is likely to increase from 367 ppm to 415 in 2020 and 590 ppm in 2055 (IPCC, 2001). In India, Madhya Pradesh is the fifth largest potato producing state after Uttar Pradesh, West Bengal, Bihar and Gujarat. Thus a study was undertaken to assess the likely impact of climate change on potential potato productivity of Madhya Pradesh using crop growth model.

METHODOLOGY

The WOFOST (World Food STudies) crop growth model, developed at Wageningen University, The Netherlands, was used in the present study. Three potato cultivars, belonging to long duration (Kufri Badshah), medium duration (Kufri Jyoti) and short duration (Kufri Pukhraj) maturity group were selected for simulation studies. The model was run for the normal date of planting for the state, *i.e.* 20th October. IMD district normal of 1971-2000 of 38 districts of Madhya Pradesh were used for baseline scenario (year 2000) and for generation of scenario for 2020 and 2055; projected changes in surface air temperature for sub-regions of the Asia under SRES A1FI pathway based on the Fourth Assessment Report (AR4) AOGCMs (Atmosphere-Ocean General Circulation Models) were added to the baseline data (IPCC, 2007). Based on the Bern-CC model for A1FI scenario projected atmospheric CO_2 concentration was used for incorporating the effect of change in CO_2 concentration in WOFOST model (IPCC, 2007). For atmospheric CO_2 concentration 367 ppm (for baseline), 415 ppm (for 2020) and 590 ppm (for 2055) were used in the present study.

RESULTS

The potato productivity varied largely within the state under baseline scenario; 26.8-52.2, 23.6-48.6, 24.0-51.2 t/ha for Kufri Badshah, Kufri Jyoti and Kufri Pukhraj, respectively. The extrapolated results have shown a baseline productivity of 43.6, 40.0, 42.2 t/ha for these cultivars. For 2020, model results have simulated a mean reduction of 5.8% in the yield of Kufri Badshah over the baseline scenario of 2000. The extrapolated results have shown a decline of 6.4, 7.3 and 7.6% in the yield of Kufri Badshah, Kufri Jyoti and Kufri Pukhraj respectively, under the A1FI climate change scenario of 2020. During 2055, greater yield losses are expected in the yield of all the three potato cultivars. While the increase in temperature is likely to decrease the yield by 22.9, 23.9 and 27% of Kufri Badshah, Kufri Jyoti and Kufri Pukhraj, increase in CO_2 (from 367 ppm in 2000 to 590 ppm in 2055) is expected to increase the yield by 11.6, 18.4 and 21.0% for respective varieties. However, the respective figures for decline in yield under the combined influence of temperature and CO_2 are 10.4, 12.3 and 13.9%, over the baseline scenario of 2000, when the means of 38 locations for which the WOFOST model was run, were considered. The extrapolated results have shown that yield of Kufri Badshah could reduce by about 7 to 12% in around 98% of the area. In case of Kufri Jyoti, most part of Madhya Pradesh (95%) may experience the yield reduction in the range of 10 to 15 %; with south-western districts, particularly Ratlam, Jhabua, Dhar and Barwani, expecting greater yield losses. Among the three varieties studied, the greatest reduction is expected in the yield of Kufri Pukhraj, with around 94% of geographical area of Madhya Pradesh likely to witness 10 – 15% yield decline.

CONCLUSION

WOFOST crop growth simulation carried out to study the impact of climate change on potato productivity in Madhya Pradesh revealed that potato yield is likely to be impacted negatively in Madhya Pradesh in future climates due to combined effect of CO_2 and temperature. Over the baseline scenario of 2000, a decline of 6.4, 7.3 and 7.6% is projected in the yield of Kufri Badshah, Kufri Jyoti and Kufri Pukhraj respectively, under the A1FI climate change scenario of 2020. During 2055, the respective figures for likely decline in yield under the combined influence of temperature and CO_2 are 10.4, 12.3 and 13.9%.

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Effect of weather parameters on okra varieties in *summer* season

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Okra [*Abelmoschus esculentus* (L.) Moench] commonly known as lady's finger or '*bhendi*' is most delicious vegetable relished world over. It belongs to the family Malvaceae. It is of African origin. In Maharashtra, *bhendi* is grown throughout the year providing continuous and good source of income to the farmers. Number of fungal, bacterial, viral diseases has been reported in India. Amongst the viral diseases, Yellow vein mosaic virus is one of the important and of common occurrence wherever this crop is grown. The objective of this experiment was to identify best okra variety in *summer* season and to work out the correlation between YVMV incidence on okra varieties and weather parameters in *summer* crop.

METHODOLOGY

The present experiment was conducted on experimental farm of Vegetable Research Centre, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, during *summer* season 2015in randomized block design with four replications. Treatments consisted of six varieties sown in *summer* season Viz. Parbhani Kranti, Parbhani OK-1, Arka Anamika, Arka Abhay, VRO-6, and Pusa Sawani and sown with a spacing 60 x 30 cm. The gross plot size was 4.2 x 3.9 m^2 and net plot size was 3.0 x 2.7 m^2. The sowing was done by dibbling method. Data were collected from five plants randomly selected from each plot. Plant height, number of functional leaves plant^{-1}, leaf area and dry matter were recorded with 15 days interval after germination. The data was subject to analysis along with average weekly minimum and maximum temperature, rainfall, rainy days, relative humidity, evaporation, bright sunshine hours and wind velocity.

RESULTS

Persual of data (Table 1) revealed that all the biometric observations like plant height and dry matter production/plant at harvest was found significantly higher in variety Arka Anamika compared to all other varieties. While, Parbhani kranti was found with highest number of functional leaves. Arka Abhay (544.58) was found to have maximum leaf area plant^{-1}. The result might be due to sufficient sunshine hours for photosynthesis and optimum temperature during crop growing period. The variety Parbhani OK-1 (7.20) was found to have more number of fruit /plant than other varieties. The highest yield was recorded with Parbhani Kranti (4.69 t/ha) followed by VRO-6 (4.09 t/ha) and it was found reduction in

Table 1. Yield and yield attributing characters of different varieties at harvest

Varieties/ Characters	V_1 (Parbhani Kranti) (Parbhan)	V_2 (Parbhani OK-1)	V_3 (Arka Anamika)	V_4 (Arka Abhay)	V_5 (VRO-6)	V_6 (Pusa Sawani)	CD (P=0.05)
Plant height	101.05	103.33	105.80	90.66	100.33	101.43	2.34
No. of functional leaves	27.66	26.00	23.33	22.66	21.00	24.00	1.96
Leaf area/plant(cm^2)	506.10	522.54	513.19	544.58	506.71	507.90	15.45
Dry matter	14.72	16.23	17.23	12.76	15.66	16.23	1.43
No. of fruits/plant	4.33	7.20	3.20	4.10	4.33	4.22	0.62
Fruit yield (t/ha)	4.69	3.43	3.62	3.75	4.09	2.81	0.053

Table 2. Correlation between weather parameters and YVMV disease incidence on different okra varieties

Weather	Varieties					
	V_1(Parbhani Kranti)	V_2(Parbhani OK-1)	V_3(Arka anamika)	V_4(Arka abhay)	V_5(VRO-6)	V_6(Pusa sawani)
RF	-0.187	-0.065	-0.170	-0.211	-0.149	-0.319
RD	-0.232	-0.137	-0.261	-0.267	-0.173	-0.357
Tmax	0.932**	0.966**	0.965**	0.960**	0.949**	0.950**
Tmin	0.668*	0.736*	0.708*	0.689*	0.658*	0.711*
RH-1	-0.704*	-0.626*	-0.694*	-0.720*	-0.649*	-0.793**
RH-2	-0.221	-0.298	-0.246	-0.239	-0.166	-0.324
Evp	0.615	0.632*	0.598	0.627	0.598	0.587
BSS	0.169	0.125	0.165	0.180	0.182	0.048
WV	0.752*	0.600*	0.670	0.740*	0.726*	0.614

*significant at 5 % (0.632); **significant at 1% (0.765).

fruit yield with different varieties. This might be due to the lesser percent disease incidence i.e., highly resistant to YVMV and influence of maximum temperature. Related observations were recorded by Prashanth *et al.* (2008). The data pertaining to disease incidence showed that the correlation between the weather parameter and disease incidence on different okra varieties are presented in Table 2. Maximum temperature showed highly significant correlation with disease incidence on different okra varieties. Minimum temperature showed significant correlation with disease incidence. Relative humidity was negatively significant with disease incidence. Evaporation observed significant correlation with disease incidence on V_2 (Parbhani OK-1) .Wind velocity observed significant correlation on all varieties i.e., V_1 (Parbhani Kranti), V_2 (Parbhani OK-1), V_4 (Arka Abhay), V_5 (VRO-6) except in V_3 (Arka Anamika) and V_6 (Pusa Sawani).Similar correlation was recorded by Safdar *et al.* (2005).

CONCLUSION

It can be concluded from result that, among the six varieties Arka Anamika was found better in case of growth parameters. Parbhani Kranti was found to give optimum yield compared to other varieties.The correlation between weather parameter and disease incidence of YVMV showed increase in disease incidence with increase in maximum temperature and minimum temperature. The different weather parameters like, maximum temperature and minimum temperature, relative humidity, evaporation and wind velocity affect the disease incidence.

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Extended Summaries Vol. 1 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Usability of weather forecast in issuing agromet advisory

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Agro advisories implemented through five tier structure to set up different components of the service spectrum. It includes meteorological (weather observing & forecasting), agricultural (identifying weather sensitive stress & preparing suitable advisory using weather forecast), extension (two way communication with user) and information dissemination (Media, Information Technology, Telecom) agencies. The Agromet Advisory Bulletins are issued twice a week i.e. Tuesday and Friday. District level weather forecast generated under this service is the useful to the user community. User community based on these forecast and its use in agromet advisory services could save losses / damages of the crops. Through IAAS integrated agro advisories are issued for various regions depending upon the realistic rainfall and contingency measures are provided to farmers (Balasubramaniam, 2013). Agro-meteorological service rendered by IMD, Ministry of Earth Sciences is an innovative step to contribute to weather information based crop/livestock management strategies and operations dedicated to enhancing crop production by providing real time crop and location specific agromet services with outreach to village level. This indeed has a potential to change the face of India in terms of food security and poverty alleviation.

METHODOLOGY

IMD issues quantitative district level weather forecast using global numerical model predictions. The value added quantitative weather forecast received from Meteorological Centre, Srinagar and the observed meteorological data at the Agrometeorological observatory, Main Campus, SKUAST-Jammu, was compared to assess the validity of weather forecasts for the months of March 2013 to February, 2014. During 2013-14, based on forecasts of 365 days, biweekly crop weather bulletins were prepared for subtropical zone (up to 800 msl) and issued on each Tuesday and Friday for the benefit of farmers of Jammu district. Verification with observed and forecast value of Jammu district was analyzed. Verification of forecast was done day basis i.e. first day, second day, third day, fourth day and Fifth day.

RESULTS

The verification is qualitative or quantitative so as to bring out the nature of the forecast errors. Error structure (correct) for rainfall expresses accuracy ranged from 46-73 %, 43-76 %, 46-84 %, 37-85 % and 49-76 % for I, II, III, IV and V day respectively for all seasons .Error structure (correct) for maximum temperature expresses accuracy ranged from 31-50 %, 31-54 %, 27-43 %, 27-68 % and 0-50 % for I, II, III, IV and V day respectively for all seasons. Error structure (correct) for minimum temperature expresses accuracy ranged from 31-47 %, 12-52 %, 12-40 %, 12-39 % and 23-46 %for I, II, III, IV and V day respectively for all seasons. Error structure (correct) for Minimum Relative Humidity expresses maximum accuracy for I, II, III & IV day respectively for all seasons. Error structure (correct) for Maximum Relative Humidity expresses accuracy ranged from 40-100 %, 29-100 %, 42-94 %, 49-88 %t and 46-89 % for I, II, III, IV and V day respectively for all seasons. RMSE calculated for all the five days during all the seasons was less than 5 indicating forecast value in agreement with observed value. Rainfall was highly correlated during IV and V day of monsoon, III and IV day of post monsoon, I day of pre monsoon and II third and IV day of winter season. The efficiency of rainfall forecast as measured by ratio score was good for day I, II, III & IV and poor for V day. But V day (Saturday) in Tuesday advisory becomes II day in following Friday advisory similarly V day (Tuesday) in Friday advisory becomes I day in following Tuesday advisory so poor efficiency of rainfall forecast for fifth day does not affect overall efficiency of rainfall forecast.

CONCLUSION

As weather forecast is in agreement with observed weather, user community based on these forecast and its use in agromet advisory services could save losses / damages of the crops.

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Influence of climate change on potato performance

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Climate change is the most discussed issue by the world today because of its direct effect on the earth's natural resources in a very wide range. This is likely to become a big challenge to human survival on the earth in one or the other way. Increased concentration of green house gases such as CO_2, CH_4, O_3, CFCs and N_2O, produced by anthropogenic activities, is the primary cause of climate change in the form of global warming (IPCC, 2007). Eleven out of the previous

12 years (1995–2006) have been ranked among the 12 warmest years since 1850 in the instrumental record of global surface temperature. Earth's linearly averaged surface temperature has increased by 0.74°C during the period 1901-2005 (IPCC, 2007). Potato (*Solanum tuberosum* L.) has got a prominent place among the modern agriculture in India. It has a wide range of adaptability to different climates and environments. It is mainly grown in the Indo-Gengatic Plains of India comprising Uttar Pradesh, West Bengal, Bihar, Punjab and Haryana which contribute about 84% of total potato production in India (Singh *et al*., 2013). Potato crop has been reported to be very sensitive to climate change as even small change in climate influences every aspect of its production and profitability. Temperature range for potato growth lies between 2 to 30ºC. Cool night temperatures are favorable to induce tuberization whereas high temperature suppress the photosynthesis, tuberization and partitioning of photosynthesis to tubers and also reduce tuber number and size (Singh and Lal, 2009). Impact of climate change on its productivity over a short and long time period has been studied with computer models. Singh *et al*. (2013) reported that tuber yield was drastically reduced even with moderate increase in temperature. Depending on the temperature regime, high temperatures decrease the yields due to increased development rates and higher respiration. However, total biomass production and photosynthesis were not much influenced. Heat sprouting and internal necrosis occurred due to high temperature which adversely affected the potato tuber quality. Contrary to the effect of temperature on potato, increased CO_2 concentration has positive effects on the growth and yield of potato with very few negative effects (Singh *et al*. 2013). Using INFOCROP-POTATO model, Singh *et al*. (2013) showed that at elevated CO_2 level of 550 ppm and with 1°C increase in temperature, there will be increase in potato production by 11.1% but will decrease with further increase in CO_2 and temperature in the year 2050. Positive correlation has been found between CO_2 concentration and assimilation of photosynthates in potato and every 100 ppm increase in CO_2 concentration has been estimated to increase 10% tuber yield. Increase in photosynthesis and decrease in evapotranspiration with increased CO_2 concentration are the main reason for this positive correlation. However, increased CO_2 accumulation in atmosphere is expected to adversely affect the post harvest quality of potato causing tuber malformation, occurrence of common scab and changes in reducing sugar contents in potatoes. Though, tuber yield is increased with CO_2 enrichment but it does not appear to compensate for the detrimental effects of higher temperatures on tuber yield. Dua *et al*., (2016) using WOFOST crop growth simulation model estimated that the increase in CO_2 concentration will bring an increase of 4.2 to 4.5% in productivity in 2020 and 17.7 to 19.3% in 2055. However, corresponding increased temperature was expected to decrease the mean productivity by 9 to 11% in 2020 and 24.3 to 29.1% in 2055. Overall combined effect of temperature and CO_2 was expected to decrease the mean productivity of potato. As it is clear from the models studied that changing climate will have negative effect on the production and productivity of potato. So, there is urgent need to adopt some strategies to mitigate these climatic effects on potato performance and maintain the yield. Singh and Lal (2009) have suggested some possible adaptations to changing climate like change in planting time, development of heat tolerant varieties, efficient agronomic and water management techniques and shifting cultivation to new and suitable agro-climatic zones. Adoption of these strategies singly or in combination is the best option to sustain the potato performance under future climates.

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Symposium 2
Organic Agriculture

Extended Summaries Vol. 1 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Carbon accrual trends and their effects on productivity in major organic management systems for rice-wheat cropping

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Soil as a carbon sink can act as a tool against global warming. Carbon dioxide (CO_2) is one of the major contributors of global warming. According to fifth assessment report of IPCC, 2014 it has been estimated that earth's temperatures will be largely determined by cumulative CO_2 i.e., climate change will continue even if CO_2 emissions are stopped. To reduce the high concentration of atmospheric CO2, soil carbon sequestration can play a major role. Being a very intense and exhaustive system, rice-wheat cropping system (RWS) has very low soil organic carbon (C) which ultimately leads to low productivity, therefore RWS is considered as a potential C sink. Organic management like green manuring, legumes in rotation, crop residue retention etc. have been advocated as viable alternatives to increase soil carbon (which is indicative of soil health) as well as provide for nutrient requirement of crops. In this study, in a long term 10 year old experiment, major organic management options for rice-wheat (R-W) cropping systems were compared for their potential to debit organic carbon (C) to soil and its effect on soil C fractions and biological yield. In the treatments with organic inputs, inorganic fertilizers doses were reduced to4˜55%, compared to control and fertilizer only treatments.

METHODOLOGY

A ten year long experiment was used to study the effects of seven treatments namely no fertilizer or organic inputs (control, O), recommended inorganic fertilizers only (F), legumes *Vigna radiata* in rotation (LE), green manure (*Sesbania esculeata*)in rotation (GM), farm yard manure (FYM), wheat straw (WS) and paddy straw (PS).The field experiment was initiated in 2005 on a soil with sandy loam texture (AquicNatrustalfs) at ICAR-Central Soil Salinity Research Institute (CSSRI), Karnal,India,located at 29.43ºN and 76.58ºE.Bulk density was measured using metallic core at depths of 0-15 cm, 15-30 cm and 30-60 cm.The total SOC stock was calculated as follows: *C stock in soil = C content X Bulk density X Depth,* where, C content is given in g C/g, BD in Mg/m^3, depth in m and C Stock in Mg/ ha.Organic carbon (OC) of soil was determined by Walkley and Black's rapid titration method. Modified Walkley–Black method was used to estimate the different fractions of organic C comprising very labile, labile, less labile and non-labile (recalcitrant). Lability index, CSP and CMI was calculated as per the standard methods. Biological yield was measured in terms of above ground biomass including the mass of grains as well as straw. Plant assimilated C was also measured by taking the above and below ground biomass of the RWS. C return to soil was measured annually by measuring all the carbon added to the soil during the experiment in the form of crop residue.

RESULTS

Organic management resulted in increase in all forms of organic C: very labile, (VL), labile (L), less labile (LL) and non-labile (NL). Total organic carbon content in FYM, GM, WS and PC were 6.75±0.15, 6.58±0.48, 6.26±0.27 and 5.98±0.18 g/kg,respectively at 0-15 cm depth, resulting in 22.5%, 19.4%, 13.6% and8.5% change, respectively over F treatment. On an average 6-20 t/ha was assimilated in form of root and shoot biomass in all treatments. In total, 1-7 t/haC was returned to soil in form of roots, incorporated above ground biomass or amendment in different treatments.Lability Index (LI) showed increasing trend with increase in depths in all treatments. C stock show decreasing trend with increase in depth and was found maximum in case of GM (1724.14 g/m^2) at 0-15 cm depth. It was also observed that active pool of carbon (VL and L) is directly proportional to the plant assimilated C and biological yield. Plant assimilated C and C return to the soil was found maximum in case of GM i.e. 20.64±1.32 and 7±.35 t/ha, respectively.

CONCLUSION

The carbon (C) returned (in form of root biomass and amendment biomass) to soil had direct relation with change in all C fractions with maximum change in VL, LL fractions. Annual C return to soil had a positive correlation with biological yield in all treatments except GM and LE, indicating, perhaps, that 'nutrient secure' and C rich management systems are less susceptible to weather fluctuations and therefore climate resilient.

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Yield potential and quality of basmati rice (O*ryza sativa L.*) grown under SRI method as influenced by different transplanting dates and organic nutrient sources

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The productivity of basmati rice in Jammu is lesser than the national average. Therefore, it becomes imperative to improve its production vertically rather than horizontal expansion. Under present agriculture scenario, the recommended management practice needs relook as due to global warming total shift of agricultural practices are being realized. Therefore, it becomes necessary to work out the optimum nursery sowing/ date of transplanting under the changing climatic conditions. To ensure and enhance the success of System of Rice Intensification (SRI) on yield and quality of Basmati rice, with different transplanting dates and the use of soil organic amendments which may as expected shall play a crucial role to optimize rice productivity, but also can play an important role under climate resilient agriculture.

METHODOLOGY

A field experiment was conducted at the research farm of Division of Agronomy of Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu during the year 2014. The experiment was laid under RBD design which consisted of three dates of transplanting (June 30th; July 15th and July 30th) and five nutrient sources (100% inorganic fertilizer (RDF); Brown manuring with *Sesbaniaspp*. + 25% inorganic fertilizer (RDF); Brown manuring with *Sesbaniaspp* (100 %); FYM + Vermicompost+ Non-Edible oil cake (1/3rd each) and Green manuring with *Sesbania spp* + Vermicompost (1:1). the rice variety basmati-370 was used as test material. All the data were statistically analyzed using the analysis of the variance (ANOVA) technique. The critical differences at 0.05% level of probability were calculated to assess the significance between treatments if treatments were significant.

RESULTS

Among different transplanting dates the basmati rice transplanted on June 30 produced significantly higher grain yield (3.272 t/ha) than July 15 (3.027 t /ha) and July 30.The per

Table 1. Yield and qualityof Basmati rice as influenced by transplanting dates and nutrient sources.

Treatment	Grain yield (t/ha)	Milling (%)	Head rice recovery (%)	Amylose (%)	L:B ratio
Transplanting dates					
June 30	3.272	69.64	55.45	20.36	3.40
July 15	3.027	68.03	54.30	20.37	3.48
July 30	2.759	67.28	51.35	20.82	3.55
SEm±	0.069	1.09	0.72	0.34	0.07
CD (P=0.05)	0.200	NS	0.92	NS	NS
Nutrient sources					
100% inorganic	3.283	68.15	52.79	20.01	3.46
Brown manuring + 25% RDF	2.879	68.27	53.78	20.52	3.47
Brown manuring 100%	2.601	68.23	54.39	20.77	3.49
FYM+Vermicompost+ non edible oil cake (1:1:1)	3.021	68.50	53.81	20.70	3.47
Green manuring + Vermicompost (1:1)	2.980	68.44	53.72	20.59	3.49
SEm±	0.089	1.41	0.92	0.44	0.08
CD (P=0.05)	0.259	NS	NS	NS	NS

cent increase in grain yield of June 30 and July 15 was in order of 18.59 and 9.71 over July 30.Application of nutrients through inorganic sources (100% RDF) increase the grain yield (3.283 t/ha) of basmati significantly over other organic nutrient sources. Among the organic sources FYM + vermicompost + non edible oil cake (three equal proportions) though being at par with green manuring + vermicompost (1:1) and brown manuring +25% RDF produced higher grain yield of basmati rice (B-370) over alone application of organic through brown manuring (100%).The milled rice recovery percentage did not differ significantly by different transplanting dates and nutrient sources while June 30 date of transplanting recorded higher milling percentage of 69.64 % than July 15 and July 30.Among different nutrient sources, application of FYM + vermicompost + non edible oil cake in three equal proportions followed by green manuring + vermicompost in two equal splits realized the higher values of milling percentage. The Head rice recovery was affected significantly by different transplanting dates as June 30 date of transplanting with 55.45% head rice recovery over July 15 (54.30%) and July 30 (51.35%). The data for amylose content and length-breadth ratio revealed that the different transplanting dates and different nutrient sources did not affect amylase content of basmati rice.

CONCLUSION

On the basis of study conducted, it may be concluded that June 30 date of transplanting has been found more beneficial. Among the nutrient sources, the 100 % inorganic dose of fertilizer (recommended dose) followed by brown manuring +25% RDF or green manuring + vermicompost (equal splits) was found to be the most suitable for achieving economic yield advantage .

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Organic management for sustainability of guar gum in rainfed condition

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Guar gum is an under exploited leguminous crop suitable under *rainfed* conditions. An edible thickening agent extracted from the guar bean, contains galactomannan gum which forms a gel in water has an industrial value. This gum is used for oil well drilling, textile printing, frozen food, tablet preparation and thus an important foreign exchange earner for the country. In view of this, a field experiment entitled "Organic management for sustainability of guar gum in rainfed condition" was conducted to find out the most suitable land configuration practice to increase the productivity of guar gum and to evaluate the suitable organic source of nutrient management.

METHODOLOGY

The field experiment was conducted at the Department of Agronomy, Dr. Panjabrao Deshmukh Krishi Vidhyapeeth, Akola during 2013-2014 which comprises three land configuration viz., Flat bed, Opening of furrow in each row and Opening of furrow in alternate rows along with four Nutrient management viz., Control, FYM, Soybean compost and Vermicompost were replicated four times in Split plot design.

RESULTS

The data on growth and yield are given in table 1 which indicated that the growth characters like plant height, number of leaves, number of branches, leaf area index and dry matter were influenced significantly due to land configuration and nutrient management. Opening of furrow in each row produced maximum number of leaves (27.96) and number of branches (7.98) which was significantly higher than conventional method of flat bed configuration. The seed yield (0.27 t/ha) was significantly higher in opening of furrow in each row which was comparable to opening of furrow in alternate rows but both the treatments were significantly superior to flat bed system of land configuration. Similar observation was also noticed with biological yield (1.05 t/ha). Significant increased in yield may be attributed by increased in plant height (43.87 cm) and dry matter accumulation (6.41 g) with opening of furrow in each row and alternate rows. Similar improvement

Table 1: Growth and yield as influenced by land configuration and nutrient management

Treatment	Plant height (cm)	No. of leaves/ plant	No. of branches/ plant	Dry matter (g)	Seed yield (t/ha)	Biological yield (t/ha)
Land configuration						
L_1 (Flat bed)	37.95	23.67	6.45	5.23	0.24	0.87
L_2 (Opening of furrow in each row)	43.87	27.96	7.98	6.41	0.27	1.05
L_3 (Opening of furrow in alternate rows)	42.19	25.44	7.54	6.13	0.26	0.98
CD (P=0.05)	2.37	3.29	1.02	0.56	0.0203	0.0558
Nutrient management						
N_0(Control)	37.40	22.73	6.03	5.31	0.23	0.87
N_1 (FYM @ 2.5 t/ha)	42.21	26.26	7.53	5.93	0.26	0.97
N_2 (Soybean compost @ 2.0 t/ha)	40.67	25.53	7.24	5.91	0.259	0.95
N_3 (Vermicompost @ 2.0 t/ha)	45.07	28.23	8.49	6.53	0.28	1.07
SEm$\pm$	0.57	0.6	0.21	0.15	0.004	0.0138
CD (P=0.05)	1.66	1.74	0.62	0.49	0.0117	0.0402
GM	41.34	25.69	7.32	423.56	0.26	0.97

NS-Not significant

in yield due to land configuration was also observed by Allolli *et al*. (2008). Amongst nutrient management, application of Vermicompost @ 2.0 t/ha produced maximum number of leaves (28.23) and number of branches (8.49) which was significantly higher than FYM @ 2.5 t/ha, Soybean compost @ 2.0 t/ ha and control. Seed yield (0.28 t/ha) and biological yield (1.07 t/ ha) were also significantly higher than FYM @ 2.5 t/ ha and soybean compost @ 2.0 t/ha and control. This may be attributed mainly due to increased plant height (45.07 cm) and dry matter accumulation (6.53 g). Increased seed yield in vermicompost was also evident by Chhipa *et al.* (2012).

CONCLUSION

Based on this experiment it can be concluded that opening of furrow in each row or alternate rows is beneficial to conserve soil moisture and drain out the excess moisture during the rainy season. The nutrients may be applied either through vermicompost or soybean compost.

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Growth and yield of wheat (*Triticum aestivum*) as influenced by organic sources of nutrients

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With rapidly increasing population, the demand of food is increasing, so there is great need to increase the productivity of wheat. Nutrient deficiency and imbalance fertilization are critical factors reducing the yield of wheat (Khan *et al*., 2010). To fulfil the demand of food, sustainable and high yielding crops have been grown which resulted in application of commercial inorganic fertilizers in larger amount in soils specially in case of nitrogenous fertilizers. Continuous application of

Table 1. Effect of different treatments on growth, yield and yield attributes of wheat (Pooled mean over 3 years).

Treatment	Plant height (cm)	Number of spikes/m^2	Spike length (cm)	Number of seeds/ spike	1000-grain weight (g)	Yield (t/ha) Grain	Yield (t/ha) Straw
Farmers practice	79.10	216.04	6.78	25.23	32.20	1.58	2.40
FYM @ 20 t/ha + PSB @ 0.5 litre/ha	80.80	237.20	7.13	25.90	33.80	1.98	2.91
FYM @ 20 t/ha + *Azotobacter* @ 10 g/kg seed+ *Azospirillium* @ 10 ml/kg seed	85.90	232.33	7.40	26.07	35.00	2.08	3.06
SEm±	1.82	3.94	0.21	1.49	0.62	0.13	.16
CD (P=0.05)	5.98	8.59	0.57	NS	1.70	.35	.49

chemical fertilizers causes soil health problems even if applied in balanced proportion. Wheat yield was increasing with the application of FYM. This may be due to the effect of higher levels of organic matter which improves soil physico-chemical properties and add significant quantities of N, P, K, Ca and Mg (Edmeades, 2003). Use of organics and bio-fertilizers is important to bridge up the increasing gap between demand and supply of fertilizers. Use of low cost indigenous organic manures like bio-fertilizers can play a vital role in sustaining the production by improving soil health.

METHODOLOGY

A field experiment was conducted during *rabi* season of years 2005-06, 2006-07 and 2007-08 at Gudkande village of Hawalbagh block in irrigated situation located at an altitude 1250 meter above mean sea level to evaluate the effect of organic sources of nutrients on growth and yield of irrigated wheat. The soil was clay loam in texture, rich in fertility status (465.4 kg available N/ha, 43.82 kg available P_2O_5/ha and 317.5 kg available K_2O/ha) having pH 6.55 and organic C 2.65%. Wheat crop variety VL 804 was sown with a spacing of 20x 5 cm. during first week of November under irrigated condition. The experiment was laid out in randomised block design with seven replications. Treatments consisted of farmers practice, farm yard manure @ 20 t/ha along with phosphate solubilising bacteria @ 0.5 litres/ha and farm yard manure @ 20 t/ha along with *Azotobacter* @ 10 g/ kg seed coupled with *Azospirillium* @ 10 ml/kg seed. The data pertaining to plant height, plant density/m^2, number of spikes/m^2 and spike length as well as yield attributed and yield were recorded at appropriate stages. In general, crop performance was very poor due to severe drought in the year 2005-06. Same situation was again observed in the year 2007-08 also. Crop was harvested in month of mid May. Three years pooled mean data was analysed for computing growth, yield and yield attributes of that particular crop.

RESULTS

Data depicted in Table 1 indicated that treatment having farm yard manure @ 20 t/ha along with *Azotobacter* @ 10 g/ kg seed coupled with *Azospirillium* @ 10 ml/kg seed recorded maximum plant height (85.90 cm) which was 8.60 and 6.30 per cent more than rest of the treatments i.e. farmers practice, farm yard manure @ 20 t/ha along with phosphate solubilising bacteria @ 0.5 litres/ha. Treatment having farm yard manure @ 20 t ha^{-1} along with *Azotobacter* @ 10 g kg^{-1} seed coupled with *Azospirillium* @ 10 ml/kg seed was on the top with 229.90 plants/m^2 followed by farm yard manure @ 20 t/ha along with phosphate solubilising bacteria @ 0.5 litres/ha and farmers practice with 229.60 and 208.20 plants/m^2. Application of farm yard manure @ 20 t/ha along with *Azotobacter* @ 10 g/kg seed coupled with *Azospirillium* @ 10 ml/kg seed recorded 10.42 per cent higher plant density over farmers practice. Application of farm yard manure @ 20 t/ha along with *Azotobacter* @ 10 g/kg seed coupled with *Azospirillium* @ 10 ml/kg seed gave maximum yield i.e. 2.01 t/ha and this treatment recorded 31.40 and 5.05 per cent more yield over farmers practice and farm yard manure @ 20 t/ha along with phosphate solubilising bacteria @ 0.5 litres/ha. Application of farm yard manure @ 20 t/ha along with *Azotobacter* @ 10 g/ kg seed coupled with *Azospirillium* @ 10 ml/kg seed recorded maximum straw yield (3.01 t/ha) followed by 2.91t/ha in farmers practice. The straw yield obtained from farm yard manure @ 20 t/ha along with *Azotobacter* @ 10 g/kg seed coupled with *Azospirillium* @ 10 ml/kg seed was 27.50 per cent more when compared with farmers practice.

CONCLUSION

It can be concluded that application of farm yard manure @ 20 t/ha along with *Azotobacter* @ 10 g/kg seed coupled with *Azospirillium* @ 10 ml/kg seed can be recommended over farmers practice in wheat for getting higher productivity and profitability under irrigated conditions of Uttrakhand hills.

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Evaluation of organic farming for groundnut-chickpea cropping sequence

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Under intensive cropping sequence, continuous use of chemical fertilizers adversely affects the soil health. Hence it is highly essential to apply organic sources which are easily available and feasible. Maintenance of soil organic matter is pre-requisite for maintaining soil health and crop productivity. Properly managed organic farming reduces or eliminates environmental pollution and helps to sustain soil productivity. Therefore, the present study was conducted to evaluate the potentially of organic farming for groundnut (*kharif*)-chickpea (*rabi*) cropping sequence in comparison to chemical fertilizers.

METHODOLOGY

A field experiment was carried out at Department of Agronomy, College of Agriculture, Junagadh Agricultural University, Junagadh (Gujarat) during summer seasons of 2012-13 to 2014-15. The soil of the experimental plot was clayey in texture and slightly alkaline in reaction (pH 7.8 and EC 0.38 dS/m) as well as low in available nitrogen (241 kg/ha), available phosphorus (23 kg/ha) and high in available potash (327 kg/ha). The experiment comprising of seven treatments viz., T_1:100% FYM, T_2: 100% castor cake, T_3: 50% FYM + 25% vermicompost + 25% castor cake, T_4: 50% FYM + 50% castor cake, T_5: 50% vermicompost + 50% castor cake, T_6: 1/3 FYM + 1/3 vermicompost + 1/3 castor cake, T_7: RDF + FYM 5 t/hawas laid out in randomised block design with three replications. The organic manures were applied on equivalent N basis (T_1 to T_6) and treatment T_7 was kept outside the organic plot. The RDF for groundnut and chickpea was 12.5-25-0 and 20-40-0 kg N-P_2O_5-K_2O/ha, respectively.The groundnut 'GG 20' and chickpea 'GG 1' were sown at 60 cm x 10 cm and 45 cm x 10 cm spacing, respectively.

RESULTS

The data presented in Table1 indicated that application of 50% FYM + 50% castor cakeand 50% FYM + 25% vermicompost + 25% castor caketo groundnut recorded higher pod and haulm yields, while that of 50% vermicompost + 50% castor cake and 100% castor caketo chickpea gave higher seed and stalk yields compared to RDF + FYM 5 t/ha. This can be ascribed to improved physical, chemical and biological properties of soil by organic manures, which increased nutrient uptake and ultimately favoured growth and development of groundnut crop. Application of 50% FYM + 50% castor cake and 50% FYM + 25% vermicompost + 25% castor cake to groundnut recorded higher net returns of Rs. 36032 and 33042/ha, while 50% vermicompost + 50% castor cake and 100% castor cake to chickpea gave higher net returns of Rs. 67373 and 63068/ha, respectively over RDF + FYM 5 t/ha(Table1). Increased yields with these treatments are directly responsible for higher net returns.Application of 50% FYM + 50% castor cake and 50% FYM + 25% vermicompost + 25% castor caketo groundnut recorded sig-

Table 1. Effect of organic farming on yield and net returns in groundnut-chickpea sequence(Pooled over three years)

Treatment	Groundnut		Chickpea		Net return (Rs/ha)	
	Pod yield (kg/ha)	Haulm yield (kg/ha)	Seed yield (kg/ha)	Stalk yield (kg/ha)	Groundnut	Chickpea
100%FYM	1379	2872	1658	2387	30260	42838
100%CC	1113	2350	2166	3155	18085	63068
50%FYM+25%VC+25%CC	1443	3087	1849	2591	33042	50410
50%FYM+50%CC	1513	3200	1798	2490	36032	48256
50%VC+50%CC	1151	2539	2269	3272	19887	67373
1/3FYM+1/3VC+1/3CC	1241	2742	2074	2905	24233	59684
100%RDF+FYM 5 t/ha	1002	2249	1587	2344	11943	37493
SEm.±	44	86	69	101		
CD (P=0.05)	126	243	195	286		

Table 2. Effect of organic farming on NPK uptake by groundnut (Pooled over three years)

Treatment	N uptake (kg/ha)		P uptake (kg/ha)		K uptake (kg/ha)	
	Pod	Haulm	Pod	Haulm	Pod	Haulm
100%FYM	43.8	51.8	3.90	5.25	7.11	15.2
100%CC	36.9	44.8	3.54	4.44	5.88	13.1
50%FYM+25%VC+25%CC	51.9	61.3	4.51	5.98	8.34	18.1
50%FYM+50%CC	54.4	64.5	4.69	6.31	9.06	20.2
50%VC+50%CC	38.2	51.7	3.47	4.77	6.33	14.5
1/3FYM+1/3VC+1/3CC	43.5	52.6	3.68	5.51	7.19	17.2
100%RDF+FYM 5 t/ha	38.2	48.3	2.60	4.69	5.77	14.1
Seems.±	1.6	2.0	0.14	0.22	0.24	0.6
CD (P=0.05)	4.7	5.5	0.41	0.63	0.68	1.7

Table 3. Effect of organic farming on NPK uptake by chickpea (Pooled over three years)

Treatment	N uptake (kg/ha)		P uptake (kg/ha)		K uptake (kg/ha)	
	Seed	Stalk	Seed	Stalk	Seed	Stalk
100%FYM	45.4	26.2	8.98	3.03	10.79	23.6
100%CC	64.3	35.7	11.99	3.43	14.96	34.3
50%FYM+25%VC+25%CC	65.3	25.5	10.57	3.14	13.46	29.0
50%FYM+50%CC	62.6	22.6	9.29	3.08	11.46	26.8
50%VC+50%CC	69.3	34.0	11.83	4.25	15.39	30.6
1/3FYM+1/3VC+1/3CC	71.4	28.2	11.41	3.36	14.37	28.8
100%RDF+FYM 5 t/ha	50.2	22.4	9.80	3.24	10.14	20.8
SEm.±	2.6	1.0	0.41	0.14	0.52	1.1
CD (P=0.05)	7.4	2.8	1.15	0.40	1.48	3.1

nificantly higher NPK uptake by groundnut (Table2). Whereas, application of 50% vermicompost + 50% castor cake and 100% castor cake removed higher NPK (Table3) compared to RDF + FYM 5 t/ha. Improved physical, chemical and biological properties of soil under these treatments might have increase nutrient availability in soil and with increased yields reflected in higher uptake of nutrients.

CONCLUSION

It can be concluded that higher yield and net return along with sustained soil health can be achieved by application of FYM 1250 kg/ha + castor cake 139 kg/ha to groundnut and vermicompost 667 kg/ha + castor cake 222 kg/ha to chickpeaon clayey soil of south Saurashtra agro-climatic zone.

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Response of sugarcane genotypes to organic cultivation practices and Economics of organic jaggery production

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The area under sugarcane hovers around 5 million ha with the production of around 300-350 MT white sugar and 6-8 MT jaggery and Khandasari to meet the domestic requirement of sweeteners and several by products (Anon., 2013).Organic and bio fertilizer sources of nutrients not only help in supplementing the nutrients to sugarcane but also maintain favorable physical, chemical and biological soil environment (Sinha *et al.*, 2014). Jaggery being an important sweetener next to crystal sugar, having good nutritive and medicinal value and is having more scope in human health. Ayurveda says it has cooling effect, diuretic refreshing, reduce throat infection, aphrodisiac and cardiac tonic. It has all the essential macro and micro nutrients including vitamin A, B, thiamine, riboflavin and folic acid (Hunsigi, 2012). It has an enormous potential in domestic market and export as the awareness on use of natural products and their health benefits are increasing. However, application of high doses of inorganic fertilizers and late N application increases the organic non-sugars, colloids, gums, and pectin and non-protein nitrogen and decreases the phosphorus content of juice, leading to dark colored poor quality jaggery. Organic manures improve the quality of jaggery due to balanced supply of all essential nutrients in right proportion and slow release throughout the cropping season. Apart from nutrient management, the qualities of jaggery are influenced by the composition of cane juice which is controlled by the genotype (Uppal *et al.*, 2005). Jaggery produced using chemicals has lower export potential due to poor quality. Use of various chemicals as juice clarificants results in presence of harmful chemicals and affects taste and storability of jaggery. On the other hand growing of sugarcane with use of organics and preparation of jaggery with the use of organic clarificants assumes importance in order to produce quality jaggery and health benefits of organic jaggery. Therefore, the present investigation was carried out with the following objectives. To study the performance of sugarcane genotypes for jaggery quality, production and economics under organic and other nutrient management practices.

METHODOLOGY

The experiment conducted at Agricultural Research Station,Sankeshawar and Mudhol on *Vertisols* under irrigated conditions. The soils were neutral in reaction; they were low in organic carbon, available N, medium in available P and high in available K. The field trail was laid out in split plot design with newly released three sugarcane genotypes (SNK-632 Co-86032 and Co 92005) during 2013-14,(CoSnk 07103 (G_1), CoSnk 05104 (G_2) and Co 92005 (G_3)) during 2014-15 at Sankeshwar and (SNK7680, SNK363, &Co 92005) during 2015-16 at Mudhol as main plot treatments and five different nutrient management practices as subplot treatments viz., N_1: 100 per cent organics through 1/3rd each of farm yard manure (FYM), Vermi-compost (VC) and green manure of sun hemp (IGM) equivalent to recommended dose of nitrogen (RDN). N_2: 100% organics through 1/3rd each of FYM, VC and enriched press mud (EPM) equivalent to RDN.N_3: 100% organics through 1/4th each of FYM, VC, IGM and EPM equivalent to RDN.N_4: 100% inorganic through only chemical fertilizers (250:75:190 kg of N: P_2O_5:K_2O/ha, respectively) and N_5: RPP (Recommended Practices as per package of practice consisting of fertilizers: 250: 75: 190 kg N: P_2O_5: K_2O/ha, respectively, $ZnSO_4$ and $FeSO_4$ @ 25 kg/ha each, coupled with organic manures (FYM @ 25 t/ha), and Bio-fer-

Table 1. Cane and jaggery yield, jaggery quality, Economics of sugarcane and Jaggery production as influenced by organic and inorgnaic nutrient management practices and genotypes (Mean of 2013-14 to 2015-16)

Treatment	Cane Yield (t/ha)	Jaggery Yield (t/ha)	Quality of Jaggery Net Rendament Value	Economics of Sugarcane production (000's/ha)			Economics of Jaggery production (000'Rs./ha)		
				Gross Returns ('000/ha)	Net Returns ('000/ha)	B:C ratio	Gross Returns ('000/ha)	Net Returns ('000/ha)	B:C ratio
Variety									
V1	127.8	16.25	56.52	346.0	215	2.65	602	354	2.39
V2	151.4	15.59	49.70	372.3	239	2.80	579	320	2.22
V3	129.8	14.83	52.55	332.9	203	2.56	551	309	2.22
SEm±	0.84	0.21	0.85	2.10	1.89	0.01	8.5	8.0	0.03
CD (P=0.05)	3.30	0.81	2.56	8.26	7.43	0.05	33.5	31.4	0.12
Nutrient management									
100 % organics equivalent to RDN through FYM+VC+IGM (1/3rd each)	140.7	15.51	56.7	352	213	2.50	639	382	2.44
100 % organics equivalent to RDN through FYM+VC+EPM (1/3rd each)	141.4	15.88	56.9	353	211	2.47	654	392	2.47
100 % organics equivalent to RDN through FYM+VC+IGM+ EPM (1/4th each)	138.1	15.29	56.1	345	206	2.45	630	374	2.43
100 % inorganics,	133.1	14.86	53.8	333	225	3.08	460	240	2.07
Recommended package of practices (RPP)	147.5	16.26	55.8	369	240	2.85	503	250	1.97
SEm±	1.60	0.26	0.56	3.9	3.5	0.02	10.1	8.8	0.03
CD (P=0.05)	4.5	0.77	1.62	11.4	10.2	0.07	29.5	25.6	0.09
Interaction	Sig	NS	NS	NS	NS	NS	NS	NS	NS

tilizers: *Azospirillum* and Phosphorus solubilizing bacteria (PSB) @ 10 kg/ha. All the organic sources were applied to plant crop in two splits @ 50 per cent as basal dose and remaining 50 per cent as top dress at 14th weeks after planting. The fertilizer nutrients were applied as per recommendation. Sugarcane Sets were treated with Trichoderma @ 5 g/l and Beejamruth in 100% organic treatments (N_1 to N_3). However, for 100% inorganic and RPP treatments chemical sett treatment was done for 10 minutes with Carbendizem @ 1 g/l and chloropyriphos @ 2 ml/l. *Azospirillum* and Phosphorus solubilizing bacteria @ 10 kg/ha were applied along with the organic manures at the time of organic manures application to fully organic treatments (N_1, N_2 and N_3) and RPP (N_5). Liquid organic manures like Jeevamruth was applied @ 500 l/ha along with irrigation water at bimonthly interval up to 240 DAP and Panchagavya was applied as foliar spray @ 3% at 60 and 90 DAP to all the organic treatments ($N_{1,}$ N_2 and N_3). Jaggery produced with modern hygienic stainless steel unit established at jaggery Park, ARS, Sankeshwar and Mudhol.

RESULTS

The results revealed that, the newly released sugarcane genotypes like CoSnk 632 during 2013-14, CoSnk 05104 (SNK 814) during 2014-15 and CoSnk 7680 during 2015-16 recorded higher cane yield (156, 136 and 168 t/ha, respectively) than Co-92005 (check). CoSnk 07103 recorded higher jaggery recovery and yield than G2 and G3. While, jaggery quality parameters measured through net rendament value by using non-reducing (76.8%) and reducing sugars (11.89%) were better with CoSnk632, Co92005 and CoSNK 7680 during 2013-14, 2014-15 and 2015-16, respectively than other genotypes. Among the nutrient management practices (NMPs), RPP recorded higher cane yield (147.5 t/ha)and jaggery yield (16.26 t/ha) than other NMPs. Among the organic treatments 100% organics through 1/3rd each of FYM, VC, EPM or equivalent to 100% organics through 1/3rd each of FYM, VC, and green manuring equivalent to RDN recorded higher cane yield, sugar and jaggery yield with better quality jaggery than other treatments. RPP recorded higher gross and net returns than other treatments. The economical returns with organic jaggery production were higher with 100% organics through 1/3rd each of FYM, VC, and green manuring equivalent to RDN than other treatments due to premium price fetched to organic jaggery than conventional chemically processed jaggery.

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Organic farming in green gram and sesame crop rotation under rainfed condition of north Gujarat region

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A field experiment was conducted during *kharif*-2007 to *kharif*-2015 at the experimental farm of AICRP for Dryland Agriculture, Centre for Natural Resources Management, S. D. Agricultural University, Sardarkrushinagar having semi-arid and sub-tropical climate. The experimental site is characterized by low and erratic rainfall occurring at different stages of crop growth. In the years 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014 and 2015 annual rainfall (mm) of 670, 580, 391.6, 1191.2, 915.3, 628.2, 1084, 622.9 and 931.2 was received, respectively. The soil was loamy sand in texture having high infiltration rate (15.2 cm/hour), poor maximum water holding capacity (20.65%) and also low in organic carbon (0.16, 0.13%), available nitrogen (135.6, 167 kg/ha), medium in available phosphorus (45.8, 46.8 kg/ha) and potash (212, 209 kg/ha) from 0-15 cm depth for the crops of green gram and sesame, respectively. The soil was neutral in reaction (pH 7.2-7.7). The experiment was established in randomized block design with six replications, comprising of four treatments viz., T_1: Control (No fertilizer), T_2: RDF through chemical fertilizer, T_3: RDN through F.Y.M. and T_4: RDN through vermicompost. Recommended doses of fertilizers (N, P_2O_5, K_2O kg/ha) in green gram and sesame were applied at the rate of 25-50-00 and 50-25-00, respectively. The results indicated that the seed yield of green gram and sesame were significantly influenced due to different treatments. Among the treatments, recommended dose of nitrogen applied through vermicompost recorded significantly higher green gram (582 kg/ha) and sesame (329 kg/ha) seed yields as well as net income of green gram (Rs.27992/ha) and sesame (Rs.32970/ha) along with sustained soil fertility status followed by RDN through FYM and RDF through chemical fertilizer than control (No fertilizer).

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Effect of organic liquid formulation on growth and yieldof rice (*Oryza sativa* L.) as influenced by crop geometry in Satna District of Madhya Pradesh

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Theapplication of biological and organic manures not only supply a balanced amount of micronutrients but also improve the physico-chemical and biological properties of soil (Abraham and Lal, 2002). Therefore, the use of organic liquid formulation of bio-products can confer significant economic advantage and service to rural areas. According to Gautam *et al*., 2008, proper planting geometry have more advantages such as, maximize light utilization efficiency, improves aeration within crop canopy, enhances soil respiration and provides better weed control thereby higher crop yields. Agronomic management is the most important input for getting potential yield and better quality of any crop. Therefore, the present study was undertaken to find out the effect of different agronomic management practices on growth and yield attributes of rice on the farmers' fields with the following objectives: To find out the effect organic liquidformulation, crop geometryon growth and yield of rice.

METHODOLOGY

The field experiment was carried out as an On Farm Adaptive Research during *kharif* season 2013 in Satna district of Madhya Pradesh in 9 villages. The experiment was laid out in randomized block design with 3 treatments and 9 replications. Different treatments of transplanted rice were T_1 (*Matka khad*+ 20 cm x 20 cm), T_2 (neem and tobacco extract + 20 cm x 20 cm) and T_3 (20 cm x 15 cm + inorganic fertilizers). The treatment T_1 *Matka khad* was prepared with [2 kg neem (*Azadirachta indica*) leaves + 2 kg akaua (*Calotropis gigantea*) + 1 litre cow urine + 2 kg cow dung + 250 g jaggery]. *Matka khad* 5% was prepared by adding 500 ml prepared and filtered solution in 10 litres of water, and applied as foliar spray 3 times at fortnightly intervals. Treatment T_2 (neem and tobacco extract)[1 kg neem (*Azadirachta indica*) leaves and 1 kg tobacco (*Nicotiana tabacum*) leaves. Further, the same procedure of preparation and application was followed as in T_1. Treatment T_3 inorganic fertilizers, conventional practice (*i.e*., 108.69 kg DAP/ha and 175.00 kg urea/ ha). FYM 10 t/ha was applied 7 days before transplanting in all the treatments.

RESULTS

The number of tillers/hill in T_1 (17.89/hill) was significantly higher over T_3 (13.28/hill) which is 34.71% higher in value. However, T_2 (17.06/hill)found statistically at par with T_1 (Table 1). Further, T_2 recorded significant and 28.46%

Table 1. Effect of organic liquid formulation on growth and yield of rice as influenced by crop geometry

Treatment	90 DAT	Yield attributes			
	Tillers/hill at 90 DAT	Number of grains/panicle	Test weight(g)	Grain Yield (t/ha)	Straw Yield (t/ha)
T_1	17.89	133.81	24.83	6.93	15.11
T_2	17.06	136.67	24.99	7.78	17.06
T_3	13.28	125.7	24.27	6.69	12.86
F-Test	S	NS	S	S	S
CD(P=0.05)	3.46	-	0.48	0.07	0.19

T_1: Matka khad solution+20 cm x 20 cm spacing, T_2: Neem + tobacco extract+20 cm x 20 cm spacing,$T_{3: DAP}$ and urea + 20 cm x 15 cm spacing

higher in number of tillers/hill over T_3 (13.28/hill).Highest number of grains/panicle was recorded in T_2 (136.67/panicle) followed by T_1 (133.81/panicle)and T_3 (125.70/panicle). The difference in grains/panicle in T_2 and T_1 transplanted may be due to the treatment source applied and due to plant spacing. However, grains/panicle was found to be non-significant. T_2 registered significant and 2.96% higher test weight over T_3 (20 cm × 15 cm + inorganic fertilizers, conventional practice but T_1 was statistically at par with T_2. The grain and straw yield of treatment T_2 (neem and tobacco extract + 20 cm x 20 cm)(7.78 and 17.06 t/ha)recorded significantly higher over T_1 (6.93 and 15.11 t/ha) and T_3 (6.69 and 12.86 t/ha) respectively, which is higher by 16.29 and 3.53% higher in grain and 12.90 and 32.65% straw yield. The higher value in grain yield in T_1 andT_2 may be due to the wider spacing. Adoption of wider spacing for rice transplanting may have resulted in higher grain weight than at closer spacing (Gautam *et al.*, 2008).

CONCLUSION

It may be concluded that treatment T_2 (neem + tobacco extract + 20 cm × 20 cm spacing) and T_1 (*Matka khaad* + 20 cm × 20 cm spacing) were regarded best in growth, yield attributes and dry matter production. The organic liquid formulations possess better soil health and productivity, which is feasible and acceptable.

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Influence of selected organic manures on soil health of western Himalaya vegetable production system

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ABSTRACT

A field study from 2009–2013 was carried out to investigate the effect of organic manure including panchagvya and biodynamic spray on commonly used tomato-coriander-pea and cauliflower-cauliflower-pea cropping system in Western Himalaya. The results revealed that tomato-coriander-pea cropping system recorded higher values for organic carbon, carbon biomass, and soil microorganisms like bacteria, fungi, actinomycetes and activity of phosphatase enzyme, yield and profit as compared to cauliflower-cauliflower-pea system. The application of farmyard manure followed by biodynamic and panchagavaya spray observed maximum increase in soil OC,

soil carbon, bacteria, fungi, actinomycetes, phosphatase, yield and profit.

Growing awareness of health and environmental issues in agriculture has demanded production of organic food, which is emerging as an attractive source of rural income generation. The addition of organic nutrients to soil could be a promising technology for mitigating ill effects of chemicals and reducing the usage of synthetic fertilizers (Karthigeyanm and Alagesan, 2011). Therefore, this study was carried out to assess the effect of Panchagavya and Biodynamic preparation-501as liquid organic manure along with enriched farmyard manure and vermicompost on the yield and soil properties of two commonly used vegetable production systems in Western Himalaya. *R*

MATERIALS AND METHODS

A long term field experiment was conducted from 2009 – 2013 at the experimental farm of the Himachal Pradesh Agricultural University, Hill Agricultural Research and Extension Centre near Kullu-Manali, India (31.8^{O}N latitude, 77^{O}E longitude at an altitude of 1090m above sea level, where annual rainfall varies from 1000-1200 mm). Two cropping systems namely Tomato (*Lycopersicon esculentum* var. commune)-coriander (Coriandrum sativum L.) -pea (Pisum sativum var. arvense) and cauliflower (Brassica oleracea var. brotytis) – cauliflower (Brassica oleracea var. brotytis)-pea (Pisum sativum var. arvense)] and five nutrient sources viz. rock phosphate enriched FYM + vermicompost (1:1); farmyard manure + BD 501 spray; rock phosphate enriched FYM + vermicompost (1:1) + panchagvya spray; farmyard manure + BD 501 spray + panchagavya spray and control were evaluated in a split plot design with three replications. Crops were transplanted/ sown in a fixed plot of 54 m^2 following recommended package of practices. The bio-pesticides (Trichoderma viride & Pseudomonas fluorescence) and bio-insecticide (Azardarachtin @ 0.15% EC) were used for plant protection purposes. Panchagavya, an organic formulation was used for spraying on crops at 15 days interval starting just after appearance of flowering. Biodynamic 501 was sprayed @ 2.5 g/ 40 L of water as per bio dynamic calendar on a moon opposite Saturn day. Composite soil samples (0-15 cm) collected after every crop cycle were analyzed as per standard procedures for soil some properties. The pooled data for 9 years was subjected to ANOVA for a split plot design and means were compared using significant difference at 5% probability using CPCS-1 data analysis package.

RESULTS AND DISCUSSION

The soil chemical properties like OC, N, P, K were significantly influenced due to cropping systems and organic amendments, however, treatment effect on soil pH was non significant (Table1). Dhull *et al*. (2005) also reported similar effect of crop rotations on soil reaction. Long-term field studies suggest that enhanced crop rotation complexity produces long term increases in soil organic carbon (West and Post, 2002). The increase in available nitrogen due to organic matter application is attributable to the greater multiplication of soil microbes which mineralize organically bound N to inorganic form. The increase in available phosphorus and potassium with FYM application might be also ascribed to the reduction of phosphorus and potassium fixation (Kelley et al. 2003).

A non significant increase in availability of soil micronutrients was observed among cropping systems (Table1) due to the reason that vegetables are heavy feeder and nutrients availability might have exceeded crop removal. The soil micronutrients (Fe, Mn, Zn and Cu) were strongly influenced due organic manure treatments but their contents among different nutrient sources did not vary significantly. Sharma *et al.* (2000) attributed the increase in micronutrients in soils with addition of organics to the enhanced microbial activity and consequent release of complex organic substances (chelating agents). The population of soil bacteria, fungi, actenomycetes and enzyme activity was significantly affected due to cropping systems and nutrient sources (Table 2). Improvement in soil microbial properties might be due to cumulative effect of organic manures in increasing organic carbon content of soil

Table 1. Soil chemical properties of cropping systems under organic nutrient management

Treatment	pH	OC(%)	N	P_2O_5	K_2O	Fe	Mn	Zn	Cu
Cropping system			kg/ha	mg/kg					
Tomato- green coriander-garden pea	5.7	0.79	191.6	58.9	187.2	5.2	3.1	2.4	2.0
Cauliflower-cauliflower-pea	5.7	0.84	177.0	56.3	172.2	5.1	3.2	2.4	2.0
CD (P = 0.05)	NS	0.01	0.34	0.48	0.46	NS	NS	NS	NS
Nutrient Source									
rock phosphate enriched FYM+vermicompost (1:1)	5.7	0.95	199.7	70.1	202.8	6.2	3.4	2.9	2.5
FYM followed by biodynamic spray	5.8	0.91	191.8	65.4	193.2	5.7	3.5	2.7	2.4
NS_1 followed by Panchagavya spray	5.7	0.92	208.8	63.4	191.1	5.5	3.4	2.5	2.4
NS_2 followed by Panchagavya spray	5.7	0.97	219.9	69.9	200.8	6.0	3.8	2.9	2.6
Control	5.6	0.56	133.8	32.5	135.4	3.4	1.9	1.0	0.9
CD (P = 0.05)	NS	0.04	8.9	3.5	5.9	0.13	0.20	0.12	0.09

Table 2. Soil chemical properties of cropping systems under organic nutrient management

Treatment	Carbon biomass (μ g/ soil)	Bacteria (10^6 cfu g/ soil)	Fungi (10^5 cfu g/soil);	Actinomycetes	Phosphatase enzyme(μg p-nitrophenol g/ soil)
Cropping system					
Tomato- green coriander-garden pea	27.9	7.6	5.4	8.3	15.3
Cauliflower-cauliflower-pea	13.4	6.2	4.4	6.3	12.7
CD (P = 0.05)	10.3	0.01	0.006	1.1	1.8
Nutrient Source					
rock phosphate enriched FYM+vermicompost (1:1)	23.4	7.9	4.6	6.4	12.3
FYM followed by biodynamic spray	27.0	8.2	4.7	6.4	13.1
NS_1 followed by Panchagavya spray	24.9	8.0	4.3	6.0	13.4
NS_2 followed by Panchagavya spray	36.6	9.3	5.4	6.9	14.8
Control	3.37	6.0	3.4	5.3	9.6
CD (P = 0.05)	4.7	0.002	0.003	0.004	0.010

which acted as carbon and energy source for microbes and fermented organics in quick build up of micro flora and fauna (Chauhan *et al*., 2011).

CONCLUSION

The results indicated that soil health could be improved in organic vegetable production systems using combination of organic manure and spray of biodynamic 501 and panchagavaya.

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Studies on nitrogen based organic manures on growth and yield of *rabi* frenchbean

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A field experiment was conducted during *rabi* season of 2013-14 with an objective to study the effect of nitrogen based organic manures on growth and yield of frenchbean. Amongst the treatments, application of 50% N through FYM + 50% N through vermicompost produced significantly higher values of growth parameters viz. plant height (44.8 cm), plant spread (37.1 cm), number of branches/plant (13.23), number of leaves/plant (23.33), leaf area (9.42 dm^2) and yield attributes *viz.,* number of pods/plant (13.20) and total dry matter/plant (43.67 g). The same treatment also resulted in significant increase in seed (2.78 t /ha) and straw yields (5.27 t /ha) than other treatments. The maximum net monetary returns (Rs. 86,919 /ha) and benefit cost ratio (1.81) was obtained higher with the application of 50% N through FYM + 50% N through vermicompost and it was closely followed by 75% N through FYM + 25% N through vermicompost and 50% N through FYM + 50% N through poultry manure. Thus, the results of the present investigation suggested that frenchbean grown during *rabi* season on clay loam soil should be applied either 50% N through FYM + 50% N through vermicompost or 50% N through FYM + 50% N through poultry manure or 75% N through FYM + 25% N through vermicompost for higher productivity and profitability.

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Productivity of summer groundnut under organic farming

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Over reliance on chemical pesticides and fertilizers have deteriorated the environment by polluting soil, water, air as well as agricultural products and posed a serious threat to the natural balance between producers and consumers, pests and their natural enemies and survival of pollinators and other non target animals and created several health related problems in human being. Therefore, to restore soil fertility, conserve biodiversity and increase crop productivity and maintain natural balance it is necessary to adopt organic farming. The information on organic farming is meager. Therefore, considering these facts the present experiment was undertaken.

METHODOLOGY

A field experiment was conducted in summer 2014 at Agronomy Instructional Farm, Chimanbhai Patel College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar. The experiment was laid out in randomized block design with ten replications (quadrate) on loamy sand soil. The soil was low in organic carbon and available nitrogen, medium in available phosphorus and high in available potash. The size of the quadrate is 5.0 m x 4.5 m (gross plot). The treatments consisting of three different modules are as under *organic Farming Module I (OFM I):* i. Soil application of 25 kg N/ha through vermicompost + *Tricoderma viride* 1.5 kg/ha. ii. Seed treatment with phosphate solubilizing bacteria 0.750 kg/ha iii. Application of *rhizobium* 0.75 kg/ha as seed treatment. iv. Planting of marigold interspersing. V. install 50 bird perches and 8 pheromone traps/ha. vi. Spray neem based product 30 ml/10 lit of water when *H. armigera* larval population exceeds 5 larvae per m row length. vii. Spray SNPV at the rate of 250 LE/ha in 500 l. water. *Organic Farming Module II (OFM II):* i. Soil application of 25 kg N/ha through farmyard manure (FYM) + *Tricoderma harzianum* at the rate of 1.5 kg/ha. ii. Seed treatment with PSB @ 0.75 kg/ha [iii]. Application of *rhizobium* at the rate of 0.75 kg/ha [as] seed treatment. iv. Planting of castor on the border of the plot. V. install 50 bird perches and 8 pheromone traps/ha. vi. Spraying of HaNPV at the rate of 450 LE/ha in 500 lit water. vii. Spray Spinosad at the rate of 75 g a.i. /ha when *Helicoverpa* population exceeds 5 larvae per m row length. *Chemical Input Module (CIM):* i. Seed treatment with carboxin + thiram at the rate of 3 g/kg seed ii. Application of 25 kg N + 50 kg P_2O_5/ha in the form of chemical fertilizers. iii. Seed treatment with Ecalux at the rate of 25 ml/ kg seed IV. Spray prophenophos 50% EC at the rate of 0.05 % when *Helicoverpa* / *spodoptera* population exceed 5 larvae per meter row length. V. spray mencozeb + carbandazim at the rate of 0.2 %, if incidence of early and late leaf spot is observed.

Groundnut (cv. GG 2) was sown on 23rd Feb, 2014 and harvested on 20th June, 2014. Total 13 irrigations were given to summer groundnut.

RESULTS

Among the different growth and yield attributes, plant height, plant spread, number of filled and unfilled pods, weight of filled pods and unfilled /plant and test weight were found significantly higher under OFM-II module as compared to CIM module but remained at par with OFM I module. However, chemical input module (CIM) recorded signifi-

Table 1. Effect of different modules on growth, yield attributes and yield of summer groundnut

Treatment	Plant height (cm)	Plant spread (cm)	No. of branches per plant	No. of pods per plant		Weight of pods per plant (g)		Test weight (g)	Yield (kg/ha)	
				Filled	Unfilled	Filled	Unfilled		Pod	Haulm
OFM-I	34.5	40.5	4.1	24.3	2.2	23.12	0.64	44.05	1733	4116
OFM-II	36.5	42.8	4.4	25.1	1.6	23.58	0.28	45.37	1839	4247
CIM	28.8	37.1	4.0	16.2	2.4	14.60	0.68	41.19	1276	3342
CD (P=0.05)	3.9	3.7	NS	2.3	0.22	2.27	0.11	3.01	205	461

cantly minimum value of all growth as well as yield attributes. Whereas number of branches per plant and shelling percentage were found non-significant. Organic farming module II (OFM-II) showed outstanding performance with respect to pod as well as haulm yield of summer groundnut than chemical input module and OFM I (Table 1). On the contrary, Maligawad *et al*. (2007) also reported that with recommended dose of fertilizer in *kharif* groundnut gave higher pod yield.

CONCLUSION

It is concluded that organic farming module II (OFM II) excel with respect to all growth and yield attributes except number of branches per plant and shelling percentage. It also produced maximum pod and haulm yield of summer groundnut.

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Improving crop nutrition with fungal network of *Arbuscular mycorrhiza*

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The term *mycorrhiza* was coined by the Albert Bernhard Frank, a German mycologist in 1885. The word*mycorrhiza* comes from two Greek words, *myco* (means fungus) and *rhiza* (means root); therefore, *mycorrhiza* literally means “fungus root”. Out of the six*mycorrhizae*(*Arbuscular, Ecto, Arbutiod, Monotropoid, Ericiod, Orchidaceous*) the *Arbuscular mycorrhiza* (AM)and *ectomycorrhiza*are most common and widespread (Garg and Chandel 2010).Their hyphal network forms tree-shaped subcellular structures within roots called *arbuscules* (from the Latin ‘*arbusculum*’, meaning bush or little tree) are specialized for nutrient and water uptake.These *arbuscules* are main site of nutrient exchange between the fungal and plant.The AM fungi belong to the phylum *Glomeromycota.*Being the obligate biotrophs theyform the symbiotic relationship with plant roots of over 80 % vascular plants in a manner similar to that of root nodule bacteria in legumes.However, the kind of symbiosis is completely absent in families*Chenopodiaceae* and *Brassicaceae*due to the presence of certain anti-fungal compounds in their root exudates. The successful AM symbiosis with plant roots involves two signaling molecules. Host plant roots exudate plant hormone *strigolactones* which stimulate the spore germination fungal metabolism and the branching. In return fungi releases “Myc factor” (as of Nod factor in legumes), that trigger symbiotic root responses of the host plant (Parniske 2008). The fungal hyphae extend out several centimeters from the roots into the soil and widen physical exploration of the soil as compared to the sole roots. The resultant is the amplification in theabsorption of nutrients with poor diffusivity and present at low concentrations in soil solution especially phosphorous and micronutrients such as iron and zinc. The improvement of phosphorus nutrition in the plants has been most recognized and well established beneficial effect of AM.The release ofcertain organic acids, enzymes like acid phosphates by AM also helps in increasing the nutrient uptake. G*lomalin*released by the AM fungi binds the soil particles,there by improves the soil aggregation and consequently provide better stability and soil structure. In contrast, upto 20 % of the plant photosynthates are estimated to be consumed by the AM for its growth and development (Javaid 2009).AM is an integral and important component of organic farming systems and othersustainable agricultural systems which mainly rely on biological processes, rather than agrochemicals to supply nutrients. The escalating cost of chemical inputs, degrading soil health and soil microbial biomass has made us to search of certain viable alternatives and AM fungi has emerge as a hope for more sustainable andenvironmentally acceptable alternative to the inorganic fertilizers. AM fungiwill therefore have a key role to play in the health and productivity of lowinputagricultural systems.

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Effect of organic sources of nutrient management of buckwheat (*Fagopyrum esculentum*)

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The experiment was conducted during the years of 2012 and 2013 at the Instructional Farm of Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar on sandy loam soil under sub-tropical par-humid to tropical humid climate of *terai* region of West Bengal, with the following treatments combinations: Composition of organic and inorganic sources of nutrients on performance of buckwheat (*Fagopyrum esculentum* Moench) T_1 = Control, T_2 = RDF (40:20:20), T_3 = Vermicompost @ 2.5 t/ha, T_4 = Vermicompost @ 5 t/ha, T_5 = Mustard Cake @ 2.5 t/ha, T_6= Mustard Cake @ 5 t/ha, T_7 = Poultry Manure @ 2.5 t/ha, T_8 = Poultry Manure @ 5 t/ha, T_9 = F.Y.M @ 8 t/ha, T_{10} = RDF +FYM @ 4 t/ha, T_{11} = Vermi Compost @ 2.5 t/ha + Mustard Cake @ 2.5 t/ha, T_{12} = Vermicompost @ 2.5 t/ha + Mustard Cake @ 5 t/ha, T_{13} = Vermicompost @ 2.5 t/ha + F.Y.M @ 4 t/ha and T_{14} = Vermicompost @ 2.5 t/ha + Mustard Cake @ 2.5 t/ha + Poultry Manure @ 2.5 t/ha + F.Y.M @ 4 t/ha. The field experiment was laid out in RBD (Randomized Block design) with three replications. The findings have been summarized here under. Treatment receiving organic sources of nitrogen significantly influenced the height of plant; leaf area index (LAI), the yield components of buck wheat were significantly differs with the combine sources organics than the sole application of organic over control treatment. The highest number of cluster/plant, number of seeds/cluster and 1000-seed weight (test weight) were maximum at T_{14} followed by T_{12}, T_8 & T_6 which were statistically at par. The lowest values of yield components were registered under T_1. The yield (seed and stem) of buck wheat was significantly influenced by the different treatments during both the years. A highest pooled seed yield of 1710 kg/ha in buck wheat.

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Effect of organic manures on yield and yield attributes of cowpea (*Vignaunguiculata* (L.) Walp) under middle Gujarat condition

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Cowpea is more cosmopolite and grown in most of the regions of India which showed very encouraging results and promises to have a far-reaching significant in achieving a breakthrough in the pulse production. Although, chemical fertilizers are playing a crucial role to meet the nutrient requirement of the crop, persistent nutrient depletion is posing a greater threat to sustainable agriculture. Therefore, there is an urgent need to reduce the usage of chemical fertilizers and inturn increase the usage of organics.Organic manures *viz*., FYM, vermicompost, poultry manure and oilcakes help in the improvement of soil structure, aeration and water holding capacity of soil. Further, it stimulates the activity of microorganisms that makes the plant to get the macro and micro-nutrients through enhanced biological processes, increase nutrient solubility, alter soil salinity, sodicity and pH. (Alabadan *et al*., 2009).

METHODOLOGY

A field experiment was conduct during summer season of 2013 at BTRS, AAU, Anand. Experiment was performed using RBD with 9 treatments *viz.* T_1-Control, T_2- RDF (20-40-0 NPK kg/ha), T_3-FYM (2.5 t/ha), T_4-Vermicompost (1 t/ha), T_5- Vermicompost (2 t/ha), T_6- Poultry manure (1 t/ha), T_7-Poultry manure (2 t/ha) with four replications. Yellow mosaic virus resistant cowpea variety "Anand Vegetable Cowpea" (AVC-1) was used as a test crop.Significance of difference between means for different factors was tested through 'F' test and least significant differences were calculated whenever variance ratio was found significant at five percent level for treatment effect.

RESULTS

Application of RDF (20-40-0 NPK kg/ha) recorded significantly higher number of pods/plantand number of seeds/pod,More number of pods, the highest green pod yield and stover yield might be mainly due to more survival of flower under high supply of photosynthates with the application of RDF(20-40-0 NPK kg/ha) as compared to other organic sources. Among various manures and their levels application of vermicompost @ 2 ton/ha was found superior over rest treatments and at par with RDF. In RDF and vermicompost treatments greater root extension under phosphorus application might have helped in greater uptake of nutrients which ultimately improved the yield attributing characters. Furthermore, higher photosynthates produced under treatment, RDF (20-40-0 NPK kg/ha) and vermicompost @ 2 ton/ha due to

Table 1. Effect of organic manures on yield and yield attributes of cowpea

Treatment	Number of pods/plant	Pod length (cm)	No of seeds/pod	Green pod yield (kg/ha)	Stover yield (kg/ha)
T_1	62.33	12.25	10.52	4525	5297
T_2	79.60	13.22	13.45	6738	6860
T_3	70.95	12.92	12.42	5877	6202
T_4	69.42	12.95	12.15	5511	5762
T_5	77.09	13.40	13.00	6265	6748
T_6	67.75	13.32	12.52	5538	5462
T_7	78.07	12.42	12.95	5881	5708
T_8	72.00	13.27	12.70	5120	5555
T_9	70.67	12.90	12.82	5608	5419
SEm ±	3.55	0.29	0.43	321.97	328.53
C.D. (P=0.05)	10.37	NS	1.27	939.79	958.92

better nitrogen and phosphorus availability, better translocation within plants and favourable sink source ratio of photosynthates.

CONCLUSION

To achieve higher yield of summer cowpea variety AVC-1 application of RDF (20-40-0 kg NPK/ha) or Vermicompost 2 t/ha or FYM 2.5 t/hawas found equally effective under middle Gujarat conditions.

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Organic tuber production is safe and sustainable: Overview of a decade research

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The growing demand for safe foods and concerns regarding environmental degradation and human health, has resulted in a rapid expansion of alternative environmentally friendly agricultural strategies like organic farming. Tropical tuber crops viz., cassava, elephant foot yam, taro, tannia, yams (*Dioscorea* spp.) etc., are climate smart crops that serve as food security crops for about 500 million of the global population. These are high energy tuberous vegetables with good taste and medicinal values. As these crops respond well to organic manures there is ample scope for organic production as as well as for export. The objectives were to compare yield, quality, economics as well as soil physico-chemical and biological properties under organic vs conventional management in these crops based on more than a decade experimentation both on-station and on-farm.

METHODOLOGY

Seven separate field experiments were conducted at the ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, India, for more than a decade (2004-2016) to compare organic vs conventional farming in cassava, elephant foot yam, taro, yams and Chinese potato in an acid Ultisol (pH: 4.3-5.0). In cassava, the experiment was laid out in split plot design with three varieties, H-165 (industrial variety), Sree Vijaya and Vellayani Hraswa (domestic varieties) in main plots and five production systems, traditional, conventional, integrated and two types of organic in sub plots. The impact of conventional, traditional, organic and biofertilizer farming was evaluated in RBD in elephant foot yam. Comparative response of five varieties of elephant foot yam (Gajendra, Sree Padma, Sree Athira and two locals) under organic and conventional farming was also evaluated in another experiment. Like wise, the response of three varieties of taro (Sree Kiran, Sree Rashmi and local) to the various production systems was studied. All the three trailing genotypes of edible *Dioscorea* (white yam: *D. rotundata* (var. Sree Priya), greater yam: *D. alata* (var. Sree Keerthi) and lesser yam: *D. esculenta* (var. Sree Latha)) were evaluated under conventional, traditional and organic systems in split plot design. The dwarf genotype of white yam (var. Sree Dhanya) as well as Chinese potato (var. Sree Dhara) were also evaluated in two separate experiments under conventional, traditional, organic and integrated systems in RBD. The on-station developed organic farming technologies for cassava, elephant foot yam, yams and taro were on-farm validated. Varietal response, tuber yield, economics, tuber quality, soil physico-chemical and biological properties were evaluated.

RESULTS

The industrial as well as domestic varieties of cassava, the elite and local varieties of elephant foot yam and taro and all the three species of *Dioscorea* responded similarly to both the systems. However, the industrial variety of cassava, Gajendra variety of elephant foot yam and all the species of *Dioscorea* yielded more under organic farming. Organic farming resulted in 10-20% higher yield in cassava, elephant foot yam, white yam, greater yam, lesser yam, dwarf white yam and Chinese potato ie., 8, 20, 9, 11, 7%, 9 and 10.5% respectively (Fig. 1). Taro preferred chemical farming as slight yield reduction was noticed under organic farming (5%). This was because taro leaf blight could not be controlled by organic measures. Cost-benefit analysis indicated that the net profit under organic farming was 20-40% higher over chemical farming in these crops (Suja *et al*., 2016).

In general, the tuber quality was improved in these crops under organic management with higher dry matter, starch, crude protein, K, Ca and Mg contents. The anti-nutritional factors, oxalate content in elephant foot yam and cyanogenic glucoside content in cassava were lowered by 21 and 12.4% respectively under organic farming (Suja, 2013; Suja *et al*., 2014). The water holding capacity was significantly higher under organic management in elephant foot yam (14 g/cm^3) and yams and higher in taro over conventional practice (11-12 g/cm^3). There was significant improvement in pH in organic farming (1.0, 0.77, 0.46, 1.20 and 0.65 unit increase over conventional system) in cassava, elephant foot yam, yams, taro and Chinese potato. The SOM increased by 10-20% in organic plots over conventional plots in these crops. In elephant foot yam, exchangeable Mg, available Cu, Mn and Fe contents were significantly higher in organic plots. Organic plots showed significantly higher available K (by 34%) in yams and available P in taro. The population of bacteria was considerably higher in organic plots than in conventional plots; 41% and 23% higher in elephant foot yam and yams respectively. Organic farming also favoured the fungal population by 17-20%. While the N fixers showed an upper hand in organically managed soils by 10% over conventional management under elephant foot yam, P solubilizers remained more conspicuous under organic management of yams (22% higher than conventional management). The count of actinomycetes was favoured by 13.5% in taro. The dehydrogenase enzyme activity was higher by 23% and 14% in organic plots in elephant foot yam and yams (Suja *et al*., 2015). Use of organically produced seed materials, seed treatment in cow-dung, neem cake, bio-inoculant slurry**,** farmyard manure incubated with bio-inoculants, green manuring, use of neem cake, bio-fertilizers and ash formed the strategies for organic production. The organic farming package for elephant foot yam is included in the Package of Practices (POP) Recommendations for crops by Kerala Agricultural University (KAU, 2011) and for yams and taro approved for including in POP Crops (2015) of KAU.

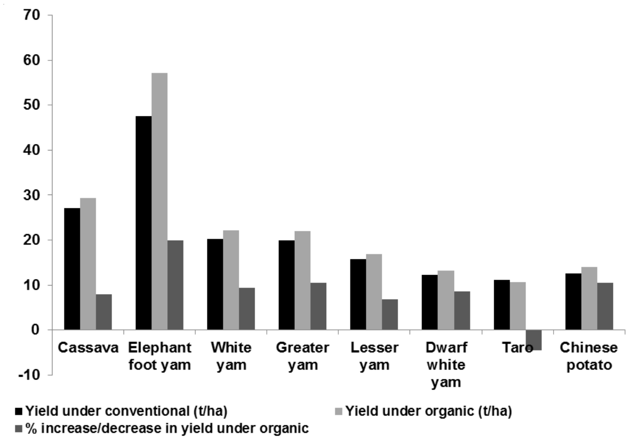

Fig. 1. Organic vs conventional farming in tuber crops: tuber yield

CONCLUSION

A decade of research in tuber crops indicated that organic farming is an eco-friendly strategy that enables 10-20% higher yield, quality tubers and maintenance of soil health.

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Vermi technologies effect on performance of soybean (*Glycine max* (L.) Merill)

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Soybean is an important oilseed crop in India and the integrated nutrient management is key for sustaining the yield of the rainfed soybean in changing climate scenarios. In this background, a study was conducted to see the effect of vermicompost on the soybean in peninsular India.

METHODOLOGY

Experiment on integrated nutrient management for Soybean (*Glycine max* (L.) Merill) variety 'MAUS-71' was carried out at Farm Section, College of Agriculture, Latur, Vasantrao Naik Marathwada Krishi Vidhyapeeth, Parbhani, Maharashtra state during *kharif*2012-13 on clayey soil having 60 cm depth in randomized block design consisting of nine treatments (combinations of fertilizers, vermicompostand vermiwash) replicated for three times.

RESULTS

Significantly higher values for all growth characters, yield contributing characters and yield were observed due to treatment having 100% RDF + vermicompost 2.5 t/ha + vermiwash (1 :1) at 2, 5, 8,11 weeks after sowing viz. plant height (33.40 cm), branches/plant (6.17), number of leaves/plant (19.07), leaf area/plant (8.97 dm^2), dry matter/plant (21.67 g), pod yield/plant (10.17 g), number of seeds/plant (73.93) and seed yield (2689 kg/ha). This might be due to presence of several enzymes, plant nutrients, beneficial bacteria and mycorrhizae in the vermicompost and vermiwash which played significant role in increasing growth, yield attributes and ultimately yield of soybean as compared to application of chemical fertilizers alone.

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Sewage sludge (biosolid): A hope for batter soil health and it's future scope in agriculture

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The fertilizer consumption demand by the farmers is becoming a vast issue in present day agriculture with reference to Indian context. The green revolution in India has been marked with phenomenal rise in fertilizer demand by the farmer but yet nutrient supply is the major constraint in the development of Indian agriculture. The excess mining of nutrients *e.g.* removal of N, P, K and micronutrients by the crops is more than their replenishment with fertilizers. In future, the problem will aggravate, as more has to be produced due to continuously increasing population. Therefore, the application of nutrients needs to be increased to keep soil fertile and make agriculture sustainable. To sustain high yield, soil must have adequate supply of nutrients. Due to continuous intensive cultivation and the use of high yielding crop varieties with high nutrient demand, the nutrient supplying capacity of the soil is becoming a limited factor. Traditional use of chemical fertilizers in agriculture production cannot be over emphasized, but with fertilizer costs going up, these need to be supplemented or substituted with available organic waste or manures. Intensive farming generally needs large addition of organic matter to maintain fertility and enhance crop yields. Sewage sludge/biosolids are by products of municipal and industrial wastewater treatment and a rich source of organic nutrients. Sewage sludge produced from sewage treatment plant and results from removal of solids and organic matter from the sewage. Sewage sludge, being organic waste, is a good source of plant nutrients such as N, P, K, S, Ca, Mg, Fe, Cu, Mn and Zn as well as other organic constituents. These nutrients are very important for growth and development of plant, hence the sewage sludge could be a source of nutrient as supplement of fertilizer. So it's have a vast importance in context with Indian agriculture.

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Yield, economics and agronomic efficiency of organically grown groundnut as influenced by nutrient management

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The area under organic farming in India increased from 42,000 ha during 2003-04 to 10.85 m ha by 2012. Of which, oilseed crops occupy an area of 1.79 lakh ha with the production of 2.23 lakh tonnes (NCOF, 2012).The certified area under organic crops in unified Andhra Pradesh is 30,967 hectares. Groundnut is an important oil seed crop in India with 5.86 m ha and 8.26 m tonnes production. As the groundnut is an important oil seed crop in rainfed conditions, experiment was conducted to evaluate the alternate sources of organic manures on groundnut in four year old organically maintained soil.

METHODOLOGY

The experiment was laid out in a randomized block design with three replications and ten treatments. Four organic manures i.e. vermicompost, FYM, vermicompost prepared with mushroom spent substrate and vermicompost enriched with using 3% rock phosphate were tested at two levels of nutrition i.e. 100 per cent (30 kg /ha) and 75 per cent recommended dose of nitrogen (22.5 kg /ha) along with two checks i.e. control (no NPK and gypsum application @500 kg /ha at flower initiation) and absolute control (no NPK and gypsum). Nutritional composition (N-P-K %)of tested organic manures, vermicompost(1.13 - 0.67 - 1.21), FYM (0.65 - 0.4 - 0.8) vermicompost prepared with mushroom spent substrate (1.93 – 1.44 – 2.74) and (1.95 – 2.15 – 2.66). Three fourth of the organic manures were applied equivalent to 100 per cent RDN (30 kg N /ha) and 75 per cent (22.5 kg /ha) RDN basally, remaining 25 per cent at 30 DAS.

RESULTS

Number of pods/plant, Pod yield , net returns and B:C ratio of organically grown groundnut were significantly with application of 100 per cent RDN through vermicompost enriched with rock phosphate and showed increase of4.3, 8.1 and 17.5 per cent pod yield over vermicompost prepared from mushroom spent substrate, vermicompost and FYM respectively. Vermicompost prepared from mushroom spent substrate has higher Calcium (5.16 %), Magnesium (2.26 %) and sulphur (0.51 %) in addition to NPK and good microbial activity of the compost discourages phytopathogens resulting in better growth, yield attributes and pod yield of groundnut. Application of 100 per cent RDN through vermicompost produced at par pod yield as that of 75 per cent RDN through phosphorus enriched vermicompost using rock phosphate 3 per cent and in turn at par with 100 per cent RDN through FYM and 75 per cent through vermicompost and spent mushroom substrate based vermicompost. This might be due to low nitrogen and phosphorus content of FYM compared to other manures. Lowerpod yield and in turn economics was obtained with absolute control. Though higher pod yield and economics was obtained with 100 per cent N through organic ma-

Table 1. Pod yield, economics and agronomic efficiency and partial factor productivity of groundnut asinfluenced by organic nutrient management.

Treatment	Pod yield (kg /ha)	Net Returns (₹/ha)	B:C ratio
T_1- 100% RDN through vermicompost.	4043	82094	3.09
T_2- 100% RDN through farm yard manure	3624	68522	2.70
T_3- 100% RDN through vermicompost preparedfrom mushroom spent substrate.	4209	87078	3.22
T_4- 100% RDN through phosphorus enrichedvermicompost using rock phosphate 3%.	4398	92700	3.36
T_5- 75% RDN through vermicompost.	3671	72936	2.96
T_6- 75% RDN through farm yard manure.	3042	53312	2.40
T_7- 75% RDN through vermicompost preparedfrom mushroom spent substrate.	3739	74990	3.01
T_8- 75% RDN through phosphorus enriched vermi compost using rock phosphate 3%.	3921	80434	3.16
T_9- Absolute control (no NPK and gypsum)	1965	27770	1.89
T_{10}- Control (no NPK and gypsum @ 500 kg/ha at flower initiation)	2754	47930	2.38
CD (P=0.05)	425	7534	0.20

A.E = Agronomic efficiency (kg pod yield from fertilised plot- kg pod yield in control plot / kg N applied)
PFP= Partial factor productivity (Kg pod yield in treatment/ kg N applied)

nures, agronomic efficiencyand apparent N recovery (ANR) was higher with 75% RDN through phosphorus enriched vermicompost using rock phosphate 3%, whereas apparent N recovery was at par with 75% RDN(22.5 kg /ha) through vermicompost prepared from mushroom spent substrate and alsovermicompost respectively.

CONCLUSION

Application of 100 per cent RDN (30 kg N /ha) through phosphorus enriched vermicompost or spent mushroom substrate based vermicomposting resulted in higher growth parameters, yield attributes, pod yield and net returns of organic groundnut.

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Studies on organic farming vs. chemical farmingof rice in hill areas

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Hill and agency areas also not an exception for yield stagnation in rice even with increased levels of chemical fertilizers. Use of chemical inputs has increased the crop yield but caused many environmental problems including soil, air and water pollution and finally human health hazards and making the crop productivity unsustainable. At the same time organic farming is gaining momentum throughout the world including India due to the farmers movement, growing awareness among the consumers and promotion from the policy makers. Organic rice posses better nutritional quality (Saha *et al.*, 2007) and fetches higher market price. Organic farming also permits the recycling of organic wastes, disposal of which could be difficult and expensive. Repeated crop failures, decreasing marginal returns due to stagnating productivity and rising input cost, emergence of niche markets and patrons of alternate production strategies ushered the re discovery of organic production system in India. As the yield levels in organic agriculture will be less, suitable varieties that responds to organic culture, cost effective and eco friendly technologies need to be identified for sustainable production. There were sporadic evidences for influence of different combination of organic sources of nutrition and varietal response to organic

Table 1. Effect of different systems of farming and varieties on productivity and economics of rice-greengram system

System of farming/Variety	Rice grain yield (kg/ha)	Green gram yield (kg/ha)	REY of the system (kg/ha)	System Gross Returns (Rs/ha)	System Cost of cultivation (Rs/ha)	System economic efficiency (Rs/Rs)
Organic farming	3885	763	6937	90915	77625	0.17
Integrated pest & Nutrient management	5568	651	8172	109039	72850	0.50
Chemical farming	5864	598	8256	110253	69800	0.60
SEm+	168	14.2	225	2710	-	-
CD (P=0.05)	466	39	622	7512	-	-
V1 – MTU 1001	5506	624	8002	106417	70225	0.52
V2 – RGL 2538	5149	637	7699	102608	71710	0.43
V3 – BPT 5204	4519	651	7125	99031	73450	0.35
V4 – MTU 7029	5256	668	7928	105580	72213	0.46
SEm±	203	21.7	282	2390	-	-
CD (P=0.05)	427	NS	593	5019	-	-

rice culture. Hence a study was conducted to generate scientific data on combination of organic sources and varieties for organic rice in hill areas of north coastal Andhra Pradesh.

METHODOLOGY

Field experiments were conducted consecutively for two years during *kharif* and *rabi* season of 2012-13 and 2013-14 at Agricultural Research Station, Seethampeta, Andhra Pradesh, India. The soil was sandy clay loam having pH 6.9, organic carbon 0.67%, available nitrogen 249 kg/ha, available P_2O_5 29.2 kg/ha and K_2O 305 kg/ha. The trial was laid out in split plotdesign with three replications with three main plots consists of types of farming (Organic Farming, Integrated nutrient & pest management and Chemical Farming) and four varieties viz., MTU 1001, RGL2538, BPT 5204 and MTU 7029 allotted to sub plots during *kharif* and tested green gram as a residual fallow crop during *rabi*. Greengram pre germinated seed sown as fallow crop in standing rice at one week before harvest. Standard and recommended cultural and plant protection measures followed for respective package as per the treatments. Data were collected duly following standard procedure and analyzed using ANOVA and the significance was tested by Fisher's least significance difference (P= 0.05) by pooling two years data.

RESULTS

Results of the two years pooled data revealed that grain yield of rice was reduced by 33.75 and 30.23 percent in organic farming (3885 kg/ha) compared to chemical farming , integrated nutrient and pest management practices respectively. Whereas fallow greengram yield was 27.59 percent higher in organic farming over chemical farming and 17.20 percent higher compared to integrated nutrient and pest management practices showed that conspicuous residual effect of organic farming on succeeding crops compared to chemical farming and integrated nutrient and pest management practices. Therefore the yield gap between different packages was reduced when rice equalent yield (REY) of rice-greengram system was considered. Gross returns and economic efficiency of the system is markedly higher with chemical farming and integrated nutrient and pest management practices over organic farming practices. These findings are in line of Rao *et al.,*(2014) who reported organic farming less productive and not profitable compared to chemical farming as per the existing market. There was marked differences were observed among test varieties, MTU 1001 performed superiorly over rest of the varieties due to its better tolerance to pests and diseases. MTU 7029(Swarna) was the next best option in this regard. While the performance of BPT 5204 was the lowest.

CONCLUSION

Chemical farming with MTU 1001 in rice-greengram system was continued to be a productive and profitable option for hill areas of Andhra Pradesh. There was a considerable residual effect of organic farming and integrated nutrient management practices in rice on succeeding greengram.

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Development of production and protection technologies in organic rice

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Good quality rice with high nutritive value without any pesticide residues needs to be produced to meet the demand of World Trade Organization. This can be achieved under least insecticide pressure and fertilizer input through organic farming.As the area under organic farming is increasing (Suresh Reddy, 2010) there is an urgent need to develop production as well as protection technologies for organic rice and hence the present investigation was taken up.

METHODOLOGY

A field scale experiment was conducted for development of production and protection technologies in organic rice consecutively for six years from *kharif,* 2009 to *Kharif*2014 at Agricultural Research Station Ragolu with two treatments Viz., complete organic farming package as one treatment and recommended dose of fertilizers RDF(80-60-50 Kg N, P_20_5 and K_2O/ha). The soil was Sandy clay loam having available nitrogen 133 kg/ha, available $P_2O_5$19 kg/ha, $K_20$228 kg/ha and 0.43% organic carbon. During2014-15,the four different organic manures, namely FYM, vermicompost, poultry manure and green manure were also evaluated along with inorganic plot (80-60-50 Kg N, P_20_5 and K_2O/ha).

RESULTS

Results of the trial revealed that, during *kharif*2009 grain yield of 4050 kg/ha was recorded in organic farming practices plot against 6.54 t/ha with RDF. The yield gap was 38.1% between organic and inorganic treatments.Net returns also reduced by 30553 per hectare with organic treatment compared to inorganicplot. After six years in the same plot during *kharif* 2014, grain yield of 3.86 t/ha was recorded in organic farming practices against 4.39 t/ha with inorganic practices(RDF).The organic plot recorded 11.9% lesser grain yield and net returns were reduced by 3380 compared to inorganic plot.Analysis of the grain revealed that, the quality of rice grain was higher to that of inorganic rice in terms of protein, riboflavin but low in sugars. Similar increase in the grain quality parameters were also reported by Saha *et al*. (2007).The pooled data of six years showed that, grain yield of 3.76 t/ha was recorded in organic farming practices against 5.16 t/ha with inorganic practices(RDF) with yield gap of 27.17% between the two treatments. Slight build up of organic carbon (0.43 to 0.49) was observed with organic farming over six years. During 2015-16,it was found that significantly higher grain yield of 6.70kg/ha recorded with application of 120 kg N/ha either through organics or inorganic sources.

Table 1. Year wise yield obtained with organic farming practices as against inorganic practices

Year	Grain yield in organic farming plot (t/ha)	Grain yield in inorganic plot (t/ha)	% difference in grain yield
2009	4.05	6.54	38.11
2010	3.03	5.24	26.97
2011	3.50	4.85	27.84
2012	3.45	4.94	30.16
2013	3.86	5.00	22.80
2014	3.86	4.39	11.93
2015	6.45	6.70	3.78

Table 2. Nutritional analysis of rice grains

Name of the sample	Organic rice	inorganic rice
Protein(g/100g)	5.83	5.19
Riboflavin(mg/100g)	1.05	0.66
Total sugars(g/100g)	2.14	2.82
Total Bacterial Count (cfu/g)	30.00	BDL
Cooking quality		
Cooked weight (per 10gms)	40.01	40.05
Average cooked grain length(in mm)	8.20	7.60
Total cooking time (min)	38.00	35.00
Cooked grain length per 25 grains (cm)	20.50	19.00

CONCLUSION

With the present management conditions and without considering premium price of organic rice, the conventional rice production is more profitable than organic system. However, if organic rice is practiced for more than four years or if it fetches premium price, then organic system may become similar to or higher than conventional system.

Table 3. Effect of different organic farming packages and inorganic farmingpractices on performance of rice

Treatment	Tillers/m²	Productive tillers/m²	No. of filled grains/ Panicle	Grain yield (t/ha)	Benefit cost ratio	Organic carbon (%)	N(kg/ha)	P_2O_5 (kg/ha)	K_2O (kg/ha)
T1	529	351	155	5.21	0.47	0.51	177	24	258
T2	533	360	146	5.15	0.55	0.49	172	25	256
T3	560	390	11	0.32	0.50	0.56	180	27	254
T4	557	384	163	6.45	0.68	0.55	183	29	251
T5	546	357	157	5.46	0.77	0.37	155	31	263
T6	596	402	173	6.70	1.05	0.39	163	30	260
SEm±	13.95	11.23	4.65	0.170	Initial	value-0.40	133	19	228
CD (P=0.05)	42	34	14	0.511					

T_1 - Organic farming practices (Green manure incorporation + Basal application of FYM @ 10 t/ha) (N @90 kg/ha),**T_2** -Application of N @80 kg/hathrough Organic sources(GM/FYM/Neem cake),**T_3** - T_1+Basal dressing of poultry manure @ 2.5 t/ha+ Application of PSB@ 2.5kg/ha(135 kgN/ha),**T_4**-Application ofN@ 120 kg/hathrough Organic sources (GM/FYM/ PM/ Neem cake),**T_5**- Application of NPK @ 80-60-50 Kg/ha,**T_6**- Application of NPK @ 120-60-50 kg/ha

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Correlation analysis of yield components of rice under normal and aerobic conditions

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The slogan "rice is life" is most appropriate for India as this crop plays a vital role in our national food security and is a means of livelihood for millions of households. A Chinese proverb says 'most precious things are not jade and pearls but rice grains'. Grain yield is complex trait which is influenced by a number of contributing characters. The estimates of the inter relationship between grain yield and other yield attributes and among themselves would facilitate effective selection schemes to improve the yield. Keeping above points in a view, an experiment was conducted with the objective to study to undertake comparison between the natures of association among different traits and to identify better combination as selection criteria for developing high yielding rice genotypes under normal and aerobic condition.

METHODOLOGY

The experimental material for the present study comprised of twenty five genotypes of rice suitable for aerobic and normal condition procured from Rajendra Agricultural University, Pusa laid in randomized block design (RBD) with three replications at the Field Experimentation Centre of Department of Plant Breeding and Genetics, Rajendra Agricultural

University, Pusa Samastipur Bihar during *kharif,* 2014.

RESULTS

Genotypic and phenotypic correlations among various yield attributing characters under aerobic and normal conditions are presented in Table 1, 2, 3 and 4. Grain yield per plot exhibited significant positive association with plant height, panicle length, number of tillers per plant, number of spikelet's/panicle, relative water content, maximum root length, flag leaf area, harvest index, chlorophyll content and 1000 grain weight under aerobic condition. Under normal condition, grain yield per plot exhibited significant and positive correlation with days to physiological maturity. However, positive and significant with proline accumulation in leaves under aerobic and normal conditions under aerobic and normal condition, days to physiological maturity exhibited strong positive correlation with panicle length. Flag leaf area exhibited significant positive association with harvest index, chlorophyll content, Peroxidase activity and grain yield per plot under both conditions. Proline accumulation in leaves showed significant negative association with flag leaf area under both condition. Chlorophyll content showed strong positive association with relative water content, panicle length, number of spikelets per panicle; 1000 grain weight and harvest index, whereas it showed strong negative association with proline accumulation in leaves under aerobic and normal condition. Panicle length showed positive association with number of spikelets per panicle, 1000 grain weight and grain yield per plot, whereas it showed negative correlation with proline accumulation in leaves under aerobic and normal condition. Chlorophyll content showed positive correlation with peroxidase activity in leaves, whereas negative association with proline accumulation in leaves indicating that lower level of chlorophyll also plays an important role in providing tolerance under aerobic condition. Proline accumulation showed positive and significant association with number of tillers per plant, and grain yield per plot indicating proline as a major stress tolerant osmolytes. Relative water content exhibited strong negative correlation with proline accumulation in leaves under aerobic condition. Peroxidase activity in leaves showed positive correlation with number of grains per panicle under aerobic condition. Our findings regarding this enzyme showed that with increasing moisture stress, peroxidase activity decreased in tolerant genotypes, whereas increased in susceptible genotypes.

CONCLUSION

It can be concluded that correlation indicated, grain yield per plot exhibited significant and positive association with yield attributing traits under both normal and aerobic condition and the knowledge of inter relationship between yield component traits must be taken into consideration when any breeding program for higher yield in rice may facilitate breeders to decide upon the intensity and direction of selection pressure to be given on related traits for the simultaneous improvement of these traits under both the conditions.

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Use of industrial waste (Press mud) under organic farming of Kalmegh (*Andrographis paniculata* Wall. Ex Nees): A medicinal plant

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Due to continuous decrease of forest area and indiscriminate exploitation of medicinal plants from forest, simultaneously possible availability of medicinal plant from forest has shrink a lot. And in such situation, meeting the sufficient quantity with optimum quality of medicinal plants for ever growing population is a big challenge in the world. In this case, only cultivation of medicinal plants is an option. Kalmegh (*Andrographis paniculata*) is an annual herb extremely bitter in taste in all parts of the plant body. The plant is known as "king of bitters". It is used as anti-typhoid and antibiotic, for controlling the fever, worms and dysentery. It is also useful for curing the liver, digestive system and weakness problems. Andrographolide, the chief secondary metabolite of the plant is reported to inhibit the in-vitro proliferation of different tumor cell lines causing various types of cancers. Press mud is good source of plant nutrients and by-product of sugarcane industries. About 75% of total world production is mainly produced by Brazil, India and China (FAO, 2011). Due to lack of scientific knowledge, press mud still is burnt in many brick kilns, resulting the loss and wastage of millions tonnes of plant nutrients, which ultimately degrades the environment. For improving the quality of press mud, various methods have been adopted for its composting (Nasir, 2006). The objective of the experiment is to find out the optimum dose of press mud for organic cultivation of Kalmegh. Considering the above facts in view, an experiment has been conducted to study the effect of different doses of Press mud on biomass yield, nutrient uptake of Kalmegh and physico-chemical & biological properties of the soil.

METHODOLOGY

A field experiment was carried out at Banthra Research Station of the CSIR-National Botanical Research Institute, Lucknow during 2014 and 2015. The geographical position of the experimental site was $26^0$42’10"N latitude and $80^0$49’46"E longitude. The physico-chemical properties of the experimental soil were pH- 8.58, EC- 0.12 dS/m, organic carbon- 3.9 g/kg, bulk density - 1.36 Mg/m^3, particle density- 2.63 Mg/m^3, water holding capacity- 36.84 %, porosity- 48.29 %, sand- 25.15 %, silt- 58.75 %, clay- 16.10 %, soil characterized as silt loam. CEC- 21.74 (c mol/kg), Available N- 95.3 (kg/ha), Available P- 23.5 (kg/ha), Available K - 280(kg/ ha), DTPA Extractable Fe - 17.37 (mg/kg), DTPA Extractable Zn- 1.494 (mg/kg), DTPA Extractable Cu- 4.352 (mg/kg), DTPA Extractable Mn- 9.078 (mg/kg). Nutrient composition of press mud was, organic carbon- 23.7 (%), Nitrogen- 1.73 %, Phosphorus- 1.36 %, Potassium- 1.48 %, Available Fe- 14.5 mg/g, Available Zn- 9.13 mg/g, Available Cu -6.93 mg/g, Available Mn- 1.49 mg/g. Treatments of the experiment were T_1- Control, T_2- 2.5 t/ha, T_3- 5.0 t/ha, T_4- 7.5 t/ha, T_5- 10.0 t/ha, T_6- 12.5 t/ha and T_7- 15.0 t/ha with four replications in the RBD. The press mud applied before 25 days of transplanting of the Kalmegh. Common cultivation practices including nursery sowing, weed management, irrigation, harvest etc. adopted as per requirement of the crop.

RESULTS

Results indicated that increasing in doses of press mud increases the mean biomass yield from 1.14 t/ ha to 2.28 t/ha with minimum in Control (T_1) and maximum in T_7 (15.0 t/ha). However, it was significant up to 10 t /ha in the treatment T_5 showing the value of 2.24 t /ha. Further increase in doses of Press mud up to 15 t/ha did not affect the plant biomass in comparison to T_5. In case of soil microbial population, total bacteria, fungi, actinomycetes and *Azotobacter* increased with increasing doses of Press mud application up to 15 t /ha. Application of press mud provided the favourable conditions for the growth of aerobic microbes for decomposition and the nutrient mineralization. In case of soil enzymes activity like – dehydrogenase, β–glucosidase, urease, protease and acid phosphatase increased with increasing levels of organic matter. However, alkaline phosphatase decreased in the order of increasing the doses of press mud.

CONCLUSION

It is concluded from this investigation that press mud 10 t/ ha is sufficient with the biomass yield of 2.24 t/ha for the cultivation of Kalmegh. The press mud had no any toxic effect on the yield and quality of the crop.

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Effect of organic nitrogen management on yield and nutrients uptake of aromatic rice genotype

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Rice widely cultivated food crops providing meal, income and employment to millions of rural growers and consumers (Dwivedi *et al*., 2003). Aromatic rice varieties have occupied a prime position in national and international market because of their excellent quality characters. The adoption of modern farming practices and integrated nutrient management are essential to produce crops in line with the observed global standards of quantity and quality. Hence, introduction of high-yielding varieties (HYVs) with infusion of irrigation water, fertilizers and pesticides got a major fillip. Among the major nutrients, nitrogen application is essential to obtain the higher yields from high yielding nitrogen responsive rice varieties. The high cost of chemical nitrogenous fertilizer and low purchasing power of Indian farmers restricts its use on proper amounts, hampering crop production. With a view to reduce the losses and indiscriminate use to chemical fertilizers, substitution of part of the chemical fertilizers by locally available organic sources of nutrients *viz.* manures, compost, green manures, crop residues, biofertilizers etc. is inevitable. The integrated use of organic and chemical fertilizers along with biofertilizers has been reported not only to meet the nutrients needs of the crop but also has been found to sustain large-scale productivity goals. Vermicompost, being a rich source of macro and micro nutrients, vitamins, plant growth regulators and beneficial microflora, appeared to be the best organic source in maintaining soil fertility on sustainable basis towards an ecofriendly environment (Tejad and Gonzaler, 2009). To achieve food security through sustainable agriculture, the requirement for fixed nitrogen must be increasingly met by BNF rather than by industrial nitrogen fixation. Therefore present research was conducted to study the effect of organic nitrogen management on yield and nutrients uptake of aromatic rice (*Oryza sativa* L.) genotype**.**

METHODOLOGY

A field experiment was conducted during *kharif* seasons of 2010 and 2011 at Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, U.P. to study the effect of integrated nitrogen management on growth, yield and nutrients uptake of aromatic rice. The experiment was laid out in split plot design consisting 21 treatment combinations and were replicated thrice. The experiment comprised three aromatic rice genotype *viz.* Pusa Basmati-1, PRH-10 and HUR-105. assigned to main plots and seven integrated nitrogen management practices *viz.* 100% RND, 75% RND + 25% RND as FYM, 75% RND +25% RND as VC, 75% RND + 25% RND as FYM + BGA, 75% RND + 25% RND as VC + BGA, 75% RND + 25% RND as FYM + *Azospirillum* and 75% RND + 25% RND as VC + *Azospirillum,* allocated to sub plots.

RESULTS

Marked effect of integrated nitrogen management was noticed on yield attributes and yield during both the years of study. Application of 75% RND + 25% RND as VC + BGA proved significant superiority over other treatment in respect of number of panicles/m^2, panicle weight (g), number of grains/panicle, 1000-gain weight (g), grain yield (t/ha) and straw yield (t/ha) (Table 1). However, it is statistically at par with 75% RND + 25% RND as FYM + BGA during both the years of investigation. Minimum yield attributes and yield were recorded with treatment 100% RND. Harvest index did not influenced by integrated nitrogen management. Interactions between genotype × integrated nitrogen management were significant with respect to grain yield of aromatic rice. Aromatic rice hybrid PRH-10 with 75% RND + 25% RND as VC + BGA recorded higher grain yield as compared to other treatment combination. Rice hybrid PRH-10 recorded significantly higher N, P and K uptake by grain and straw over Pusa Basmati-1. Whereas HUR-10 at par with PRH-10 during both the yeas of experimentation. Incorporation of integrated nitrogen management brought about significant improvement in N, P and K uptake. Application of 75% RND + 25% RND as VC + BGA significant superior over rest of the treatment and be-

Table 1. Effect of integrated nitrogen management on yield attributes and yield of aromatic rice genotype

Treatment	Grains/panicle (No.)		1000-grain weight (g)		Grain yield (t/ha)		Straw yield (t/ha)		Harvest index (%)	
	2010	2011	2010	2010	2011	2011	2010	2011	2010	2011
Genotype										
Pusa Basmati-1	109.43	112.91	19.27	19.83	4.21	4.36	7.04	7.13	37.43	37.96
PRH-10	131.26	134.82	22.21	22.61	5.11	5.25	7.48	7.62	40.57	40.81
HUR-105	127.15	131.01	21.90	21.93	4.89	5.05	7.38	7.54	39.83	40.08
SEm±	2.61	2.67	0.28	0.32	0.05	0.06	0.08	0.09	0.36	0.38
CD (P=0.05)	10.23	10.47	1.10	1.27	0.20	0.21	0.33	0.35	1.40	1.49
Integrated nitrogen management										
100% RND	108.11	111.73	19.69	19.93	4.24	4.34	6.81	6.83	38.38	38.87
75% RND + 25% RND as FYM	116.11	118.96	20.53	21.06	4.60	4.70	7.14	7.25	39.19	39.28
75% RND + 25% RND as VC	119.12	122.90	20.79	20.79	4.69	4.84	7.25	7.35	39.24	39.64
75% RND + 25% RND as FYM + BGA	131.22	135.49	22.21	22.50	4.96	5.15	7.56	7.72	39.57	39.93
75% RND + 25% RND as VC + BGA	135.96	140.44	22.58	22.73	5.06	5.25	7.70	7.83	39.62	40.09
75% RND + 25% RND as FYM + *Azospirillum*	122.67	125.11	20.88	21.27	4.77	4.94	7.30	7.47	39.43	39.74
75% RND + 25% RND as VC + *Azospirillum*	125.11	129.12	21.39	21.83	4.82	5.01	7.35	7.55	39.52	39.77
SEm±	2.20	2.47	0.26	0.27	0.04	0.05	0.07	0.08	0.31	0.33
CD (P=0.05)	6.32	7.09	0.74	0.77	0.13	0.14	0.23	0.25	NS	NS
Interaction										
V x F					S	S				

RND = Recommended nitrogen dose, FYM = Farmyard manure, VC = Vermicompost, BGA = Blue green algae

ing at par with 75% RND + 25% RND as FYM + BGA in respect of N, P, K uptake by grain and straw. The lowest N, P and K uptake by grain and straw was observed with application of 100% RND during both the years. Genotype × integrated nitrogen management produced marked variation on N uptake by grain during both the years. Application of 75% RND + 25% RND as VC + BGA with PRH-10 recorded maximum N uptake by grain. Integrated approaches of organic inorganic and biofertilizers nutrient management have increased the N, P, K uptake by grain and straw.

CONCLUSION

Thus, it could be concluded that aromatic rice hybrid PRH-10 should be grown with the application of 75% RND + 25% RND as VC + BGA to get maximum yield and nitrogen use efficiency under agro-climatic condition of Easter Uttar Pradesh.

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Effect of different sources of organic nutrients on the performance of greengram under Nagaland condition

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North Eastern regions of India have tremendous potential for increasing the pulse production and productivity due to favourable climatic condition and therefore, its cultivation needs to be popularized. Moreover, with increase in consumer concern about issues such as food quality, environmental safety and soil conservation,there has been a substantial increase in the use of organic sources of nutrients. These nutrient requirements can be met by supplying them through organic manures such as FYM and vermicompost or through use of bio-fertilizers such as *Rhizobium* and PSB for their increased growth and development. With greengram being a high fertility crop and highly responsive to nutrient application, cultivation of such crops gives an added thrust for organic farming in the region. Therefore, considering all the above facts, the present study was conducted.

Mf green gram is around 2.5 M

METHODOLOGY

The research was carried out in the experimental farm of School and Agricultural Sciences and Rural Development (SASRD), Nagaland University, during *Kharif* season, 2014.The field was laid out in randomized block designwith seven treatments and replicated thrice.The treatments were T_1= control,T_2= FYM @ 5 t/ha, T_3= FYM @ 5 t/ha+ *Rhizobium* @ 200 g/kg seed, T_4= FYM @ 5 t/ha+ *Rhizobium* @ 200 g/kg seed + phosphotika@ 200 g/kg seed, T_5= vermicompost @ 2 t/ha, T_6= vermicompost @ 2 t/ha + *Rhizobium* @ 200 g/kg seed, T_7= vermicompost @ 2 t/ha + *Rhizobium* @ 200 g/Kg seed + phosphotika@ 200 g/kgseed. For taking the biometrical observations, five healthy plants were selected randomly from each plot excluding the border row plants and tagged to determine the various growths attributes of the plants. The growth and yield attributes were recorded from 25 DAS till pod development stage and at harvest respectively.

RESULTS

It was observed that plant heightwas found to be significantly increased with the application of vermicompost @ 2 t/ha + *Rhizobium* @ 200 g/kg seed + phosphotika@ 200 g/kg seed while the lowest plant height was observed in control.The application of vermicompost @ 2 t/ha + *Rhizobium* @ 200 g/kg seed + phosphotika@ 200 g/kg seed also recorded the highest number of leaves per branch and the lowest was recorded with FYM @ 5/t ha. Application of vermicompost @ 2 t/ha+ *Rhizobium* @ 200 g/kg seed + phosphotika@ 200 g/kg seed also recorded the highest number of branches per plant while control recorded the lowest number of branches.A similar trend was also recorded incase oftotal dry matter accumulation, LAI and crop growth

Table 1. Effect of different sources of organic nutrients on yield attributes of green gram

Treatment	Pods/ plant	Test weight (g)	Seed yield (kg/ha)	Stover yield (kg/ha)	Harvest index(%)
T_1	17.22	27.23	400	1120	26.42
T_2	17.83	28.25	430	1180	26.8
T_3	19.59	28.15	600	1570	27.69
T_4	20.29	30.85	760	1820	29.45
T_5	18.50	28.2	520	1370	27.43
T_6	19.83	28.85	670	1630	29.28
T_7	21.00	31.6	900	1980	31.22
SEm ±	0.141	0.172	0.004	0.01	0.105
CD (P=0.05)	0.435	0.53	0.013	0.03	0.325

rate.The findings were similar with the work carried out by Singh *et al*. (2004) who reported that application of bio-fertilizers had a significant effect on the growth attributes of greengram.The application of vermicompost @ 2 t/ha + *Rhizobium* @ 200 g/kg seed + phosphotika@ 200 g/kg seed (Table 1) had a significant influence on the number of pods per plant, length of pod which alsogave the highest number of seeds per pod,highest seed pod ratio, test weight, seed yield, stover yield and harvest index. Control recorded the lowest number of pods per plant, shortest pod length, test weight, seed yield,stover yield and harvest index while the treatment FYM @ 5 t/harecorded thelowest number of seeds per pod during the study.The above observation was found to be in close conformity with Tak*et al*. (2014) who reported that application of increasing levels of vermicompost from 5 to 7.5 t/ha significantly enhanced the pods per plant, pod length, grains per pod, test weight, grain yield, stover yield and harvest index of green gram.

CONCLUSION

The application of the treatment vermicompost @ 2t/ha + *Rhizobium* @ 200 g/kg seed + phosphotika@ 200 g/kg seed was found to have a significant influence on the performance of the crop, increasing the growth and yield attributes of the crop.

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Use of organic sources for nitrogen management in sesame (*Sesamum indicum*)

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Sesame is the oldest oilseed crop which contains 50% oil, 25% protein and 15% Carbohydrates. Sesame oil is used in cooking, manufacture of soaps, paints, perfumes and insecticides. In India sesame is grown in 1.67 mha with production of 0.67 mt and productivity of 405 kg seeds/ha (IIOR, 2014).Nitrogen plays key role maximization ofsesame. Nitrogen applied through the chemical fertilizers have a rapid reaction and its supply makes nutrient available immediately to the plants for a shorter period, not for longer period. The nitrogen is either utilized by plants or lost by leaching or volatilization. The crop requires slow supply of nitrogen including phosphorus and potassium which is possible only through applying organic sources.

METHODOLOGY

The experiments was conducted on clay loam soil during semi rabi season of 2015 at research farm of Project Coordinating Unit (Sesame and Niger), JNKVV, Jabalpur (M.P.). Nine treatments of recommended dose of nitrogen integrated with three organic sources (Table 1)were tested in a randomised block design with three replications. Sowing of sesame cv. TKG 22 was done on 11/08/2015 in rows 30 cm apart by using 5 kg seeds/ha at about 3 cm depth. Full quantity of phosphorus, potassium alongwith organic manures and 1/3rd quantity of nitrogen were applied at the time of sowing and then well mixed in soil. The remaining 2/3rd quantity of nitrogen was top dressed at 30 day growth stage of crop. Harvesting of crop was done on 01.12. 2015. Data recorded on various observations were statistically analysed and then results were interpreted. The significant findings of the present investigation are discussed here under

RESULTS

The data presented in (Table 1) indicated that the maximum seed yield of 630 kg/ha was noted in N_8(100%RDN) followed by 611 kg/ha in N_5(75% RDN + 12.5% RDN through FYM + 12.5% RDN through oil cake), 593 kg/ha in N_6(75% RDN + 12.5% RDN through vermicompost + 12.5%

Table 1. Effect of integration of organic sources on seed yield, economics and oil yield

Treatment	Seed Yield (kg/ha)	NMR (Rs/ha)	B:C Ratio	Oil Yield (kg/ha)
N_1-75% RDN+ 25% RDN through FYM	522	17042	1.96	247
N_2-75% RDN+ 25% RDN through vermicompost	554	22129	2.44	257
N_3-75% RDN+ 25% RDN through oil cake	428	13318	1.89	211
N_4- 75% RDN + 12.5% RDN through FYM+12.5% RDN through vermicompost	581	22042	2.24	273
N5 - 75% RDN + 12.5% RDN through FYM + 12.5% RDN through oil cake	611	24678	2.47	291
N_6 - 75% RDN + 12.5% RDN through vermicompost + 12.5% RDN through oil cake	593	25126	2.65	277
N_7-75% RDN (chemical)	378	15178	1.87	174
N_8-100%RDN	630	28843	3.03	286
N_9 - Absolute control	289	6909	1.58	129
CD (P=0.05)	76	6869	0.33	36

RDN through oil cake) and 581 kg/ha in N_4 (75% RDN + 12.5% RDN through FYM + 12.5% RDN through vermicompost). These treatments were equally good for application of required quantity of nutrients. Thus it could be said that 25% of N of RDN can be substituted though organic sources by integrating them with 75 % RDN either by addition of two organic sources in equal quantity or single source alone. The minimum seed yield of 289 kg/ha was recorded in N_9 (Absolute control). The maximum NMR of Rs 28843/ha recorded in $N_8$was followed by Rs 25126/ha in N_6 and Rs 24678/ha in $N_5$with the minimum of Rs 6909/ha in N_9. The maximum B: C ratio of 3.03 recorded in $N_8$was numerically higher than 2.65 in N_6 and 2.47 in N_5 with the minimum of 1.58 in N_9. The maximum oil yield of 291 kg/ha was recorded in N_5 followed by 286 kg/ha in N_8, 277 kg/ha in N_6 and 273 kg/ha in N_4. The minimum oil yield of 129 kg/ha was noted in $N_{9.}$

CONCLUSION

Integration of organic manures jointly for supplementation of 25% N with 75% RDN through chemical fertilizers is recommended for substitution of N in sesame. This integration proved better for obtaining higher seed yield and remunerative productivity.

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Enhancing sustainability in organic farming

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Organic agriculture is currently practiced in 170 countries in 43.1 million hectares with annual market of US$72billion. In India too, the cultivated area under certified organic farming has grown almost 17 fold in last one decade (42,000 ha in 2003-04 to 7.23 lakh ha in 2013-14). The Government of India is also keen to promote organic animal husbandry through focused attention on native breeds and local practices. In XII plan, the GOI has launched *Paramparagat Krishi Vikas Yojana*, under which Rs. 300 Crores (Union Budget 2015-16) have been allocated to promote organic agriculture.The organic livestock and poultry standards have also been notified for implementation (APEDA, 2015) since 1st June, 2015. Organic production systems are knowledge and skill intensive, where the producers are expected to be knowledgeable about production norms, standards and practices for production and processing prescribed under approved standards by the designated authorities in implementing countries including in India viz APEDA, BIS, FSSAI etc. It is expected from the organic producers that they are not only familiar with organic standards, but also well versed in good agricultural/livestock production practices, animal welfare standards, and regulatory requirements as applicable to food production in general. At one end, there is traditional husbandry practices, while conventional system production in between and the most innovative one i.e. organic farming is the latest system. The farmers wishing to switch from traditional and conventional production systems to organic farming need information, knowledge and skills to follow organic standards, where there exists currently a big gap. The stakeholders including organic certification agencies have to regularly update themselves on organic standards. Field level extension functionaries need to have wider awareness and knowledge about organic standards for onward dissemination of information and orientation of the stakeholders involved in organic farming.

The standards, guidelines and production practices under organic systems at times look impractical, thus, many consider organic farming as utopian or fad. For instance, suggesting no chemical use for fertility enhancement, pest and weed control, while effective alternatives to soil fertilization, control pest, diseases and weeds in cropsare not adequate enough. Chemical fertilizers which supply essential nutrients like NPK including micronutrients are not allowed in organic farming, while the recommended sources of these nutrients like compost, FYM, bio fertilizers are not capable enough to meet the requirements.It is important to mak organic farming more practical, feasible and sustainable in practice. There are general principles, standards and practices accepted globally for organic production, yet there is scope for regional variations necessitating region specific changes in these production standards. There are wide variations in size of farms around the worldas also there are differences in agricultural practices. There are at least 570 million farms worldwide, of which more than 500 million can be considered family farms. Most of the world's farms are very small, with more than 475 million farms being less than 2 hectares in size. Besides, there are huge regional variations in agronomic/ agricultural practices as determined by geographical and cultural differences among countries. When we compare these differences with the organic standards which are more or less uniform irrespective of the varying local situations, it looks paradoxical at times. For instance, stocking densisty in case of livestock raised under low input low output systems. The standards prescribe max 2 milch cattle can be maintained in 1 ha land. This looks quite impratical, considering the size of some cattle breeds in India vis vis large sized exotic cattle breeds like Holestein mostly raised in Europe. For instance, the indigenous Indian cattle breed in general **–***Vechur*in particular**-** with an average length of 124 cm and height of 87 cm, is the smallest cattle breed in the world. It is valued for the larger amount of milk it produces relative to the amount of food it requires. It weighs around 130 kg, yielding up to 3 litres of milk a day.

Recently while framing Indian National Standards for organic livestock production for domestic market in India, this issue was discussed but the changes could not be made in stocking density citing alignment of national standards (APEDA, 2015) with international standards including those of CODEX (http://www.fao.org/docrep/010/a1385e/a1385e00.HTM) and IFOAM (http://www.ifoam.bio/en/ifoam-norms). If such amendments are not made, there is little likelihood of farmers switching to organic livestock production. In India, over 80% holdings are <1ha and farmers cannot do organic livestock farming sustainably with this limited number of cattle in their limited land holdings. There could be several similar changes required in different countries considering the country specific situations. Such changes can be made if the scientifically validated rationale for the same is generated. The stocking density should be based on body size, weight and feed requirements of a particular breed as decided through valid experiments including carrying capacity of land where these animals are raised. There is an obvious need to discuss the organic standards in context of the local situations, which have scope for changes to be made through experimentally validated justifications, so as to make organic agriculture more acceptable, popular and sustainable practice around the world.Until effective and acceptable alternatives to substitute chemical inputs and allopathic therapies (Antibiotics) are available,organic food production to meet the requirements of human and livestock populations is not possible. The following recommendations are made towards making organic farming a sustainable alternative to chemical intensive agriculture.

a. Agronomic interventions to promoter ecological intensification, while helping reduce dependence on chemicals for plant protection and soil fertility improvement.
b. There is need to rethink livestock stocking densities based on experimental data on on-farm feed and fodder availability for the body size of livestock raised.
c. Research funding needs to be augmented to carry out research on organic production systems.
d. Alternatives to chemical fertilizers, plant protectants, feed supplements and antibiotics need to be found.

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Evaluation of organic, inorganic and integrated crop management practices on crop productivity, economics and soil health of different cropping systems

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'Green Revolution' of India has undoubtedly changed the scenario of foodgrain production from 'ship-to-mouth' status to self-sufficient status. However, chemical intensive exploitative agriculture that has been followed after 'Green Revolution' has resulted into damaging impacts on environment, human animal and soil health; and water resources (Anonymous, 2001). Auspiciously, alternatives to chemical agriculture are available in organic and eco-technological farming approaches. Fortunately, due to its diverse agro-climatic conditions, India is bestowed with lot of potential to produce all varieties of organic products. Moreover, 74% of Indian farmers are having less than 2 ha land and these small holdings can adopt the organic principles easily and can manage the on-farm inputs and labour efficiently (Babalad *et al.*, 2008). But as the organic farming requires huge quantity of organic manure for nutrient supply, it always suspected for low yield and returns. Therefore, field studies were carried out to assess the impact of organic, inorganic and integrated management practices on productivity, economics and soil health of different cropping systems.

METHODOLOGY

Field experiment was carried out during 2014-15 at Research Farm, ICAR-IIFSR, Modipuram, Meerut, in strip plot arrangement consisting of six crop management practices *viz.*, 100% organic; 75% organic + innovative practices (biofertilizers & *Pannchgavya*); 50% organic + 50% inorganic; 75% organic + 25% inorganic; 100 % inorganic; farmer's practice (6 t FYM+ recommended dose of fertilizer) in main plots. In sub plots, four cropping systems *viz.,* basmati rice (PB-6)–durum wheat (HI-8498) - *Sesbania* green manure; coarse rice (Saket-4) – malt barley (DWRB-91) – green gram (Pusa vishal); pop corn (Bajaura) – potato (chipsona-3)–okra + *Sesbania* green manure; and sweet corn (Madhuri) – mustard (Pusa Bold) - *Sesbania* green manure were taken following the standard package of practices for each crop. The organic source nutrients were supplied equally through FYM and vermicompost based on recommended dose of nitrogen. While in inorganic management the nutrients were supplied through urea, DAP and MoP based on recommended dose of NPK for each crop. Biofertiloizers and *Panchagavya* were applied as per recommended practice. On the basis of prevailing market price system productivity in terms of Basmati Rice Equivalent Yield (BREY) and net returns were calculated and soil organic carbon (SOC) was estimated as per standard laboratory procedures (Walkley and Black, 1934).

RESULTS

The results in Table 1 reveals that due to higher and consistent nutrient supply by organic manures and fertilizers in combination, highest system productivity in terms of BREY was recorded under 75% organic+25% inorganic closely followed by 100% organic and 75% organic + Innovative practice. Due to higher cost of organic manures involved in organic practice; the combination of 50% organic+50% inorganic recorded highest net returns (Rs. 184066/ha) which were Rs. 52705/ha and Rs. 12090/ha higher as compared to 100% inorganic and farmer's practice, respectively. Moreover, taking the advantage of biofertilizers and panchgavya application and partially cost reduction of manures, 75% organic + innovative practices registered 38.2 and 12.3% higher BREY and fetch Rs. 39404/ha higher net returns over 100% inorganic and was comparable to farmer's practice. Besides, due to higher application and slow mineralization, 100% organic practice recorded 134.3 and 36.1% higher SOC as compared to 100% inorganic and farmer's practice. Due to higher productivity per unit time, short duration crops and better market price, popcorn– potato– okra system recorded 98.9 and 82.7% higher BREY and net returns, respectively over conventional cropping system of basmati rice-wheat. Among cropping systems, sweet corn–mustard registered highest SOC (0.746%); and it was because of higher root biomass and leaf fall these crops.

CONCLUSION

The higher and consistent nutrient supply by organic manures and fertilizers in combination ensured higher system productivity and net returns across the cropping systems.

Table 1. Effect of different crop Management practices and cropping systems on BREY, net returns and soil organic carbon status

Treatment		BREY (t/ha)	Net Returns (Rs./ha)	SOC (%)
Crop Management practices				
Organic	100% Organic	8.15	167768	0.862
	75% organic + Innovative practice	8.09	170766	0.825
Integrated Crop Management	50% organic+50% inorganic	7.99	184066	0.803
	75% organic+25% inorganic	8.28	183362	0.811
Inorganic	100% inorganic	5.86	131361	0.368
	State recommendation	7.21	171977	0.634
Cropping System				
Basmati rice-wheat		6.75	162051	0.726
Rice– barley–green gram		4.55	74334	0.696
Pop corn– potato– okra		13.43	296103	0.701
Sweet corn – mustard		5.65	140378	0.746

However, organic crop management of 75% organic + innovative practice besides recording highest SOC; registered comparable productivity and net returns to integrated crop management practices and markedly higher productivity and returns to inorganic practices. Among cropping systems, pop corn– potato– okra system recorded highest BREY and net returns across nutrient management practices.

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Biocompost as nutrient source for sesame–rice-blackgram cropping system

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The historic cultivation practice especially in Cauvery delta zone of Tamil Nadu is rice-rice-pulses(blackgram and green gram). Owing to uncertainty in rainfall in catchment area due to monsoon failure,the farmers were forced to withdraw the first rice crop (*kuruvai/ kharif*).In order to avoid these high risks and to provide better returns to the farming community it is advised to diversify the cropping system sustainably with remunerative short duration non rice crops which require less moisture requirement.Sesame (*Sesamum indicum* L.) is one of the important oilseed crops in Indian agriculture. By virtue of its early maturing, sesame fits well into a number of multiple cropping systems. System-based integrated nutrient management is more opt than concerning to individual crops. Pronounced effect of integrated application of biocompost(Pressmud +spentwash) along with chemical fertilizer on succeeding crops were noticed byMeena *et al.*(2010).Keeping the aforesaid facts in consideration, the present investigation was carried out to study the effect of integrated plant nutrient supply with biocompost fertilization in sesame- rice-blackgram cropping system for Cauvery delta zone of Tamil Nadu.

METHODOLOGY

Field investigation was carried out during June 2014 to April 2015 to study the effect of integrated plant nutrient supply of inorganic nitrogen in conjunction with biocompost on

Table 1. Effect of biocompost on sesame-rice-black gram cropping system

Treatments	Seed yield of sesame (t/ha)	Grain yield of rice (t/ha)	Grain yield of black gram (t/ha)	BCR of the cropping system
T_1 – Control	0.33	2.54	0.32	1.56
T_2 – 100% N as chemical fertilizer	0.63	5.21	0.84	3.19
T_3 – 75% N as chemical fertilizer +25% N as biocompost	0.69	5.73	0.91	3.33
T_4 – 67% N as chemical fertilizer +33% N as biocompost	0.78	6.23	0.79	3.36
T_5 – 50% N as chemical fertilizer +50% N as biocompost	0.76	4.62	0.65	2.75
T_6– 33% N as chemical fertilizer +67% N as biocompost	0.56	3.98	0.58	2.22
T_7– 25% N as chemical fertilizer +75% N as biocompost	0.54	3.86	0.56	2.10
T_8– 100% N as biocompost	0.48	3.25	0.32	1.74
SEm±	0.022	0.21	0.022	1.56
CD (P=0.05)	0.049	0.48	0.051	3.19

sesame (cv VRI-2) and rice (*cv*. ADT-49) and their possible residual effect on rice fallow blackgram (*cv*. ADT-3) cropping system at Experimental farm, Department of Agronomy, Annamalai University, Annamalai nagar, Tamil Nadu. The treatments were tested in randomized block design and replicated thrice. The treatments were imposed for sesame and rice crops. The effect of treatments was observed in the rice fallow crop (blackgram). The treatments included in the study were listed in Table 1.

RESULTS

It was observed that the growth and yield of sesame distinctly influenced by the application of biocompost in conjunction with inorganic N. The treatment T_3, (75% N as chemical fertilizer +25% N as biocompost) was categorized by many benefactors *viz*., growth and yield attributes yield of sesame crop 100% N as chemical fertilizer ranked second next to T_2.The least values at all the parameters were observed with T_1 (Control). Sesame being a short duration crop, replacing the chemical fertilizer over and above 25% with organic manure could not stretch the yield as evidenced by the falling seed yield with increasing organic manure proportion (Barik and Fulmali, 2011). The growth parameters, yield attributes and yield of rice were significantly influenced by the application of biocompostin conjunction with inorganic N. The treatment T_4,(67% N as chemical fertilizer +33% N as biocompost) was categorized by many benefactors *viz*., growth and yield attributes of crop - rice *viz*., plant height, LAI, number of tillers/m^2 , grain and straw yields were favourably influenced by the conjunctive use of inorganics and organics. The treatment T_3 (75% N as chemical fertilizer +25% N as biocompost) andT_2 (100% N as recommended chemical fertilizer) were ranked next to $T_{4.}$ (67% N as chemical fertilizer +33% N as biocompost).The positive effect on residual crop (black gram) was also noticed due to integrated supply of plant nutrients. The higher value of growth, yield parameters and yield was observed with T_4 (67% N as chemical fertilizer +33% N as biocompost) and it was on par with T_5 (50% N as chemical fertilizer +50% N as biocompost). Yield improvement observed due to incorporation of organics and inorganics on preceding crops and its possible residual effect on succeeding crop could be documented to the cumulative effect of organic and inorganic in improving the yield appreciably (Meena, 2010 and Patel *et al.*, 2012). The treatment T_4, (67% N as chemical fertilizer + 33% N as biocompost), exhibited a salutary effect on economic analysis in terms of gross return, net return and return per rupee invested (3.36) in sesame – rice –blackgram cropping system.

CONCLUSION

The results of field trails evidently proved that the application 67% N as chemical fertilizer along with33% N as biocompostis a suitable and sustainable practice of integrated plant nutrient supply system for sesame -rice- rice fallow blackgram cropping system of Cauvery Delta zone of Tamil Nadu.

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Effect of compost inoculants and indigenous technical knowledge on decomposition of rice crop residue

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India being an agriculture-dominant country produces more than 500 million tons of crop residues annually. A large portion of crop residues are burnt in the fields primarily to clear the left-over straw and stubbles after the harvest. In rice-wheat cropping system of India, rice residue is considered poor feed for animals due to its high silica content, and it is 80% often burnt by farmers in 3-4 weeks during October-November (Yadvinder-Singh *et al.,* 2010). Farmers do not incorporate rice straw in the crop field because of its slow degradation rate, disease infestation, unstable nutrients and reduced yield caused by the short-term negative effect of nitrogen immobilization. Proper management and disposal of bulky rice straw is a serious concern all over the world. Microbial decomposition with indigenous technical knowledge (ITKs) molasses, cow urine and urea solution is an effective environmentally sound alternative for the recycling of rice straw. Compatible lignocellulolytic fungal consortium might play a vital role in the rapid *in-situ* decomposition of rice straw. Thus, information on decomposition process of rice residue under field condition using microbial consortia *via-a-vis*ITKs are lacking, hence present experiment was undertaken.

METHODOLOGY

After the harvest the rice crop residuewas collected from field and stored in farm. 40 kg rice straw was stacked in 3 layers of 1 m height, 1 m width and 1.5 m length to form a pile. The pile was sprinkled with water for adequate moisture. Charcoal based solid formulation of mix strain of hyper-lignocellulolytic fungi namly (*Aspergillus nidulans, Trichoderma viride, Phanerochaetechrysosporium* and *Aspergillus awamori*) and molasses, cow urine and urea solutionwere applied on paddy straw with inlayers.Molasses, cow urine and urea solution applied as per treatment. Turning and water spraying were done at regular intervals. Sample collected at 20 days intervals for nutrient analysis.

Initial C: N ratio and nutrient content in rice residue (on dry weight basis)

Crop	Per cent (%)		
	C: N ratio	C	N
Rice straw	88.3	46.6	0.528

The CHNAnalyser find utility in determining the percentages of carbon, hydrogen, nitrogen, sulphur and oxygen of organic compounds, based on the principle of "Dumas method" which involves the complete and instantaneous oxidation of the sample by "flash combustion" (Instrumental Criteria Subcommittee, 2005).

Table 1. Effect of different compost inoculants and ITKs on C: N ratio, C and N content at different interval on rice residue

Treatment	C : N ratio			C content (%)			N content (%)		
	Days after								
	20	40	60	20	40	60	20	40	60
RR (control)	87.2	81.3	78.6	45.8	42.3	40.1	0.525	0.520	0.510
RR + Cow urine 10% spray	77.6	73.6	68.6	42.7	39.8	35.9	0.550	0.541	0.523
RR + 4% Urea spray	77.3	72.5	68.2	42.5	39.5	35.8	0.550	0.545	0.525
RR + 8% Urea spray	75.0	70.5	67.0	42.2	39.1	35.4	0.563	0.555	0.528
RR + CI	72.8	67.6	64.7	41.5	37.9	34.3	0.570	0.561	0.530
RR + *Trichoderma* Sp.	74.1	69.2	67.6	42.0	38.6	35.7	0.567	0.558	0.528
RR + Molasses 5% spray	79.2	75.5	70.4	42.9	40.4	36.6	0.542	0.535	0.520
RR + Molasses 5% spray +4% Urea spray	70.8	64.3	62.3	41.4	36.2	33.0	0.585	0.563	0.530
RR + CI + Molasses 5% spray	66.6	60.7	57.0	39.3	34.9	30.5	0.590	0.575	0.535

CI= Compost inoculants, RR=Rice residue

RESULTS

N ratio represent the total C content in straw in respective to unit amount of nitrogen. The result showed that C/N ratio of rice straw before treating was 88.3 and it was lowest (57) at 7-8 weeks after treating with compost inoculant and molasses 5% spray (Table 1). Highest value of C/N ratio was recorded with control (87.2, 81.3 and 78.6) while lowest value recorded with compost inoculants +molasses 5% spray (66.6, 60.7 and 57.0) at 20,40 and 60 days interval. Lowest value of C/N ratio with compost inoculants + molasses 5% spray might be due to higher multiplication of applied microbial consortia with 5% molasses. Higher population of microbes feed the carbon content and lower the value of C/N ratio. Treatment with molasses 5% spray +4% urea spray also recorded lower value of C/N ratio compared with consortia + molasses 5% spray due to lower microbial activity in this treatment. The favourable temperature for microorganismgrowth varied between 30-40˚C. But low temperature (average 10-20˚C) during winter season (December-January) the activity of applied microbes adversely affected therefore rate of residue decomposition was very slow. Microbes prefer a C: N ratio of around 10:1, but the ratios of different crop residues vary greatly due its chemical composition.

CONCLUSION

Many biological and chemical processes take place during the course of crop residue decomposition. These processes are influenced by environmental factors such as air temperature, moisture, pH, oxygen level and available microbial communities. The research findings of present experiment have shown that use of microbial consortia along with different ITKspositively influenced therate of decomposition and reduced the time of N immobilization.

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Influence of organic amendments on yield and quality of traditional red rice (*Oryza sativa)*

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Rice is one of the world's leading sources of nutrition for centuries, comes in hundreds of varieties and in many other colours besides the expected shades of brown. Several varieties of rice are having appealing red colour(Sivasamy *et al.,*1994). Red rice grain has a more complex taste and contains more nutrition, fibre-filled bran than much lighter coloured rice. The change in food habits from traditional food to junk food has increased the risk of lifestyle related health issues and diseases such as diabetes, cancer and other health problems. Red rice meets most of the requirement of a good and healthy food. This cereal is the only one that is eaten as a whole grain, and is more easily digestible than in any processed form as red rice has been found to have greater antioxidant property than white rice.In Tamil Nadu, more number of red rice land races continued to exist in Ramnad District and it was found to be drought resistant. The average yield of many traditional rice varieties were found to be in the range of 700 to 1000 kg/acre (1.7 to 2.5 tonnes per ha). Hence, the benefits of the red rice make it imperative to explore the possibilities of raising them successfully under irrigated conditions for enhancement of their yield and nutritional values. In Ramnad district red rice land races are raised under rain fed situation. Some farmers raise completely as organic and some farmers go for recommended dose of fertilizers 50:25:25 (NPK kg/ha).The studies conducted shows that complete organic cultivation gives better nutritional values and net returns.

METHODOLOGY

The experiment was conducted in field No.A. 43, at Central farm, Agricultural College and Research Institute, Madurai. The field is located in the southern agro climatic zone of Tamil Nadu. The farm is geographically located at 9^{o}54’ N latitude 78^{o}54’ E longitude and at an elevation of 147 m above mean sea level.The farm experiences the mean annual rainfall of 893 mm in 45 rainy days and the mean annual maximum and minimum temperature are 33.7^{o}C and 23.8^{o}C, respectively. The mean relative humidity is 83.4 per cent.The soil of the experimental field at AC&RI Madurai is sandy clay loam in texture taxonomically called as *Typic haplustalf*.The treatment combination of organic amendments like main plot five different nutrient management practices viz. M1-100 % FYM +Azophos, M2-150 % FYM + Azophos , M3-50 % FYM +50% Vermicompost + Azophos, M4-75 % FYM + 25 % Vermicompost + Azophos, M5-RDF 50 :25:25 NPK kg/ha were taken . In subplot five different landraces (red rice) viz. S1-Chandikar, S2-Norungan, S3-Nootripathu, S4-Kuliyadichan and S5-Kuruvaikalangium were taken. Field experiments were laid out in Split Plot Design with three replications.After harvest the grain samples were air dried to 12-14% moisture content. Hulling was carried out by Palm de husker that is made up of rubber material. During hulling the lemma and palea were removed and finally red rice was obtained. Red rice grains were powdered by using pestle and mortar and made into a fine powder or rice flour. The estimation of minerals likes Iron& Zinc were carried out using Atomic Absorption Spectrophotometer (AAS)

RESULTS

The yield data showed that the favorable effect of combinations of 50 %FYM 50 % Vermicompost+ Azophos with the variety Norungan (M_3S_2) recorded higher grain yieldthan RDF 50:25:25 NPK kg/hawith the variety Nootripathu(M_5S_3)(124 percent:165 per cent) .The increase in grain yield by N application might be due to favourable increase in growth attributesand effective utilization of N at needy stages of crop growth. Nitrogen is an important substrate for the synthesis of organic N compounds, which constitutes the protoplasam and chloroplasts. Increased photosynthesis with favourable effect on various growth and yield parameters resulted in higher yield. The enhancement in yield attributes and yield of rice might be due to the slow and steady release of nutrients from organic sources which enabled the rice plant to meet nutrient requirement at all the stages as and when required. The variety Kuliyadichan (S_4) recorded higher Carbohydrate and Fibre content. The Protein, Iron and Zinc content Table 2 was recorded higher in the variety Norungan (S_2).The variety Nootripathu (S_3) recorded higher fat content. The protein iron and Zinc content was recorded in the variety Chandikar. The higher fat content was recorded in the variety Nootripathu.

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Organic cultivation of medicinal plants: Enhanced raw drug yield and secondary metabolites content

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The millennium development goal ‘food security’ and ‘health for all’ are cohesively interlinked to realize the sufficient, safe, affordable and nutritious food and healthcare for people along with environmental sustainability. The medicinal and aromatic plants are cheaper, accessible, affordable, have societal acceptance and preference, and proven their significance in prevention as well as curing of human health problems across the globe. Due to growing popularity for drugs and dietary supplements derived from plants all over the world, herbal medicines have undergone a major revival in the last twenty years and now exists side-by-side with western forms of medicine. Safety, efficacy, quality and availability of herbal products are the principal factors in deciding their uses, and preposition to the policy-makers, health professionals and the public. However, in order to ensure quality and safety of herbal medicines, their production, sale and use should be officially and legally controlled as in case of allopathic medicines and take holistic views of the entire chain from sustainable utilization to economic development, conservation of vital biodiversity, crop diversification, value addition and marketing with the advancement of technologies. The effective agriculture, sanitary, safety treatments and collection practices for medicinal and aromatic plants are the first step in quality assurance of herbal medicinal and aromatic products (WHO guidelines). Organic agriculture is a holistic production management system which promotes and enhances agro-ecosystem health, including biodiversity, biological cycles, and soil biological activities. Organic cultivation practices besides their beneficial effects on ecosystem health, improve the quality and safety of medicinal plant and their products.

RESULTS

Realizing the safe and effective herbal drugs supply as well as environmental sustainability, organic nutrient management through on/off farm organic inputs [organic manures; farm yard, manure, castor cake, vermicompost, biofertilizers; *Azotobacter* and phosphate solubilizing bacteria (PSB), bioformulation; Jivamrut] were evaluated in three medicinal crops; kalmegh (*Andrographis paniculata*), ashwagandha (*Withenia somnifera*) and isabgol (*Plantago ovata*) through field studies. Castor cake and *Azotobacter*+PSB+Jivamrut improved yield attributes and herbage production of Kalmegh. Andrographolide content in Kalmegh also improved with the use of castor cake along with Jivamrut. In Ashwagandha, vermicompost and *Azotobacter* + PSB + Jivamrut recorded maximum plant biomass, dry root yield and root length, whereas, withanolides content were found maximum with castor cake and *Azotobacter* + PSB + Jivamrut. Castor cake and Jivamrut found superior in terms of straw and seed yield, swelling factor and husk content in Isabgol. Application of vermicompost and Jivamrut improved soil organic carbon, microbial biomass carbon, soil phosphorus and potassium, and also soil enzymes like, dehydrogenase, alkaline phosphatase, acid phosphatase and fluorescein diacetate in crop fields. However, soil nitrogen was quite improved with castor cake. The use of organic sources (manures, biofertilizers and bioformulation) in the present study have imparted their beneficial effects on raw drug yield, secondary metabolites content and improved chemical properties of the soil. It might be due bio-mediated effects of organics on soil nutrient mineralization, availability and acquisition and improved soil physical properties which resulted into improved yield and quality of medicinal plants.

CONCLUSION

This study showed the potential of organic cultivation of medicinal plants to harvest better herbage yield as well as quality with sustained or improved soil health simultaneously.

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Production efficiency of maize (*Zea mays*) – vegetable pea (*Pisum sativum*) cropping system under diverse tillage and organic nutrient management practices in mid hills of Sikkim Himalayas, North East India

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The productivity of rainfed mono cropping farming system in North Eastern Region of India is low and it is a high economic risk activity due to intensive natural resources mining, continuous degradation of natural resources, which can be improved by adopting conservation tillage practices and crop diversification with considerable change in cropping techniques (Babu *et al.,* 2016). Conservation tillage covers the soil surface through organic mulches, which reduces the runoff, increases the surface soil organic matter promoting greater aggregate stability which restricts soil erosion (Franzluebbers, 2002).Conservation agriculture with diversified maize-based cropping systems by inclusion of legume crops in sequence will helps to overcome the major challenges *viz.* declining factor productivity and deterioration of the resource base and

Table 1. Yield, system productivity, production efficiency of maize and vegetable pea as influenced by tillage and organic nutrient management (Data pooled over 2 years)

Treatment	Maize grain yield (t/ha)	Vegetable pea pod yield (t/ha)	System productivity (t/ha)	Production efficiency (kg/ha/day)
Tillage practice				
Conventional tillage (CT)	3.62	4.68	9.37	25.67
Reduced tillage (RT)	3.90	5.11	10.21	27.98
Zero tillage (ZT)	3.88	5.32	10.63	29.13
CD (P=0.05)	NS	0.12	0.24	0.65
Nutrient management				
Control (FP)	3.12	4.31	8.62	23.62
100% RDN	4.24	5.45	10.90	29.87
75% RDN + maize stalk/ pea stover	4.02	5.34	10.67	29.24
50% RDN + maize stalk/ pea stover	3.81	5.04	10.09	27.64
CD (P=0.05)	0.27	0.29	0.59	1.60

RDN: recommended dose of nitrogen

also plays a vital role in sustainable agricultural production. In view of the above, fixed plot field experiment was conducted at mid altitude of Sikkim Himalayas to identify the efficient tillage and organic nutrient management practices for enhancing land productivity of mono-cropped areas of the region.

METHODOLOGY

A fixed plot field experiment was conducted during two consecutive years (2014-15and 2015-16) at Research Farm, ICAR-NOFRI, Tadong situated at a latitude of 27^{o}32' N and longitude of 88^{o}60' E altitude of 1350 meters amsl. However, the experiment was maintained under organic conservation tillage practices since 2013 during both*kharif* and *rabi* seasons. The experiment was laid out in split-plot design, assigning three tillage practices *viz.,* conventional (CT), reduced tillage (RT) and zero tillage (ZT) in main plots and four organic nitrogen management*viz.,* control (FP), recommended dose of organic N, 75% recommended dose of organic N + maize stalk/ pea stover, and 50% recommended dose of organic N + maize stalk/ pea stover to sub-plots. All the treatments were replicated thrice. Field was prepared as per the treatment for planting of maize and vegetable pea. The crop was grown as per the recommended package of practices of the region.All the observations on maize and vegetable pea were recorded as per the standard procedures.

RESULTS

Poled data of two years showed that tillage practices failed to show any significant effect on maize grain yield, however, significant effect was observed on pod yield ofsucceeding vegetable pea. However, among the tillage practices, maximum grain yield of maize was recorded with reduced tillage (3.90 t/ha)followed by zero tillage (3.88 t/ha). In vegetable pea, significantly higher pod yield was recorded with zero tillage (5.32 t/ha) and lowest in conventional tillage (4.68 t/ha). The increase in pod yield of vegetable pea of under zero tillage may be due to better establishment and earliness over reduced and conventional tillage. This may also be due to lower incidence of diseases, which was also observed under zero tillage. With respect to organic nutrient management,a pplication of 100 % recommended dose of N to both the crops in the system, recorded significantly higher grain yield of maize (4.24 t/ha) and vegetable pea (5.45 t/ha) over others. This cause 26.4, 10.1 and 5.1 per cent and 20.9, 7.5 and 2.0 per cent increase over control (farmers practice), 50% RDN + maize stalk/ pea stover and 75% + maize stalk/ pea stover in maize and vegetable yield, respectively. System productivity and production efficiency : Tillage and organic nutrients management practices showed the significant effect on system productivity (SP) and production efficiency (PE) under study. Among the tillage practices, zero tillage recorded significantly higher value of SP (10.63 t/ha) and PE (29.13 kg/ha/day) over other tillage practices. Among the organic nutrients management practices, application of 100% recommended dose of nitrogen recorded significantly higher SP (10.9 t/ha) and PE (29.87 kg/ha/day) to control (FP) and 50% recommended dose of nitrogen but remained at par with 75% recommended dose of nitrogen.

CONCLUSION

On the basis of study, it is concluded that zero tillage with recommended dose of nitrogen through various organic manures was most effective for sustaining the productivity of maize-vegetable pea cropping system under organic management condition of Sikkim Himalayas.

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Long-term effect of manuring on quality of soil organic matter and yield of potato based cropping systems in Inceptisol of semi-arid subtropical India

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The quantity of SOC has tremendous implications on long-term storage of SOC for carbon sequestration and low quality organic carbon is related to the strong chemical inter-molecular interactions of organic carbon with reactive mineral phases. Management systems had greater effects on total SOM and its fractions than did N fertilization and indicates that those recently developed integrated soil crop system management in rice rapeseed rotation was suitable for improving soil organic matter (Tian *et al*., 2013). The labile component of SOM can be enhanced by adoption of balanced and optimum nutrient management practices. The long-term application of vermicompost alone or in combination with crop residues or integrated use of chemical fertilizer along with vermicompost might influence the stability as well as quality of organic carbon in potato–based cropping systems.

METHODOLOGY

Soil samples were collected (0–15 cm, 15–30 cm depth) from the on-going field experiment involving rice–potato–wheat and maize–potato–onion cropping systems continuing since at the research station of Central Potato Research Institute Campus, Modipuram, Meerut, Uttar Pradesh, India since the year 2005. The soil of the experimental site is alkaline in reaction with sandy loam in texture and the following treatments were imposed: control (T1), 100 % NPK-Fertilizer (T2), 100% N-vermicopost (VC) (T3), 50 % NPK-Fertilizer + 50% N-vermicopost (VC) (T4), 100% NPK-Fertilizer + crop residue (CR) (T5), 100% N-vermicompost + CR (T6). Different soil quality parameters e.g., particulate organic matter (POM),dissolved organic carbon (DOC) and total dissolved nitrogen (TDN), microbial biomass carbon (MBC), Microbial biomass N (MBN), MBC:N, microbial metabolic quotient (MMQ) were estimated by standard procedures.The yield of the rice (grain), potato (tuber) and wheat (grain) in rice-potato-wheat cropping system and maize (grain), potato (tuber) and onion (bulb) was recorded after harvest of each crop in the year 2014–2015.

RESULTS

In Rice–potato–wheat cropping system, microbial biomass carbon (MBC) was observed higher in 50% NPK + 50% NPK–VC (T4) (537 mg/kg) and 100% NPK + CR (T5) (524 mg/kg). Incorporation of CR over 100% NPK significantly increased MBC. In 15–30 cm soil depth, MBC varied from 312 mg/kg in T1 to 526 mg/kg in T5. The MBC in 15–30 cm soil depth was significantly lower in 100% NPK–VC (T3) (Table 1). Microbial biomass nitrogen (MBN) in 0–15 cm soil depth was observed highest in T2 (56.9 mg kg^{-1}) and application, remaining all treatments were non–significant as compared to the treatment control. In 15–30 cm soil depth, it varied from 42.1 mg/kg in T1 to 59.9 mg/kg in T5. The ratio of MBC: N in 0–15 cm soil depth varied from 5.67 in T1 to 9.62 in T4 and in 15–30 cm soil depth the ratio did not vary significantly across the treatments. Hao *et al.* (2007) reported that incorporation of rice straw increased the SOC and MBC contents in soil. The particulate organic matter C (POM–C) in 0–15 cm depth varied from 1.98 g/kg in control to 13.0 g/kg under 100% NPK–VC (T3). Further, POM–C in 100% NPK–VC + CR (T6) and 50% NPK + 50% NPK–VC (T4) increased by 5.56 fold and 3.84 fold, respectively over the control (T1). It was reported that the additional organic carbon input from FYM in 100% NPK + FYM treatment applied over more than three decades in maize–wheat–cowpea cropping system in Inceptisol of semi-arid subtropics further en-

Table 1. Long-term impact of manuring and fertilization on microbial biomass carbon (MBC) and microbial biomass nitrogen (MBN) fraction (mg/kg) and MBC: N ratio of soil under rice–potato–wheat cropping system

Treatment	MBC	MBN	MMQ	MBC:N	MBC	MBN	MMQ	MBC:N
	(mg/kg) 0-15 cm				(mg/kg) 15-30 cm			
Control	274d§	48.1b	1.03a	5.67c	312b	42.1c	1.03a	7.53a
100%NPK	451c	56.9a	0.91ab	7.93b	375b	53.0ab	0.91ab	7.36a
100%NPK–VC	470bc	51.6ab	1.03a	7.93b	372d	51.4b	1.04a	7.21a
50%NPK+50%NPK–VC	537a	56.0ab	0.71bc	9.62a	474a	54.4ab	0.71bc	8.74a
100%NPK +CR	524ab	55.3ab	0.61c	9.46a	526a	59.8a	0.61c	8.79a
100%NPK–VC+CR	458c	52.5ab	0.79abc	8.73ab	461a	52.7ab	0.79abc	8.71a

§The values followed by different lowercase letters are significant according to Duncan's Multiple Range Test at P = 0.05, VC, Vermicompost; CR, Crop residue; MMQ, Microbial metabolic quotient.

hanced the POC accumulation (Rudrappa*et al*., 2006). The dissolved organic C and N ratio (DOC: N) was wider in various manuring and fertilization treatments than that in the control treatment. The DOC: N varied widely between 7.49 in T1 to 27.0 in 100% NPK + CR (T5) in 0–15 cm soil depth and it varied between 5.15 in T1 to 20.6 in T6 treatment. The DOC:N did not vary significantly across various manuring and fertilization treatments excepting 100% NPK–VC + CR showed significantly lower ratio over other manuring treatments in 0"15 cm soil depth but in 15–30 cm soil depth all the manuring and fertilization treatments (T2 to T6) were at par.

CONCLUSION

Complete or partial substitution of chemical fertilizer with vermicompost could be recommended for rice–potato–wheat and maize–potato–onion cropping systems for enhancing quality of soil organic matter in Inceptisol of semi–arid sub–tropical India. The soil organic matter quality parameters like microbial biomass C (MBC) and dissolved organic C (DOC) in rice–potato–wheat could well predict the system productivity of both the cropping systems.

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Performance of different cropping systems under organic farming conditions

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Nowadays organic farming is gaining popularity and importance as farmers and consumers have realized the benefits of organic farming not only in terms of improvement in soil health, soil fertility, and sustainable productivity but also in production of safe and nutritious food. In organic crop production use of eco friendly agro-techniques and various bioformulations and composts are used. Compositing provides an effective and environment friendly procedure of organic waste disposal (Millner *et al*., 1998) because it is more economical and environmental friendly, whereas eco-friendly agro techniques are useful for the management of pests and maintaining the productivity of the system on sustainable basis without harming the environment. An experiment was laid out to develop and evaluate pulse based cropping system under organic to gather the information on best legume based cropping system on the basis of crop productivity and economics of the system.

METHODOLOGY

A field experiment was conducted during both Rabi and Kharif seasons of 2014 at the experimental area of Department of Organic Agriculture, CSKHPKV, Palampur. The area represents mid-hill wet temperate zone of Himachal Pradesh, situated at an altitude of 1290.8m and is bounded between 32^0 north latitude and 76^0 east longitude. The experiment area soil was silty clay loam in texture, acidic having pH around 5.5-5.7, organic carbon 0.65% acidic in reaction having pH 5.7, nitrogen 255kg/ha, phosphorus 6.0 kg/ha and potassium 268 kg/ha. The experiment was laid out in randomized block design with three replications and sixteen treatments using 4m x 3m plot. The treatments consisted four different crops (Soybean, Cowpea, Maize and Maize+Soybean during Kharif season and with combination of four Rabi season crops (Wheat + Gram, Wheat, Gram and Lentil). In total sixteen treatments were there for comparison. A uniform basal dose of Vermicompost (10 t/ha) was applied at the time of field preparation in all the treatments. The spray of vermiwash was applied thrice in a crop season. All agronomic operations were kept normal and uniform for all the treatments. Data collected were statistically analyzed using the CPCS programmer.

RESULTS

The data revealed that maize equivalent yield of different cropping system varied from 3.84 t/ha in maize-wheat cropping system to 9.55 t/ha in maize + soybean-wheat + gram. cropping system. There was a sufficient contribution of legume intercrop on the total equivalent yield of the cropping system not only in the main season but also on the succeeding crop season. Maize + soybean-wheat + gram and maize + soybean- gram cropping sequences being at par with each other resulted in significantly higher maize equivalent yield (MEY)

Table 1. Equivalent yield & Economics of different legume based cropping systems

Sequences	MEY (t/ha)	Net Returns (₹)	B: C
Maize –Wheat+ Gram	4.97	32121	0.57
Maize+Soybean –Wheat + Gram	9.55	109467	2.06
Soybean - Wheat+ Gram	6.98	59860	1.18
Cowpea - Wheat+ Gram	6.4	51783	1.02
Maize – Wheat	3.84	8495	0.13
Maize+ Soybean –Wheat	6.79	57641	0.93
Soybean – Wheat	6.22	46243	0.78
Cowpea – Wheat	5.47	33419	0.56
Maize – Gram	4.6	29006	0.61
Maize+ Soybean – Gram	8.78	93154	2.09
Soybean – Gram	6.99	62860	1.49
Cowpea – Gram	5.68	43240	1.02
Maize – Lentil	5.37	40847	0.86
Maize+ Soybean – Lentil	8.02	82384	1.85
Soybean – Lentil	6.03	48460	1.15
Cowpea – Lentil	5.88	46180	1.09
CD (5%)	0.53	-	-

as compared to other cropping systems. Net return and benefit cost ratio also behaved similar to the maize equivalent yield. The next best treatments in the system was maize+soybean-lentil which resulted in higher returns (82384) and benefit: cost ratio (1.85) over the remaining treatments.

CONCLUSION

The data revealed that maize+soybean-wheat+gram and maize+soybean- gram cropping sequences being at par with each other resulted in significantly higher maize equivalent yield (9.55 and 8.78 t/ha/annum, respectively), net returns (109467 and 93154) and benefit cost ratio (2.06 & 2.09 respectively).

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Response of crops and soil fertility changes under 12 years of organic farming in maize-onion sequence

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Fertilizer consumption in the agricultural sector increased five-fold between 1975 and 1990 and increased slightly further afterwards. Long term field experiments have made clear the negative impact of continuous use of chemical fertilizers on soil health (Yadav, 2003). The occurrence of multi-nutrient deficiencies and overall decline in the productive capacity of the soil due to indiscriminate fertiliser use, have been widely reported. Organic farming could be an option to ensure food, air, and water and soil quality leaving the environment safe for the present and future generations.

METHODOLOGY

Experiment was conducted from 2003-04 to 2014-15 at the College of Agriculture, Rajendranagar to evaluate the impact of organic farming practices in comparison to chemical farming on productivity of crops and soil fertility using maize-onion as test crop sequence. The experiment was laid out on a sandy loam soil with seven treatments on large plots of 300 m^2. Years of experimentation were considered as replications for statistical analysis of the data. Farmyard manure (FYM), vermicompost (VC) and neem cake (NC) was applied on N equivalent basis. The recommended dose of fertilizers (RDF) for maize and onion were 180:60:40 and 150:60:60 kg NPK /ha respectively. During all the years FYM and neem cake were applied one week prior to planting of *kharif* and *rabi* crops. In T5 and T6 treatments, *Azospirillum* and PSB were thoroughly mixed with 25 kg FYM and applied evenly in the entire plot. Vermicompost was applied as top dressing at 30 days after sowing of maize or planting (DAP) of onion crop. Soil analysis was carried out by adopting standard procedures.

RESULTS

During the conversion period (initial 3 years) maize registered a productivity level of around 2.0 t /ha with the organic treatments and 3.3 t/ha of grain yield with RDF and 3.2 2 t/ha with INM treatment supplying 50% N through FYM + 50 RDF. During initial 6 years a straight variety of maize was used as test variety and later a popular hybrid DHM – 117 was used as a test cultivar in the study. There was no improvement in yield levels of maize with different treatments even during first 3 years of organic farming with variety (4^{th}–6^{th} crop cycle) over that of conversion period. The complete chemical and INM treatments maintained greater productivity level over complete organic farming treatments. As the yield potential of hybrids is high, the yield of maize in the present investigations from 7^{th} to 12^{th} crop cycle in maize-onion system was ranging between 4.5 – 5.7 t /ha. Nevertheless, the crop responded well to organic farming and a yield level of 4.5 to 5.3 t /ha was recorded during this period and it was close to that of INM (5.6 t/ha) and complete chemical fertilizer (5.7 t /ha) treatments. The results clearly showed the response of maize (either variety or hybrid) to organic farming was neither equal nor superior to complete chemical and INM treatments. The productivity level of onion during conversion period (initial 3 years) was greater with INM treatment (12.95 t/ha) followed by sole chemical fertilizer application (11.83 t /ha) over organic treatments (6.58 to 8.68 t/ha). The onion started responding to of in the 7^{th} crop cycle (2009-10) and yield levels in organic treatments (10.58 to 11.92 t/ha) are comparable to that of INM (13.50 t/ha) and RDF (13.57t/ha) treatments. The treatments were found at a par, the differences were less during OF period (mean over 4^{th} to 12^{th} year: 2007-08 to 2014-15). Further, introducing carrot as an intercrop in onion during rabi season with sole organic manure application resulted in significant reduction in onion both yield conversion period & organic farming period. This loss in both yield was compensated by almost similar or at times greater carrot yield which has ultimately out yielded the sole onion crop yield under organic nutrient supply system. The mean content of organic carbon (OC) over 12 years was high with organic (0.70%), integrated (0.60%) and chemical (0.51%) treatments when compared to initial status (0.36%). Improvement in OC with organic nutrient management was 66.2 to 9.3.5% when compared to initial status. When compared to inorganic nutrient management, INM had 17.9% higher OC and organic nutrient management had 16.7 to 35.9% higher organic carbon. Available nitrogen was not influenced by nutrient management practices; the improvement over conventional farming with organic farming was 4.1 to 13.8%. Build up of available phosphorus over initial status was observed during the twelve year period by 45.7% in chemical farming and 49.0 to 84.6% under different organic nutrient management practices. Different organic farming treatments registered 2.3 to 26.7% higher phosphorus than inorganic nutrient management. Available potassium also registered an increase of 8.7% with application of fertilizers alone and 15.9 to 44.0% with various organic nutrient management practices over it its initial status and 6.6 to 32.4% over conventional farming.

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Assessment of vermicompost enriched with microbes on growth and yield of late sown chickpea *(Cicerarietinum L.)*

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Among the several pulses grown in India, chickpea is commonly known as gram *(Cicerarietinum L.)*is the most important crop. The average productivity of chickpea in MP is only 674 kg/h, which is low as compared to national average productivity i.e., 705 kg/ha. The factor which is responsible for the low productivity is reduction in plant population. The low plant population/ unit area is due to soil borne pathogens i.e. dry rot, wet rot, *Fusarium*wilt etc., these causal organisms may successfully managed with the use of *Trichoderma* alone or in combination of *pseudomonas* which are known as antagonist for biological suppression. Soil application of *Trichoderma* along with FYM before sowing in addition to seed treatment proved effective to control wilt in chickpea. Most of the organic manures are very low in nutrient content and protective microbes. Hence, the fortification of organic manure with additives viz. rock phosphate, micro culture contribute to enhancement of N and P contents through solublization. Keeping the above points in view, the study on Assessment of vermicompost enriched with microbes on growth and yield of late sown chickpea *(Cicerarietinum L.)* was conducted to assess the suitability of enrich vermicompost for enhancing protection and production of chickpea.

METHODOLOGY

A field experiment was conduct at technology park, KVK, JNKVV, Jabalpur during 2014-15. A total of 13 treatment combinations (T_1 VC of Soybean Stover + without additive, T2VC of Soybean Stover + *Trichoderma* + PSBT_3VC of Soybean Stover + Cow dung+ *Trichoderma,*T_4VC of Soybean Stover + Cow dung+ *Trichoderma* +PSB, T_5VC of Soybean Stover + Rock phosphate + PSB,T_6VC of Soybean Stover + Rock phosphate + PSB + *Trichoderma,* T_7VC of Paddy straw + Without additive, T_8VC of Paddy straw + *Trichoderma* + PSB, T_9VC of Paddy straw + Cow dung + *Trichoderma,* T_{10}VC of Paddy straw + Cow dung + *Trichoderma* + PSB, T_{11}VC of Paddy straw + Rock phosphate + PSB, T_{12}VC of Paddy straw + Rock phosphate + PSB + *Trichoderma,*T_{13} Recommended dose of (20:60:20 kg NPK/ha)were arranged in Randomized Block Design with three replication. Prepared vermicompost were applied @ 2 Ton/ha as per the treatments along with 20:60:20 NPK kg /ha. The crop variety JG-14 were sown @ 75 kg/ha were sown on 15th DEC. 2014. Results and study shows that Addition of vermicompost prepared from inoculated with *Trichoderma* either of the substrata proved beneficial in order to maintain the plant population throughout the crop period. Whereas, without of *Trichoderma* inoculation the plant population of chickpea ranging from 30.6 to 56.5 per cent. The reduction in plant population (68%) was observed where the vermicompost was not applied (applied only the recommended dose of NPK.

RESULTS

The maximum plant height (43.50c.m.) and branches (11.2) per plant were recorded under T_4 in which the vermicompost of soybean stover+ cowdung+ *Trichoderma*+ PSB were used. Similarly the yield attributes viz. seeds/pod, pods/ plant and grain yield/plant also higher in the T_4 treatment. Thus, the vermicompost of soybean stover enriched with *Trichoderma* +PSB proved beneficial for the sac of yield enhancement. Vermicompost of soybean stover amended with either of Cowdung or rock phosphate and then inoculation with PSB and *Trichoderma* proved to be superior in production of grain and straw yields .The maximum grain and straw yields of chickpea was under T_4 which was at par to recommended dose of NPK. The protein content and protein yield of 20.12% and 318.29 kg/ha were noted under T_6 closely followed by 20.0 % and 297.8 kg/ha, respectively under T_5 treatment. On the other hand the total uptake of N,P and K was 57.83, 6.45 and 136.8 kg in recommended NPK@ 20:60:20 kg/ha. Whereas, total up take of nitrogen phosphorus and potassium in T_4 was 54.16, 7.39 and 150.83 kg respectively.

CONCLUSION

Thus, it showed that nitrogen uptake increased with the application of chemical fertilizer. Whereas P and K uptake were higher under vermicompost. Which was amended and inoculated with cow dung, *Trichoderma* and PSB.

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Development of organic farming package for scented rice-potato cropping system

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Organic farming implies a farming system that primarily aims at cultivating land and raising crops under ecologically favorable conditions. The use of locally available agro-inputs in agriculture by avoiding or minimizing the use of synthetically compound of agro-chemicals appears to be one of the probable options to sustain the agricultural productivity. Addition of organic manures such as FYM, recycling of organic wastes through composting, green manures and biological inputs like vermicompost and biofertilizers etc. constitute important components for plant nutrition in organic farming. Cultivation of both crop components under scented rice-potato cropping sequence under organic farming situation appears to be one of the remunerative cropping system in rice growing pockets of M.P. because of its high market value in the domestic markets and in export potential. Under such circumstances the use of organic with inorganic fertilizers in combination with inorganic fertilizers in proper proportion may be cheap, socially acceptable and environmentally sound, nutrient management for increasing productivity of crops in sustainable manner. Therefore, it is essential to assess the ability of organic manures to replace certain properties of fertilizers to be applied in scented rice-potato crop sequences without declining the yields. The objective of experiment was to evaluate the productivity of scented rice-potato system under organic, inorganic and integrated nutrient managements.

METHODOLOGY

The present investigation was consisted with a field experiment entitled "Development of organic farming package for scented rice-potato cropping system" which was conducted at Research Farm, Krishi Nagar, JNKVV, Jabalpur (M.P.) during the year 2003-04 to 2009-10 under irrigated production system. Thus, the present study was a part of continuous studies pertaining to the 7^{th} crop-cycle without changing the treatments, site and layout plan. The seven treatment consisted with T_1 - 50% NPK through fertilizers + 50% N through FYM, T_2 - organic manures equivalent to 100% N% as 1/3 N through each of FYM, vermicompost (VC) and neem cake (NC), T_3 –T_2 + Intercropping of Isabgol in potato, T_4 – T_2 + agronomic practices of weed control in both crops, T_5 - T_2 + BGA + rock phosphate + PSB, T_6 –T_2 + *Azospirillum* + PSB, T_7 - 100% NPK through fertilizers + Zn as per soil test values (STV), T_8 - T_2 + green manuring in rice only.

RESULTS

In rice-potato crop sequence the combined yield of both rice and potato crops were determined in terms of rice equivalent yields (REY) for all treatments. Rice equivalent yields of various nutrient management treatments during 7 consecutive years of investigation the mean rice equivalent yield of rice-potato cropping sequence was maximum (7.84 t/ha/yr) with T_7 -100 % NPK through fertilizer +Zn as per STV nutrition every year which was significantly superior over all the treatments, T_1- INM (6.8.9 t/ha/yr) was next to it. Both treatments produced significantly higher REY among all treatments. Among organic nutrition, the REY was maximum (6.70 t/ha/yr) under T_3- 100% organic with intercropping of isabgol in potato which was at par to T_4- (6.31 t/ha/yr) 100% organic with agronomic practices of weed control in both crops. Treatment T_5-100% organic with BGA + rock phosphate + PSB and T_6-100% organic with *Azospirillum* + PSB were next best treatment with the REY of 6.19 t/ha/yr and 6.21 t/ha, respectively followed by T_2- (6.10 t/ha/yr) 100% organic. Treatment T_8- 100% organic with green manuring in rice produced the lowest REY (6.03 t/ha/yr) among all the treatments. Though application of 100% inorganic nutrient management to both crops gave significantly higher rice equivalent yield (REY) (7.84 t/ha/yr) than those of obtained with the application of 50% N through fertilizer + 50% N through FYM (6.89 t/ha/yr). Application of 100% organic manures (1/3 N through each of FYM, vermicompost and neem cake) with green manuring in rice only gave lower rice equivalent yield- T_8 (5.76 t/ha). Additionally intercropping of isabagol with potato under organic nutrient management enhanced the yield 6.80 t/ha/yr in terms of REY.

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Response of moth bean (*Vigna aconitifolia*) genotypes to spacing and organics under dry land situation

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A field experiment was conducted at Agriculture College Farm, Bijou in Northern dry zone of Karnataka to study the response of moth bean genotypes to spacing and organics during *kharif* 2013. The experiment was laid out in randomized complete block design with factorial concept and replicated thrice. There were 14 treatments including 12 treatment combinations involving three genotypes (MBS-27, BJMB-1 and local), two spacing (30 cm x 10 cm and 45 cm x 10 cm) and two organics (2.5 t/ha FYM and 1 t/ha vermicompost) along with two controls (local variety at 30 cm x 10 cm spacing with 10:20 kg N:P_2O_5/ha and local variety at 30 cm x 10 cm spacing with 10:20:10 kg N P_2O_5 K_2O/ha). Seed and haulm yield were recorded and grain quality parameters were analyzed. The moth bean local variety recorded significantly higher seed yield (796 kg/ha) and haulm yield (3921 kg/ha) compared to MBS- 27 (681 kg/ha and 3246 kg/ha, respectively) and BJMB-1(538 kg/ha and 2732 kg/ha, respectively). The spacing of 45 cm x 10 cm recorded significantly higher seed yield (716 kg/ha) compared to 30 cm x 10 cm. Application of 1 t/ha vermicompost recorded significantly higher seed yield (714 kg/ha) compared to 2.5 t/ha FYM. However, grain quality was not influenced by genotypes, spacing, organics and their interaction. In Northern dry zone of Karnataka, the moth bean local variety at spacing of 45 cm x 10 cm with application of 2.5 t/ha FYM produced significantly higher seed yield (983 kg/ha), haulm yield (4886 kg/ha), net returns (Rs.42425/ha).

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Effect of liquid organic manures and biofertilizers on wheat + gram inter-cropping system

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Under organic conditions, application of liquid organic manures (Vermiwash, compost tea, biosol, matka khad) is essential to maintain the activity of micro-organisms and other life forms in the soil (Hargreaves *et al*., 2008). Likewise, biofertilizers are also essential component of organic farming. These are used for application to seed, soil or composting areas with the objective of increasing microbial processes which augment the availability of nutrients that can be easily assimilated by plants. The interaction of various organic farming components play a vital role in meeting the nutritional requirement of wheat + gram inter-cropping system for enhancing the productivity and soil health on sustainable basis. Therefore, the present investigation was under taken with the objectives:To study the effect of liquid organic manures and biofertilizers on productivity of wheat + gram intercropping system, to work out the best liquid organic manure alone or in combination with biofertilizers in wheat + gram intercropping system andto work out the economics of the treatments.

METHODOLOGY

A field experiment was conducted during *Rabi* 2010-11 at Holta organic farm, department of Organic Agriculture, CSK HPKV, Palampur to study the effect of liquid organic manures and biofertilizers on wheat + gram inter-cropping system under organic conditions. The treatments comprising of all possible combinations of five liquid organic manures (vermiwash (1:10), compost tea (1:5), matka khad (1:10), biosol (1:15) and control) and two biofertilizer levels (inoculated and uninoculated), were tested in factorial randomized block design, replicated three times. The crop was fertilized with 10 t /ha vermicompost at the time of sowing as basal application. Soil of the test site was silty clay loam in texture, moderately acidic in reaction, medium in organic carbon and low in available nitrogen, medium in available phosphorous and potassium.

RESULTS

Results revealed that growth, yield attributes, grain and straw yields of wheat and gram were increased with the application of biofertilizers and liquid organic manures over control. The increase in grain yield with biofertilizers inoculation was 12.61% in wheat and 10.03% in gram over un-inoculated check. The magnitude of increase in grain yield with the application of different liquid organic manures ranged from 33.87 to 13.61% in wheat and 19.25 to 11.75% in gram over control. It might be due to enhanced biological processes by

Table 1. Effect of treatments on productivity and economics of wheat + gram inter-cropping system

Treatment	Wheat (kg /ha)		Gram (kg /ha)		Wheat grain equivalent yield (kg/ha)	Net return (Rs.)	Net returns per rupee invested
	Grain yield	Straw yield	Seed yield	Straw yield			
Biofertilizer							
Inoculated	1853	3304	410	790	2929	17874	0.57
Un-inoculated	1646	3083	373	737	2689	14898	0.49
CD (P=0.05)	156	209	20	47	139	1628	0.05
Liquid Organic Manure							
Vermiwash	1836	3319	405	786	2980	18612	0.60
Compost tea	1976	3417	417	798	3035	19797	0.64
Matka khad	1782	3265	395	783	2860	17245	0.56
Biosol	1677	3108	390	764	2770	15480	0.50
Control	1476	2857	349	686	2400	10796	0.36
CD (P=0.05)	247	331	32	74	219	2574	0.08

microbes in plant and soil enzymatic activity which increased the yield contributing characters of wheat. Also, the translocation of photosynthates favours plant growth and development of yield attributes and consequently leading to higher yields. There was significant advantage of biofertilizers inoculation as compared to the treatment without inoculation and recorded an increase of 8.89 per cent in wheat grain equivalent yield over un-inoculated check. Application of compost tea, vermiwash and matka khad resulted in 26.4, 24.16 and 19.1 per cent higher wheat grain equivalent yield, respectively over control.Inoculation of wheat and gram seeds with biofertilizers and application of compost tea, vermiwash and matka khad as liquid organic manures with dilution ratio of 1: 5, 1: 10 and 1:10 respectively, proved to be significantly better for recording higher values for different growth parameter and resulted in significantly higher wheat equivalent yields, higher net returns (Rs. 19797, Rs.18612 and 17245, respectively) and net returns per rupee invested (0.64, 0.60 and 0.56, respectively) in wheat + gram intercropping system under organic condition.

CONCLUSION

Inoculation of wheat and gram seeds with biofertilizers and application of compost tea, vermiwash and matka khad as liquid organic manures proved to be significantly better for productivity and profitability in wheat + gram intercropping system under organic condition.

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Extended Summaries Vol. 1 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Developing micro-irrigation based organic farming system for potato crop

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Scenario of Indian agriculture has undergone a paradigm shift in potential business opportunities in past one decade. Now the plenty has to be converted into quality production for big emerging domestic and export market. Potato has not remained unaffected by the developments in agricultural sector. Time has come for planning about quality concerns as slowly demand for quality organic productsis rising. Current benefits to farmers are to be doubled in next five years by improving production technology and its adoption. Progressivepotato growers are thinking for raising potatoes for diversified use like organic potatoes and ask for the agro-technology (CPRI, 2015). Further, the face of agriculture has to be more environment friendly due toglobal warming and climatic aberrations. Main emphasis would be in future on developingadvanced production technologies which are sustainable in long run. For consumers, organically grown food is safe, nutritious and will remain in high demand. The work is going on optimizing potato productivity under food grain based organic farming system.

METHODOLOGY

Field trial was initiated during 2013-14 for developing food grain based organic farming system for potato crop in sprinkler irrigation. Rotation of groundnut- potato- maize+ *moong* bean was formulated for the experiment conducted on fixed plots in replicated randomized block design. Treatments (7) consisted: control, conventional system, organic system of crop residue recycling (CRR), organic system of bio-fertilizers and microbial application (BM), and organic system of organic manures incorporation (OM), organic system with homeopathic approach (HO), and organic system with all combinations of source of nutrition excepting homeopathic products (IA). Planting was done in last of October and haulms cutting was done at 110 days for Kufri Himsona. Harvesting was done 10 days later, where, grading was done manually, and tuber of marketable (process size) grade was >45 mm. Succeeding crops i.e. maize (hybrid) andgreen gram (cv. Nirali) in inter-cropping were raised in 2:1 ratio in bed planting (width: 1.32 cm) during March- June by following the recommended package of practices. Groundnut (cv. TG37A) was grown during July- October by adopting standard practices. Observations of emergence, growth, yield attributes and yield were recorded as per the schedule for all component crops.System productivity, variable cost,gross re-

Table 1. Influence of nutrient management options on marketable & total tuber number (000/ha) and yield (t/ha), and specific gravity of cv. K. Himsona under sprinkler irrigation

Nutrient management	Tuber number		Tuber yield		Specific gravity
	Process grade	Total	Process grade	Total	
Control	120.7	514.3	12.0	25.9	1.097
Conventional system	211.6	743.2	26.8	44.2	1.085
Organic system (CRR)	97.7	567.9	10.9	27.6	1.094
Organic system (BM)	92.8	588.7	9.8	25.6	1.095
Organic system (OM)	96.9	563.6	10.5	26.1	1.092
Organic system (HO)	92.3	512.4	9.9	23.8	1.096
Organic system (IA)	95.5	565.7	10.8	26.5	1.093
CD (P=0.05)	54.8	81.4	3.98	2.97	0.004

Table 2. Influence of nutrient management options on system productivity and economics of production under sprinkler irrigation

Nutrient management	System productivity (t/ha)	Cost of cultivation (Rs/ha)	Gross returns (Rs./ha)	Net returns (Rs./ha)	B: C ratio
Control	30.1	160710	240800	80090	0.50
Conventional system	63.6	180807	508800	327993	1.81
Organic system (CRR)	44.7	165850	357600	191750	1.16
Organic system (BM)	43.0	165800	344000	178200	1.07
Organic system (OM)	55.5	170800	444000	273200	1.60
Organic system (HO)	47.8	168000	382400	214400	1.28
Organic system (IA)	56.6	179900	452800	272900	1.52

turn, net return and B:C ratio were calculated following standard procedures.The data was analysed statistically using software IRRISTAT (IRRI, Phillipines).

RESULTS

Process grade and total tuber numbers (000/ha), and yield (t/ha) varied statistically with variations in source of nutrition. Lesser tuber number and lower tuber bulking adversely affected graded and total tuber yield in organic treatments. Conventional system recorded highest process grade (211.6) and total (743.2) tubers, whereas organic system (IA) recorded significantly lower (54.9 and 23.9%, respectively) process grade (95.5) and total (565.7) tubers. Conventional system attained highest process grade (26.8) and total (44.2) tuber yield, which was distinctly higher over all other treatments. Organic system (IA) had lower process grade (59.7%) and total (40.0%) tuber yield over conventional system.Specific gravity (SG) improved significantly in various combinations of organic nutrition (1.092-1.096) in comparison to conventional system (1.085) andorganic system (IA) recorded SG of 1.093 (Table 1). Clear cut difference was visible in maize yield attributes i.e. cob number (000/ha), and grain, straw and biomass yield (t/ha) with inorganic and organic nutrition. Conventional inorganic source attained maximum and statistically superior cob no. (58.2), grain (5.00), straw (18.1) and biomass yield (26.9) over other treatments. Organic system (IA) remained second best option and it could achieve 87% grain productivity as compared to inorganic system.Yield attributes and yield (t/ha) were not influenced by variation in plant nutrition in component crop Green gram. Organic system (IA) recorded comparable pod (0.36), grain (0.23), straw (1.8) and biomass yield (2.2). Pod, grain, straw and biomass yield (t/ha) were not affected significantly by different source of nutrition in Groundnut. Organic system (IA) recorded comparable pod (0.81), grain (0.59), straw (5.0) and biomass yield (5.8) to inorganic nutrition. Organic system (IA), organic system (OM) and organic system (HO) recorded 56.6, 55.5 and 47.8 t/ha system productivity, respectively (Table 2), which was 89.0, 87.3 and 75.2% of the inorganic treatment productivity (63.6 t/ha). Inorganic nutrition had 16.7 and 11.6-16.0 % higher net return and B:C ratio over best organic system (OM).Organic system (IA) had net return of Rs. 273200 and 272900/-ha, and B:C ratio of 1.60 and 1.52, respectively (Khakbazan*et al*., 2015). Variety Kufri Himsona could maintain 40.3% process grade and 60.0% total tuber productivity in organic system (IA) over conventional nutrition.Among organic systems, organic system (IA) seems promising based upon system productivity, net return and B: C ratio.

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Mineralization pattern of basic EDTA–extractable organic phosphorus under organic farming systems

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In recent times, the need for organic farming is increasingly felt in view of consumer's concern for better health from organically produce food stuffs. As such, the demand for organic husbandry is progressively increasing for quality products and sustaining the productivity with the increase in biological buffering of soil. But, in practice, it is observed that the average productivity of organically produced crop is less than that of conventional farming. This is mostly due to non-consideration of crop nutrition with the tune of crop demand as well as lack of balanced nutrition (Saha and Mandal, 2011). It has been hypothesized that extractants normally used in conventional soil testing methods for extracting dynamic P fractions do not equally applicable for extraction of plant available P and for estimation of reserve and potentially mineralizable fraction of plant nutrients in soil. Developing appropriate management of P under organic rotations requires a good understanding of the complex plant-soil interactions which control P dynamics in soils and the efficiency of P supply from added crop residues, manures or brought-in fertilizing materials. Determination of organic –P turnover rate, mean retention time (MRT) and half life of different organic pools will be helpful for detecting the contributing P-pool for nutrition under organically managed systems. The experiment was conducted to develop suitable extractant for identifying the most contributing mineralizable P pools under organic production system, to understand rate of mineralization of organic P pools, and to measure the mineralization potential of organic P under different management regime.

METHODOLOGY

With a view to understand such transformation; soils were sampled from different organic tea estates of Assam under two agro-ecological zones of Brahmaputra Valley and Barak Valley. Soils of conventional tea estates of these regions were also collected and treated as check to understand the edge of organic husbandry. A set of extractants comprising graded strength of NaOH, with 0.05 (M) EDTA were used to extract different fractions and their dimensions remained in organic P pool which underwent mineralization with different turnover rates under organic and conventional farming systems. (Bowman and Moir, 1993). With the use of first-order kinetics model, organic P mineralization rate, half-life of residual organic P and their mean residence time (MRT) of different organic P fraction extracted by different extractants were measured under both organic and conventional tea estates. The first order kinetic model well described the mineralization of different fractions of organic P extracted by basic EDTA extractants.

RESULTS

The speediest mineralization rate of different organic P pools extracted by graded strengthof basic EDTA under organically managed soil suggests that organic P pool under this tea estate is highly labile than those of other tea estates. Moreover, this tea estates also possess organic carbon at higher level. These findings strengthen the argument that concentration of organic matter is one of the factors determining factor for mineralization more potentially mineralizable organic P. Organically managed tea estates stimulated faster mineralization with shorter half-life and mean residence time with higher enzyme activities leading to organic P mineralization. Overall results showed that in few cases 0.125(M) NaOH+ 0.05 (M) EDTA extractable organic p was identified as most contributing P pool but in other cases 0.5 (M) NaOH+ 0.05 (M) EDTA extractable organic p was identified as most potential. But in most of the cases, 1 (M) NaOH + 0.05 (M) EDTA extractable organic P was qualified as potential contributor as measured by predicted mineralized P.

CONCLUSION

0.5 (M) NaOH + 0.05 (M) EDTA extractable organic P was qualified as most potential P source. Thus, this extractant may putatively be selected as suitable extractant for potential P estimation under organic production systems. More aged organic farms from diverse agro ecosystems along with unfertilized forest soil may be attempt to fine tuning the research.

Moreover, soil test P should be correlated with crop response under organic production systems.

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Organic recycling of leaf litter for integrated nutrient management in *Amorphophallus paeniifolius* in an agroforestry home garden of southern Kerala

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Agroforestry gardens are characterized by the high organic matter production *insitu* especially in the form of litter from the perennial components included in the system. Litter decomposition studies have revealed nutrient release from litter, the period varying with the species, soil biology and environmental characteristics, but remains the major pathway for enrichment of the soil nutrient pool. Recycling and use of litter as organic sources in crop production have little been exploited and in this background the investigation on the use of leaf litter as nutrient source in *Amorphophallus paeniifolius* Dennst raised as understory crop in a selected agroforestry home garden of Southern Kerala, India was attempted.

METHODOLOGY

The field experiment was laid out in randomized block design in Ummannur Panchayat, Vettikavala block, Kollam district, Kerala located in the agro ecological unit of Southern and Central laterites $9^{0}16'$N latitude, $76^{0}37'$E longitude and 91.44m above MSL. Leaf litter collected from the different tree species in the home garden was mixed with cow dung in the ratio of 10: 1 and composted using earthworms, *Eudrillus eugeniae.* The compost obtained was analyzed for the NPK contents and the composted litter (1 .31: 0.89:0.27 % NPK) was used as nutrient source for *Amorphophallus* at varying levels of nitrogen substitution 25, 50 75 and 100 % (T1, T2, T3, T4) compared with 100 % inorganic nutrition (T5) as per POP recommendations of 100:50:150 kg NPK/ha in four replications. The crop was planted in March 2014 and treatments were imposed after sprouting. Cultural practices were adopted as per the package recommendations and crop was ready for harvest in November 2014.Observations on plant growth characters, yield were recorded and changes in soil nutrient status were assessed. The data were statistically analysed so as to assess the response of *Amorphophallus* to the litter compost added.

RESULTS

The effect of litter compost application as nutrient source in *Amorphophallus* is presented in Table.1. It is evident that litter compost did not have any significant influence on the vegetative growth, although 100 % chemical fertilizer treatment showed slightly better growth at 5MAP. On nearing harvest, tallest plants were observed in the treatments receiving 75% N as litter compost while canopy spread maximum in the 50 % N substituted plants. It is inferred that the easily available forms of nutrients in the chemical fertilizers have triggered better growth initially. However, significant variations were recorded in per plant yields and per hectare yields. Yield characters of corm sizes, although non-significant were comparatively higher in the 50% N substitution treatment indicating that the benefits of the inorganic and organic sources had a cumulative effect on the corm weights. The nutrient requirements were readily made available from the chemical sources in the early stages while the beneficial effects of microbial activity and hormones and documented in vermicompost (Ansari, 2008) would have influenced the yield

Table 1. Plant growth characters of *Amorphophallus* in response to the levels of nitrogen substitution

Treatment	Plant height (cm)			Canopy spread (cm)			Height of corm (cm)	Weight/ plant kg	Yield t/ha
	3 MAP	5 MAP	7 MAP	3 MAP	5 MAP	7MAP			
T1	79.05	90.95	95.37	132.73	136.80	140.90	11.73	5.65	23.44
T2	80.33	90.17	95.93	139.18	145.88	149.28	12.23	7.55	32.18
T3	81.22	93.08	97.82	127.50	131.55	106.93	11.08	6.25	22.81
T4	75.65	89.53	95.15	134.25	138.55	144.05	11.18	6.24	24.06
T5	75.00	127.33	93.18	133.05	138.23	143.22	12.10	7.03	31.04
CD	NS	NS	NS	NS	NS	NS	NS	0.95	6.29

Table 2. Changes in soil properties with varying levels of litter compost application in *Amorphophallus*

Treatments	pH	EC	Organic C %	Available N kg/ha	Available P kg/ha	Available K kg/ha
T1	6.24	0.15	0.76	184.65	332.87	130.37
T2	6.33	0.15	0.88	211.32	436.46	124.77
T3	6.85	0.21	0.73	169.53	419.48	209.03
T4	6.70	0.17	0.81	167.23	410.55	156.65
T5	6.53	0.24	0.78	151.99	316.89	162.14
CD	0.28	0.05	NS	NS	65.89	48.63

performances. Yields with inorganic nutrition (31.04 t /ha) was on par with the level of 50 %substitution (32.18 t/ha) while that of 100 % organic nutrition was the least (24.06 t/ ha). Bairagi and Singh (2013) have reported that in *Amorphophallus* organic manures should be advocated either as sole or in combination for sustaining yield potential of the crop. The beneficial effects of organic sources is also evident in the soil properties after the experiment (Table 3). The organic C, available NP and K status were higher than the chemical applied plots bringing to light the beneficial effects organic nutrition has in sustaining the soil health and the feasibility of using litter compost as nutrient source in *Amorphophallus*. Economic analysis with litter compost use revealed higher benefit cost ratios with 50 % substitution (2.72) compared to chemical fertiliser use (2.50). Taking into account the economics and benefits accrued with the organic recycling, the leaf litter that is available in plenty and at times that are removed from the agroforestry system can be recycled as compost and can be recommended as a viable nutrient source for *Amorphophallus*cultivated in agroforestry systems.

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Designing of efficient and profitable rice–based cropping systems for organic growers of Sikkim Himalayas, India

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Maize and rice are the two principal food crops of Sikkim. Farmers of the state mostly grow rice and maize in rotation causing low productivity of these crops mainly due to high nutrient demand of both the cereal crops. Replacing maize/ rice completely by any other crop is practically not feasible. Hence, diversification of rice based system by inclusion of short duration vegetable crops offers very good opportunities to get higher production along with variable produce without increasing the cost of cultivation. Since, sustainability of the production system depends on the rational use of soil recourses, it is necessary to develop and adopt soil management technologies that increase soil organic matter contentsand biological activities. Induction of green manure andleguminous crops in the existing rice-maizebased systems can improve the soil fertility and crops productivityon sustainable basis. Hence, temporal intensification by incorporation of high value crops in rice–maize system is the need of the hour for sustaining the crop productivity and profitability in changing climatic condition. Keeping these points in mind, present study was undertaken at Research Farm, ICAR Research Complex for NEH Region, Sikkim Centre, Tadong, Gangtok, Sikkim (India). New cropping system may help to farmers grow two or more currency (high value) crops in a year, where before they could only grow rice/maize. The new system combines cereals and vegetables, which may secure livelihoods and generate more profit per unit are and time.

METHODOLOGY

A fixed plot field experiment was conducted during 2013-15at Research Farm, ICAR Research Complex for NEH Region, Sikkim Centre, Tadong, Gangtok, Sikkim (India). situated at a latitude of 27^{o}32' N and longitude of 88^{o}60' E altitude of 1350 meters amsl. Seven cropping systems *viz.,* rice-maize, rice-fenugreek (leafy vegetable)-maize (green cobs), rice- broccoli-*Sesbania* (green manuring), rice-vegetable pea-maize (green cobs), rice-coriander (green leaf)-cowpea (vegetable), rice-fenugreek (leafy vegetable)-baby corn and rice-buckwheat were tested under three replications in randomized block design. All the cropswere grown as per the recommended organic package of practices of the region. Observations on all the tested crops were recorded as per the standard procedures. System productivity (SP) or rice equivalent yield (REY) and production efficiency (PE) of various cropping systems were calculated as per the following formulae:REY (t/ha) = Productivity of the component crop (kg/ha) x Price of component crop (Rs./kg)/Price of rice (Rs. /kg); PE (kg/ha/day) = REY (kg/ha)/365.

RESULTS

Inclusion of legumes in the rice based cropping system significantly increase the yield attributing characters and yield of rice after three year of experiments under organic management condition of Sikkim Himalayas (Table1). Among the diversified cropping systems, significantly higher values of yield attributing parameters and grain yield of rice (4.2 t/ha) were recorded with rice-broccoli-*Sesbania* cropping system. Thus, adoption of rice-broccoli-*Sesbania* cropping leads to 20% higher rice grain yield as compare to that recorded with existing rice-maize systems in irrigated ecosystems of Sikkim Himalayas. Legume crops grown either for greenmanuring or fodder or grain production areknown to play an important role in maintaining the soil fertility. They leaveconsiderable residual nitrogen in the soil, thereby increasing the yields of succeedingcrops in addition to the improvement in soilphysical properties (Yadav *et al.*, 2013).In general all the

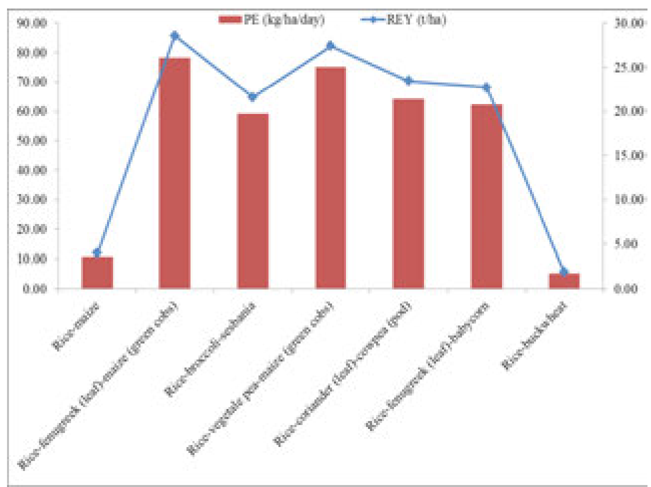

Fig. 1. Effect of cropping system on system productivity and production efficiency

Table 1. Effect of cropping systems on yield attributes and yield of rice

Cropping systems	Filled grains/ panicle	Panicles/hill	Panicle length (cm)	Grain yield (t/ha)
Rice-Fenugreek-Maize (Cobs)	126	9.07	22.6	3.9
Rice-Vegetable pea-Maize	125	9.67	22.8	4.0
Rice-Coriander-Cowpea	143	8.75	22.1	3.9
Rice-Fenugreek (leafy vegetable)-Baby corn	134	9.12	23.6	4.0
Rice-Broccoli-*Sesbania* (GM)	145	11.17	24.7	4.1
Rice-Buckwheat	119	8.25	22.2	3.8
Rice-Maize	113	9.07	21.3	3.5
SEm±	3.14	0.54	0.5	0.05
CD (P=0.05)	7.91	1.36	NS	0.12

GM: Green manuring

tested intensified cropping systems resulted in higher REY and PE over existing rice-maize system (Fig.1). However, among the cropping sequences, rice-fenugreek (leafy vegetable)-maize (green cobs) recorded the maximum REY (82.2 t/ha) followed by rice - vegetable pea - maize (green cob). Similarly, PE (25.3 kg/ha/day) was also higher in rice-fenugreek (leafy vegetable)-maize (green cobs) followed by rice-vegetable pea-maize (green cobs) and the lowest was under rice-buckwheat. Crop yield, duration and sale price of the produce greatly influenced the overall return and PE of various systems (Mukherjee, 2010) and resulted in higher production efficiency.

CONCLUSION

Diversification of existing rice/maize based cropping system by inclusion of legumesenhanced system productivity and production efficiency. Therefore, it is recommended that growers canrationally select, rice-fenugreek (leafy vegetable)-maize (green cobs) or rice - vegetable pea - maize (green cob) in irrigated ecosystems of Sikkim Himalayas for improving system productivity and economic returns.

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Status of organic agriculture in Mizoram

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The role of organic agriculture, whether in farming, processing, distribution, or consumption, is to sustain and enhance the health of ecosystems and organism from the smallest microbe in the soil to the human beings (Sharma, 2001). Mizoram is one of the 'Seven Sisters' states of the North East Region in India. These are three agro climatic zones in Mizoram (i) Humid temperate sub alpine zone (ii) Humid subtropical zone (iii) Humid Mild-Tropical Zone. Total forest cover area 15, 93700 ha, Gross crop area 1, 05575 ha, net sown area 94187 ha, and irrigated area 15,749 ha net irrigated area 11,388 ha, area under jhum 44,947 ha, number of cultivators families 88,819 families (Statistical Abstract 2009-10) Jhuming or shifting is the main agricultural practice on the hill slopes of the area. State is gifted with different climate at different altitudes suitable for quality production of vegetables and spices. Naturally, organic farming system is looked upon as one of the means to remedy these maladies there. Here is a case study with special reference to organic farming in the Mizoram state of NEH region.

METHODOLOGY

Survey of Mizoram was conducted during 2010-11 and 3 districts namely Aizwal, Kolasib and Mamit were selected using multistage stratified random sampling method. Again 2 blocks from each district namely Mamit and Zavylnuam from Mamit, Tlangnuam and Thingsulthlian from Aizwal, Thingdawl and Bulkhawthlir from Kolasib districts were selected using the same sampling procedure. Thus a total of 6 blocks were chosen for the proposed study. Thereafter 4 village from each block and 10 farm families from each village were selected. Finally a total of 240 households were selected for collecting the data. Information were collected with respect to the area under organic, inorganic and organic+ inorganic agriculture of each farm group on the prescribed and well tested questionnaire through interview of the head of the farm families. The productivity of rice and maize crop was recorded as per organic classification. The simple average and percentage were used as analytical tools in processing the data.

Table 1. Socio-personal characteristics of respondents in Mizoram 2010-11

Particulars	Aizwal		Kolasib		Mamit		Average	
	No.	%	No.	%	No.	%	No.	%
Age								
Young (<25 years)	18	22.50	26	32.5	21	26.25	65	27.08
Middle (25 - 50 years)	45	56.25	38	47.5	44	55.00	127	52.92
Old (> 50 years)	17	21.25	16	20.00	15	18.75	48	20.00
Education								
Llliterate	19	23.75	13	16.25	11	13.75	43	17.92
Primary	9	11.25	17	21.25	13	16.25	39	16.25
High School	37	46.25	29	36.25	29	36.25	95	39.58
Graduate	8	10.00	12	15.00	17	21.25	37	15.42
Post Graduate	7	8.75	9	11.25	10	12.5	26	10.83
Land Farm Size (ha.)								
Small (< 5)	49	61.25	53	66.25	58	72.50	160	66.67
Medium (5 - 10)	23	28.75	16	20.00	13	16.25	52	21.67
Large (>10)	8	10.00	11	13.75	9	11.25	28	11.67
Farm Family Labour								
Male	110	45.83	90	37.50	85	35.42	285	118.75
Female	90	37.50	83	34.58	76	31.67	249	103.75
Type of Occupation								
Agriculture only	32	40.00	43	53.75	39	48.75	114	110.00
Agriculture+ Livestock	15	18.75	11	13.75	15	18.75	41	38.75
Agri + Poultry+ Fish	9	11.25	8	10.00	6	7.50	23	23.75
Agri.+service+Hort.	13	16.25	12	15.00	11	13.75	36	35.83
Agri.+service+Business	11	13.75	6	7.50	9	11.25	26	25.00
Land use pattern								
Organic	58	72.50	71	88.70	63	78.70	192	80.00
Inorganic	22	27.50	9	11.30	17	21.30	48	20.00

Table 2. Rice and maize productivity underorganic and inorganic cultivation in Mizoram (2010-11)

District	Paddy (kg/ha)		Maize (kg/ha)		Increase over organic (%)	
	Organic	inorganic	Organic	Inorganic	Paddy	Maize
Aizwal	1210	1550	990	1250	28.1	26.26
Kolasib	1390	1580	1120	1390	13.67	24.11
Mamit	1240	1490	1230	1480	20.16	20.33
Average	1280	1540	1113	1373	20.31	23.35

RESULTS

The data presented in Table 1 showed that 72.5, 88.7 and 78.7 percent of farmers were following organic agriculture in Aizwal, Kolasib and Mamit districts while the corresponding figures for inorganic practice were 27.5, 11.3 and 21.3 percent for Aizwal, Kolasib and Mamit respectively. The average of all the districts indicated organic and inorganic cultivators to be 80% and 20% respectively in the survey districts. The average productivity of rice and maize shown in Table 2 indicated marginal variation in productivity of these crops between both farm groups. The marginal disparity in yield was because of the consumption of chemical fertilizers less than 22kg/ha in case of inorganic growers.

CONCLUSION

A country like India can enjoy a number of benefits from the adoption of organic farming in this region like premiums price for the organic products, conservation of the natural resources in terms of improved soil health and water quality, prevention of soil erosion, preservation of natural and agro-biodiversity apart from socio-economic benefits in terms of employment generation, food and nutritional security to rural households particularly to small and marginal farmers by reducing their dependency on external inputs. With the sizable acreage under naturally organic/default organic cultivation, Mizoram has bright prospects for organic production of crops.

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Extended Summaries Vol. 1 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Prospects for small-holders' entrepreneurship through eco-organic agriculture

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Smallholder farmers are vital for India's agriculture and rural economy (Sikka, 2014). The average size of operational holding has been steadily declining in the country. The contribution of small farmers to total farm out put in India exceeds 50 per cent, while they cultivate about 45 per cent of land. Small farmers are the ones who have lesser capital but higher use of labour and other family-owned inputs, and usually have a higher index of cropping intensity and diversification. However, the constraints to progress of small-holders include, declining productivity, low profitability, sustainability, degradation of natural resources, *etc*. Despite a general archetype of setbacks and impediments, there are some beacons of light, who have overcome the seemingly insurmountable situations, mainly by way of being more eco-friendly and innovative (Abraham, 2014). Soil health care is fundamental to sustainable intensified farming and the concepts of eco-organic agriculture, entails productivity and economic stability through promotion of biological diversity because of the potential for compensation among components of the system. The phenomenon of biological and economical bufferings in the farming systems is the emergent need of the present day agro-eco-technology with alternatives that depend more heavily on internal renewable resources available on the farm. The certified SHIATS Model Organic Farm (SMOF) which is currently in the 8th consecutive year [Certificate No. ORG/SC/1009/001070, valid till May 2017], demonstrates an integration of over 75 species under multiple cropping systems with immense diversity. It has been observed that invariably all the bio-organic formulations either singly or in combinations showed appreciable improvement in crop productivity which were either on a par with or even better than the conventional technologies, taking into consideration both quantum and quality. Some of these bio-organic inputs also proved to possess plant protecting properties (Abraham *et al*., 2015).Choice of enterprises for any farming community is highly desirable, which enables flexibility and adaptable mechanism to work. At the SMOF persistent endeavours to explore feasible enterprises are attempted and 2 of the successful proponents are presented in this paper. Abraham *et al*., 2013reported that there was immense potential for small holder farmers to become entrepreneurs through organic farming in the Asia-Pacific, particularly in the NEPZ (North Eastern Plain Zone) under the Indo Gangetic plains of Asia-Pacific regions.The model [Integrated Rice-Duck Farming System (IRDFS)] is fairly stabilized and standardized as an on-station as well as on-farm trialsover 4 years. The salient features under the IRDFS include the important practices, which include the introduction of 50 ducklings big/ ha (200 ducklings/ha), released 10 days after transplanting of rice crop, on a daily basis for about 11 hours (6 am to 5 pm). The positive consequence was in the form of improvement in some of the fundamental bio-physical factors of rice cropping system, like the control of most of the weeds and insects. Further, reduced cost of labour and inputs and an augmentation of a better moisture regime in the rhizosphere and the persistent maintenance of oxidized zone through the paddling movement of webbed feet of the ducklings were acceptable by the farmers. The droppings of these birds undoubtedly improved the fertility leading to reduction in the manurial requirement coupled with the enhancement of productivity of *japonica* rice.The availability of eggs and meat as valuable food or income from this system certainly proves as an acceptable alternative for farmers, through a resourceful use of water and family labour, which was adopted in a small scale by 15 odd farmers from Jasra Block of the district. At SMOF, while conducting the economic analysis it was observed that against a gross expenditure of ₹12250 *big /ha* (₹49,000 /ha) in the 1st year, the income was ₹10000 *big/ha* (₹40,000 /haseason). It had been extrapolated that in a period of 5 years (with two crops of *japonica* rice per year) a revenue generation of ₹100,000 *big/ha* (₹400,000 /ha) makes this system potentially feasible for farmers. The economic analysis of the *japonica* rice component revealed that against an expenditure of about ₹7075 *big/ha* (₹28,300 ha^{-1}) a net income of ₹31625 *big /ha* (₹1,26,500/ha) with a highly desirable BCR of 5.46 can be obtained (the support price offered to *japonica* rice is ₹30 to 40 kg). Currently, it is being implemented by the 30 adopted farmers belonging to 2 blocks, *viz*., Jasra and Kaundhiara, who produce, process and market *japonica* rice through the active facilitation of the AOAC (Allahabad Organic Agriculture Cooperative under the *aegis* of the MSCNE (Makino School of Continuing and Non-Formal Education), which has a good premium in nearby cities of Varanasi and the capital New Delhi.Within the limited area, the diverse land use system by raising the woody perennials with shrubs and herbs through alley cropping, boundary plantings and live hedges as a buffer zone, enables harvest of fuel wood and green leaf manure, besides aiding as wind breaks and enriching soil. The woody portion of prunings from Leucaena, guava, gooseberry, mango, *etc.* are chipped at the wood chipper-cum-fermenter unit for utilizing as oyster mushroom substrate, besides the usual rice and wheat straw. The oyster mushroom unit generated a mean annual revenue of ₹67560.00. The meanannual total quantum of vegetable crops through the 3 seasons of about 4.8 tand fruit crops of about 450 kg was worth ₹137203.87 and 26970.00 respectively. Taking into consideration the cost of certification, which is mandatory for trading, the annual income may be slashed to about ₹2, 25,000.00, which is an acceptable figure for a small net cultivated area of 1 acre. Nevertheless, in the current times the emergent up-market trends, particularly with premium available for food crops can open greater prospect for agri-business in the peri-urban sectors. The prospect of becoming entrepreneurs – even if it is for a few weeks out of the 52 in a year or half a season, becomes a reality, once the farming systems are able to cross threshold of optimal production with ample diversity. Thus, quality addition to livelihoods through the marketing of surplus produce from a homestead or farmstead system lies in the diversity(Abraham *et al*., 2013). It may be concluded that the SMOF is a model depicting both food and nutrition security proving that the sustainable livelihoods of marginal and small farmers is feasible to cater to some of the necessities of a homestead, including feed/fodder (for the piggery / duckery / poultry units), fuel as well as certain high value crops like mushroom and exotic vegetables (broccoli, pockchoi, *etc.*), apart from the scope of generating some additional revenue through an integrated organic farming system.

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Effect compost on growth and yield of deshi organic cotton

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The ill effects of modern agriculture forced people, especially in the countries with high income economies to demand food grown without fertilizer and pesticides and this paved the way for organic farming (Prasad, 2005). Organic agriculture does not imply the simple replacement of synthetic fertilizers and other chemical inputs with organic inputs and biologically active formulations. In healthy soil the biotic and abiotic components covering organic matter including soil life, mineral particles, soil air and water exist in a stage of dynamic equilibrium and regulate the ecosystem processes in mutual harmony by complementing and supplementing each other (Palaniappan and Annadurai, 2006). Cotton contributes 29.8

% of the Indian agricultural GDP. Still there exits large potential for export of raw cotton and value added products. In current scenario farm yard manure become constraints in organic cultivation due to less availability of livestock in rainfed area of Maharashtra. Hence, it is necessary to find out alternative to farm yard manure by using crop residue of major cultivated crops like soybean straw, pigeonpea stalk, cotton stalk and many other prevailed on the farm. It is real pathway to sustainable agriculture by recycling the farm waste backs to soil. The study was under taken with the objectives to study the effect of compost on growth and yield of organic cotton with impact on soil health.

METHODOLOGY

A field experiment was carried out at Agronomy farm, Dr. PDKV, Maharashtra, Akola during *kharif* season of 2011-12 and 2012-13 on clayey soil. The experiment was laid out in factorial randomize block design with three replications. FYM, Soybean and Pigeonpea composts were applied to *deshi* organic cotton var. AKA-8 with three levels of recommended dose of nitrogen i.e. 100, 125 and 150 % RDN and dose of phosphorous was adjusted with phosphor compost.

RESULTS

Experimental results revealed that growth characters plant height and sympodial branches were higher with FYM application which was found at par with soybean compost. The yield contributing attributes i.e. bolls/ plant (17.59) and seed cotton yield/plant (36.19 g) were found significantly higher with FYM application over pigeon pea compost but found at par with soybean compost. Seed cotton yield was found significantly higher (1.93 t/ha) with FYM than pigeon pea compost (1.66 t/ha), whereas it was found at par with soybean compost (1.91 t/ha).The nutrient management through organic sources imposed significant effect on plant growth characters of *G. arboreum* cotton. Application of 150 % recommended dose of nitrogen recorded significantly vegetative and yield contributing growth and over 100 % RDN and found statistically at par with 125 % RDN. The interaction effect between Compost and Nitrogen levels was not reached to level of significance in all growth and yield parameters. Significantly higher Gross Monetary Return was obtained with application of FYM over pigeon pea compost and found at par with Soybean compost application. Whereas higher NMR and B: C ratio was recorded with Soybean compost application and lowest NMR and B: C ratio was recorded with of FYM.
This could be the better result might be due to nitrogen was released slowly over the growing season and increase in availability of nutrients, which promoted cell division and enlargement and synthesis of more carbohydrates. Compost contains micronutrients which could also have enhanced plant growth. These results are in conformity with those reported by Prakash *et al.* (2001).

CONCLUSION

On the basis of above findings, it could be concluded that use of organic sources i.e. soybean straw compost was better alternative to FYM for maximize yield, economic returns by nutrient recycling.

Table 1. Growth, yield and economics of organic cotton (*Kharif*, 2011 and 2012)

Treatments	Pl. Height (cm)	Symp br/pl	Bolls/ plant	SCY (g/pl)	SCY (t/ha)	GMR Rs/ha	NMR Rs/ha	B:C Ratio
Source of compost								
C_1 – Soybean Compost	199.07	23.74	16.89	35.81	1.91	76430	36474	1.91
C_2 – Pigeonpea Compost	192.64	22.72	15.91	31.29	1.66	66381	27384	1.71
C_3 – FYM	202.31	23.97	17.59	36.19	1.93	77230	22734	1.42
'F' TEST	SIG	NS	SIG	SIG	SIG	SIG	SIG	—
SEm ±	2.10	0.43	0.32	0.65	0.03	1557	1557	—
CD (P= 0.05)	6.29	1.28	0.95	1.93	0.10	4449	4449	—
Levels of nitrogen								
N_1 (100 % N)	190.81	22.34	16.09	32.79	1.74	69760	29461	1.75
N_2 (125 % N)	197.63	23.83	16.83	34.84	1.86	74223	29514	1.69
N_3 (150 % N)	205.59	24.26	17.48	35.67	1.90	76059	27617	1.60
'F' TEST	SIG	SIG	SIG	SIG	SIG	SIG	NS	—
SEm ±	2.10	0.43	0.32	0.65	0.034	15587	1557	—
CD (P= 0.05)	6.29	1.28	0.95	1.93	0.102	449	—	—
Interaction (A x B)								
'F' TEST	NS	NS	NS	NS	NS	NS	NS	—
CHECK								
Absolute control	170.75	18.71	11.27	19.41	1.04	41598	16122	1.63

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Sustainability of soil health for growth and productivity of certified organic rice [*Oryza sativa* (L.) sub sp. *Japonica*]

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In India *japonica* rice [*Oryza sativa* (L.) sub sp. *Japonica*] grown total 21% among the Asian countries. Continuous and increased/indiscriminate use of sole chemical fertilizers lead to several harmful effects on the soil environment, ground and surface water and even atmospheric pollution, reducing the productivity of the soil by affecting soil health in terms of physical, chemical and biological properties. Further, untamed and excessive use of toxic chemicals has shown ugly consequences expressing erratic pattern in the environment in general and the soil system in particular, which has drastically changed the soil biota (Abraham, 2009). It has become important to use available organic manures efficiently through suitable application methods, time of application and follow integrated nutrient management practices by combining inorganic fertilizers with organics such as FYM, green manure and crop residues (Khan *et al.,* 2006). Therefore, the present investigation was undertaken to study the "Sustainability of soil health for growth and productivity of organic rice".

METHODOLOGY

The experiment was carried out during *kharif* season 2013 at Crop Research Farm, SHIATS Model of Organic Farm (SMOF), Department of Agronomy, Allahabad School of Agriculture, Sam Higginbottom Institute of Agriculture, Technology and Sciences, Allahabad (U.P.). The soil was sandy loam, pH of soil was 8.0 with 0.36% OC, N 0.031%, P 13.05 kg/ha, K 165.55 kg/ha, OS 8.84 ppm, Zn 0.65 ppm and Mn 7.81 ppm. The experiment was laid out in randomized block design with three replications, having four planting methods, *viz.,* conventional transplanted rice (CTR, 20 × 15 cm), system of rice intensification method of transplanting [SRI(t), 20 × 20 cm], direct seeded rice (DSR, 20 × 10 cm) and machine transplanted rice (MTR, 30 × 10 cm); two green manure crops, *viz., dhaincha* (*Sesbania aculeata* L.) and sunnhemp (*Crotalaria juncea* L.); two liquid forms of organic manures, *viz., Panchagavya* (P) and Fish amino acid (FAA). *Panchagavya* was prepared with a mixture of five components in the ratio of 5:4:3:2:1, *viz.,* cow dung, cow urine, cow milk, curd and ghee respectively and twelve ripe bananas. Fish amino acid was prepared in the ratio of 1:1, with fish waste (3.0 kg) and jaggery (3.0 kg). *Panchagavya* (3%) and Fish amino acid (3%) were fermented for 20 days and applied after extraction as foliar spray at 20, 35 and 50 days after sowing/days after transplanting as per the treatment. There were total 16 treatment combinations in all. The variety *Akitakomachi* (*japonica* rice) was sown as experimental crop.

RESULTS

The organic carbon status enhanced between 13.89 to 38.89% and total nitrogen 12.90 to 38.71% as a result of planting methods, green manure crops and liquid forms of organic manures. The available phosphorus was increased between 31.88 to 76.63% over the pre-experimental stages. Available potassium was increased by 78.47 to 105.38% as influenced by the three factors. The combined effect of planting methods, green manure crops and liquid forms of organic manures increased secondary and micro nutrients, *viz.*, available organic sulphur (26.47 to 90.61%), zinc (44.62 to 100.00%), iron (33.44 to 135.58%) and manganese (43.41 to 124.07%) (Table 1). Green manure with *Sesbania aculeata* L. and *Crotalaria juncea* L. may have increased more atmospheric N biologically in the soil and also higher amount of organic matter, which is good indicator of soil fertility and improving the status of available nutrients in the soil (Dwivedi *et al.*, 2005). Significantly maximum number of tillers/hill 10.80 was recorded in the treatment T_6 [SRI (t) +*Sesbania aculeata* L. +Fish amino acid], which was 440% higher compared to T_{11} (DSR+*Crotolaria juncea* L. +*Panchagavya*) and T_{12} (DSR+*Crotolaria juncea* L. +Fish amino acid) with 2 tillers/hill (exactly same values). However, T_{14} (MTR+*Sesbania aculeata* L.+Fish amino acid), T_{13} (MTR+*Sesbania aculeata* L.+*Panchagavya*), T_1 (CTR+*Sesbania aculeata* L.+*Panchagavya*), T_2 (CTR+*Sesbania aculeata* L.+Fish amino acid), T_{15} (MTR+*Crotolaria juncea* L.+*Panchagavya*), T_3 (CTR+*Crotolaria juncea* L.+*Panchagavya*), T_4 (CTR+*Crotolaria juncea* L.+Fish amino acid), T_{16} (MTR+*Crotolaria juncea* L.+Fish amino acid), T_5[SRI(t)+*Sesbania aculeata* L.+*Panchagavya*] and T_8 [SRI(t)+*Crotolaria juncea* L.+Fish amino acid] were statistically at par with T_6 [SRI(t)+*Sesbania aculeata* L.+Fish amino acid] (Table 2). Maximum number of tillers per square meter generally registered in the treatments with SRI method of transplanting component, which may be due to younger seedlings. Significantly higher plant dry weight of 9.250 g/hill was registered in the treatment T_6 [SRI (t) +*Sesbania aculeata* L. +Fish amino acid], which was 296.48% higher than T_{11} (DSR+*Crotolaria juncea* L. +*Panchagavya*) with 2.333 g/hill (Table 2). The combined effect of the 3 factors in the trial recorded significantly higher grain yield, straw yield and harvest index of rice with 2.10 t/ha in the treatment T_6 [SRI(t)+*Sesbania aculeata* L.+Fish amino acid], which was 195.77% higher than T_{12} (DSR+*Crotolaria juncea* L.+Fish amino acid) with 0.71 t/ha. However, T_2 [SRI (t) +*Sesbania aculeata* L. +Fish amino acid], T_1 (CTR+*Sesbania aculeata* L. +*Panchagavya*) and T_{14} (MTR+*Sesbania aculeata* L. +Fish amino acid) were statistically at par with T_6 [SRI (t) +*Sesbania aculeata* L. +Fish amino acid].

CONCLUSION

In the study of present investigation indicated that utilization of green manure crops as pre *japonica* rice has been found to be improving soil available nutrients, and obtaining higher grain yield of organic *japonica* rice.

Table 1. Soil chemical status before sowing/transplanting and after harvesting of organic rice as influenced by all the 3 factors

Treatment	Available OC (%)	Available N (%)	Available P_2O_5 (kg/ha)	Available K_2O (kg/ha)	Available OS (ppm)	Available Zn (ppm)	Available Fe (ppm)	Available Mn (ppm)
Pre-experimental stage								
	0.36	0.031	13.05	165.55	8.84	0.65	6.52	7.81
Post-harvest soil status								
T_1	0.45	0.038	20.12	313.10	15.65	1.01	12.40	14.22
T_2	0.48	0.041	19.05	336.00	14.95	1.22	12.50	13.10
T_3	0.46	0.039	18.30	338.00	16.85	1.24	12.36	16.26
T_4	0.43	0.037	23.05	302.13	15.73	1.20	12.36	16.26
T_5	0.44	0.038	22.01	320.11	15.52	1.24	14.20	15.00
T_6	0.50	0.043	22.50	340.00	16.44	1.02	15.36	17.50
T_7	0.41	0.035	22.03	295.45	13.07	0.96	14.20	17.04
T_8	0.42	0.036	18.15	310.02	12.38	0.98	10.00	16.40
T_9	0.50	0.043	20.04	308.44	11.21	1.13	10.64	14.22
T_{10}	0.45	0.038	18.51	333.33	11.18	1.20	9.86	11.20
T_{11}	0.49	0.042	20.22	322.21	13.21	0.96	10.88	13.14
T_{12}	0.43	0.037	17.21	309.18	13.23	0.96	8.70	14.40
T_{13}	0.45	0.038	17.60	330.33	15.34	1.20	9.50	15.30
T_{14}	0.46	0.039	22.07	324.50	14.14	1.30	9.30	12.34
T_{15}	0.45	0.038	22.00	305.55	15.16	1.10	12.30	13.12
T_{16}	0.42	0.036	21.00	311.75	13.11	0.94	10.70	13.21

Note: [T_1 (CTR), T_5 (SRIt), T_9 (DSR) and T_{13} (MTR) + (*Sesbania aculeata* + *Panchagavya*)]; [T_2 (CTR), T_6 (SRIt), T_{10} (DSR) and T_{14} (MTR) + (*Sesbania aculeata* + Fish amino acid)]; [T_3 (CTR), T_7 (SRIt), T_{11} (DSR) and T_{15} (MTR) + (*Crotolaria juncea* + *Panchagavya*)]; [T_4 (CTR), T_8 (SRIt), T_{12} (DSR) and T_{16} (MTR) + (*Crotalaria juncea* + Fish amino acid)]

Table 2. Growth and productivity of organic *japonica* rice as influenced by all the 3 factors

Treatment		No. of tillers/hill	Dry weight (g/hill)	Grain Yield (t/ha)	Straw yield (t/ha)	Harvest Index (%)
T_1:	CTR + *Sesbania aculeata* + *Panchagavya*	10.13b	8.116b	1.88b	3.23b	36.73a
T_2:	CTR + *Sesbania aculeata* + Fish amino acid	10.00b	8.900b	2.08b	3.66b	36.54b
T_3:	CTR + *Crotalaria juncea* + *Panchagavya*	9.93b	4.966	1.18	2.13	35.15b
T_4:	CTR + *Crotalaria juncea* + Fish amino acid	9.73b	4.683	0.96	1.91	33.47
T_5:	SRI(t) + *Sesbania aculeata* + *Panchagavya*	9.13b	6.400b	1.53	2.76	35.66b
T_6:	SRI(t) + *Sesbania aculeata* + Fish amino acid	10.80a	9.250a	2.10a	3.90a	35.02b
T_7:	SRI(t) + *Crotalaria juncea* + *Panchagavya*	7.66	5.183	1.21	2.28	34.67b
T_8:	SRI(t) + *Crotalaria juncea* + Fish amino acid	8.40b	3.833	0.91	1.80	33.45
T_9:	DSR + *Sesbania aculeata* + *Panchagavya*	2.06	2.650	0.83	1.78	31.68c
T_{10}:	DSR + *Sesbania aculeata* + Fish amino acid	2.13	2.566	0.83	1.75	32.26
T_{11}:	DSR + *Crotalaria juncea* + *Panchagavya*	2.00c	2.333c	0.80	1.63	32.58
T_{12}:	DSR + *Crotalaria juncea* + Fish amino acid	2.00c	2.450	0.71c	1.55c	31.71
T_{13}:	MTR + *Sesbania aculeata* + *Panchagavya*	10.40b	7.000b	1.58	2.95b	35.12b
T_{14}:	MTR + *Sesbania aculeata* + Fish amino acid	10.66b	7.566b	1.73b	3.06b	36.53b
T_{15}:	MTR + *Crotalaria juncea* + *Panchagavya*	10.00b	5.600	1.23	2.41	33.85
T_{16}:	MTR + *Crotalaria juncea* + Fish amino acid	9.66b	5.150	1.20	2.15	35.78b
	CD (P= 0.05)	2.48	3.623	0.50	0.95	2.69

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Extended Summaries Vol. 1 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Impact of organic nutrient management on productivity and profitability of scented rice

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Basmati rice production in India is 8.7 million tonnes from an area of 3.8 m ha with an export of 3.70 million tonnes, bringing Rs 27,597.87 crore as foreign exchange to the country (Anonymous, 2014-15). The organic nutrient management has been considered as one of the best options for protecting and sustaining soil health and productivity and is gaining lot of importance in present-day Agriculture. Significant improvement in soil physico-chemical and biological properties have been reported in several organic farming experiments (Ramesh *et al.,* 2008). Under organic farming package, there is possibility to grow scented rice due to high demand of organic production. Keeping all these points in view, the present investigation was undertaken to study the effect of organic nutrient management on growth, yield and quality of scented rice with the following objectives:

METHODOLOGY

The experiment was conducted at Agronomy Research

Table 1. Grain yield, protein content, GMR, NMR and B: C ratio as influenced by varieties and organic nutrient management

Treatment	Grain yield (kg/ha)	Protein content (%)	Gross monetary returns (Rs/ha)	Net monetary returns (Rs/ha)	Benefit: Cost Ratio
Varieties					
V_1 (Pusa Sugandh 5)	2,828	7.86	89786	35,015	1.65
V_2 (Pusa Basmati 1509)	2,934	7.88	93063	38,293	1.70
SEm±	13.1	0.02	-		
CD (P=0.05)	38.4	NS	-	-	
Organic nutrient management					
ONM_1 (100 % FYM)	2,952	7.88	93701	35,201	1.60
ONM_2 (100 % Vermicompost)	3,330	7.90	105647	31,546	1.43
ONM_3 (50 % FYM + 50% VC)	3,391	7.93	107495	41,195	1.62
ONM_4 (25 % FYM + 25% VC+25 % *Azospirillum* + 25 % BGA)	3,592	8.06	113821	66,171	2.39
ONM_5 (Control)	1,138	7.59	36459	9,158	1.34
SEm±	20.8	0.03	-	-	
CD (P=0.05)	62.3	0.09	-	-	

Farm, Krishi Nagar, Jawaharlal Nehru Krishi Vishwa Vidyalaya, and Jabalpur (MP) during *kharif* season 2015. The soil of the experimental field was sandy clay loam, neutral in reaction (pH 7.3) with medium OC (0.71%) contents, normal in EC (0.28 ds/cc) and analyzing low in available N (287.83 kg/ha), medium in available P (12.69 kg/ha) and medium in available K (278.3 kg/ha) contents. The experiment was laid out in factorial randomized block design with three replications. There were two factors namely two varieties *viz.,* V_1 (Pusa Sugandh 5), V_2 (Pusa Basmati 1509) and five organic nutrient management *viz.,* ONM_1 (100 % FYM), ONM_2 (100 % Vermicompost), ONM_3 (50 % FYM + 50% VC), ONM_4 (25 % FYM + 25% VC+25 % *Azospirillum* +25 % BGA), ONM_5 (Control). Organic sources *viz.,* FYM, Vermicompost, *Azospirillum* and BGA as per treatments were applied before transplanting of rice seedlings. The rice seedlings of Pusa Sugandh 5 and Pusa Basmati 1509 were transplanted at the planting geometry of 20 cm X 20 cm on 30/7/2015. The crop was harvested on 5/12/2015.

RESULTS

Data (Table 1) indicated that varieties and organic nutrient management had significant effect on grain yield, protein content, gross monetary returns, net monetary returns and Benefit: Cost ratio. The Pusa Basmati 1509 produced markedly higher grain yield (2933.74 kg/ha) as compared to Pusa Sugandh 5 (2827.74 kg/ha). The former variety (Pusa Basmati 1509) gave 3.61% higher grain yield than that of Pusa Sugandh 5. These finding are in accordance with those of Das *et al.* (2002).The protein content was non significant due to different varieties. The yield was appreciably more under ONM_4 (3592.26 kg/ha) in comparison to rest of the organic nutrient management. However, variation in grain yield owing to ONM_2 and ONM_3 was non significant. The per cent increase in grain yield with ONM_4 was 5.61, 7.25, 17.81 and 66.33 per cent over ONM_3, ONM_2, ONM_1 and ONM_5, respectively. Application of ONM_4 resulted in appreciably higher protein content in grain (8.06%) over rest of organic nutrient management. However, the differences in protein content between ONM_1-ONM_2 or ONM_3 were statistically at par. The lowest (7.59%) protein content was noted under ONM_5 (control). Adhikari and Mishra (2004) also expressed similar results. Pusa Basmati 1509 had maximum GMR (Rs. 93063/ha), NMR (Rs. 38,293/ha) and B: C ratio (1.70) followed by Pusa Sugandh 5 (Rs. 89786/ha, Rs. 35,015/ha and 1.65, respectively). Among the different organic nutrient management, ONM_4 had maximum GMR (Rs 113821/ha), NMR (Rs. 66,171/ha) and B: C ratio (2.39). All these values were minimum under ONM_5 (control).

CONCLUSION

Based on above results it could be concluded that transplanting of Pusa Basmati 1509 with organic nutrient management of 25 % FYM + 25% VC+25 % *Azospirillum* +25 % BGA was more productive and remunerative.

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Response of rice varieties to different levels of FYM under organic conditions

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Organic farming plays an important and growing role in Indian agriculture. Emerging research on organic farming has shown that organic farming enhances soil organic carbon, available phosphorus content and microbial population/enzymatic activity of soil thus making it sustainable for organic crop production. Use of different organic amendments in combinations and in a cumulative manner can meet the nutrient requirement of organic rice in rice-wheat cropping system. The application of farmyard manure (FYM) to soil has been practiced for many centuries, and its application to soil have been reported to increase crop yield, soil fertility, soil organic matter, soil microbial activity and soil structure for sustainable agriculture (Blair *et al.,* 2005; Kundu *et al.,* 2006). Rice-wheat cropping systems which is considered to be the backbone of food sufficiency is however facing a sustainability problem in recent years due to indiscriminant use of chemicals and pesticides. This calls for an urgent attention towards varietal screening under organic amendment conditions to meet future challenges. Keeping in view of the above facts it is thought appropriate to evaluate the suitable and adaptable varieties of rice with different levels of FYM application under organic conditions.

METHODOLOGY

Field experiment was conducted at research farm of Indian Institute of Farming Systems Research, Modipuram, Meerut. Thirty rice varieties were screened for two consecutive years of 2008-09 and 2009-10 under organic conditions. Out of which, five varieties of rice (PS-4, Vallabh-21, PS-5, Pant Su-15 and PB-1), which showed better performance were evaluated for two consecutive years of 2010-11 and 2011-12 at different levels of FYM (0, 10, 20, 30 and 40 t/ha) in strip plot design under organic conditions. FYM was applied before sowing and mixed well in experimental plots as per treatments. Weeds were controlled manually. The soil was typic Ustochrept sandy loam having pH 7.6, 0.44 % organic carbon and 150.3, 18.6 and 226.0 kg/ha available N, P and K respectively.

RESULTS

Significant difference in tillers/m^2, panicle length and grain as well as straw yield were observed in different rice varieties under influence of different levels of FYM application (Table 1). Significant difference in plant height was observed in different varieties of rice, maximum being in Vallabh-21 (102.2 cm) followed by PB-1 (101.3 cm) whereas no significant effect of FYM level was noted on plant height. Similar effect of varietal influence on no. of tillers/m2 was also noted. Vallabh-21 showed maximum no. of tillers/m2 (268.2) closely followed by PB-1 (210.0). Among different varieties maximum panicle length was observed in PB-1 where as maximum panicle length was seen at FYM application of 30 t/ha. Highest grain yield was recorded in PS-5 (3360 kg/ha) variety followed by PS-4 (3300 kg/ha) whereas maximum grain yield was observed in FYM amendment of 20 t/ha. Significant difference in straw yield was also recorded due to varietal influence highest being in PS-4 (10250 kg/ha) and lowest being in Pant Su-15 (6340 kg/ha). Highest straw yield was noticed under FYM application of 20 t/ha. There was no significant change in the harvest index (HI %) in none of the varieties under different FYM application rate.

CONCLUSION

Results obtained from the study revealed that among the rice varieties PS-5 recorded maximum production (3360 kg/ha) followed by PS-4 (330 kg/ha). Response of FYM was obtained up to 20 t/ha with 3475 kg/ha of rice yield.

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Effect of different organics on growth and yield of *arboreum*cotton

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Organic cotton is grown without the use of toxic and persistent pesticides and synthetic fertilizers. The regulations also prohibit the use of genetically engineered seed for organic cultivation. Globally about 1.51 lakh tons of organic cotton is being produced which is grown on 3.25 lakh hectares and equals 0.7 percent of global cotton production Organic cotton is grown in about 20 countries across the globe led by India (Anon., 2011). The quality of desi cotton *viz*., herbaceum or arboreum is of prime importance and yarn of these species grown organically has more demand in the western countries. Under Indian conditions several types of organic manures are available for crop production by substituting the inorganic fertilizers. The productivity of desi cotton under different organic manures may not be comparable with the productivity of the same with application of inorganic fertilisers during first one or two years, but it may attain higher productivity level after few years of continuous application of organics. In view of it, a field experiment was conducted over years under AICRP on cotton in medium deep black soil under assured rainfed conditions to assess the effect of different organics on growth and yield of *arboreum*cotton.

METHODOLOGY

A Field experiment was conducted at Agricultural Research Station, Dharwad, Karnataka, India during *kharif* season of 2011 to 2014. The soil was medium deep black clay having pH 7.06 and electrical conductivity (EC) of 0.20 dS/m. The soil had medium organic carbon (0.49 %), low available nitrogen (225 kg/ha), high available phosphorus (34 kg/ha) and high available potassium (520 kg/ha). There were eight treatments namely, T_1: FYM /Compost @ 5 t/ha + seed treatment with Azotobactor + PSB @25 g each /kg seed, T_2: Vermicompost @2.5 t/ha + seed treatment with Azotobactor + PSB @25 g each/kg seed, T_3: FYM /Compost @10t/ha + seed treatment with Azotobactor + PSB @25 g each/kg seed, T_4: Vermicompost @5 t/ha+seed treatment with Azotobactor+PSB @25 g each/kg seed, T_5: *Insitu* Green manuring of Sesbania/sunhemp+ seed treatment with Azotobactor + PSB @25 g each/kg seed, T_6: Castor Cake @ 500 Kg/ha+ seed treatment with Azotobactor + PSB @25 g each /kg seed, T_7: RD of Nutrient through organic based on P equivalent basis+ green manuring with sun hemp 50kg seed / ha and incorporated at 30-45 DAS, T_8 : Control (RDF: 40:25:25 NPK kg/ha) only inorganics. These treatments were on fixed site for four years since 2011. The experiment was laid out in Randomized block design with three replications. A promising arboretum variety DLSa-17 released by University of Agricultural Sciences, Dharwad was used for sowing. Need based plant protection measures were undertaken to manage sucking pests and boll worms with organic formulations/ cultures and neem based insecticides.

RESULTS

The data on yield parameters and seed cotton yield (SCY) and economics of *arboreum*cotton varieties as influenced by different organic manures is presented in Table 1. All yield parameters were significantly influenced by different organic treatments in pooled data over three years. Among the organics significantly higher seed cotton yield was obtained with application of FYM @10t/ha + Seed treatment with Azotobactor and PSB each @ 25 g/kg seed (819 kg/ha) which was on par with application of only RDF (848 kg/ha), but significantly higher as against other organics application. *In situ* green manuring + Seed treatment with Azotobactor and PSB each @ 25 g/kg seed resulted in lowest seed cotton yield (526 kg/ha) which may be attributed to the competition of sunhemp with cotton crop. Higher number of bolls per plant was recorded with application ofRDF (14.7), closely followed by the application of FYM @10t/ha + Seed treatment with Azotobactor and PSB each @ 25 g/kg seed (13.3). Lowest number of bolls per plant was obtained with application of *In situ* green manuring+seed treatment with Azotobactor and PSB each @ 25 g/kg seed (9.9). Higher single boll weight of 2.10 g was recorded with application of FYM @10t/ha+Seed treatment withAzotobactor and PSB each @ 25 g/kg seed which was on par with application of RDF (2.11 g). Similar trend was observed with seed cotton yield/plant in pooled data. Gross and net returns were significantly influenced by different organic treatments in pooled data. Application of inorganic fertilisers alone (RDF: 40:25:25 NPK kg/ha) resulted in significantly higher net returns (Rs.23296/ha). Among the organics higher net returns were recorded with the

Table 1. Seed cotton yield and yield components of *G.arboreum* variety as influenced by different organics (Pooled data of 4 years, 2011-2014)

Treatment	Bolls/ plant	Single boll weight (g)	Seed cotton yield (kg/ha)	Gross returns (Rs/ha)	Net returns (Rs/ha)
FYM/Compost@ 5 t/ha+seed treatment with Azotobactor+PSB @25 g each/kg seed	12.4	2.05	707	35497	14796
Vermicompost @2.5 t/ha+seed treatment with Azotobactor+PSB @25 g each/kg seed	10.8	1.91	621	30521	3021
FYM @10t/ha+seed treatment with Azotobactor+PSB @25 g each/kg seed	13.3	2.10	819	40572	16635
Vermicompost @5 t/ha+ seed treatment with Azotobactor + PSB @25 g each/kg seed	12.7	2.03	673	32623	-5177
Insitu Green manuring of sunhemp+seed treatment with Azotobactor+PSB @25 g each/kg seed	9.9	1.84	526	27846	8268
Castor cake @ 500 kg/ha+ seed treatment with Azotobactor+ PSB @25 g each/kg seed	13.3	1.90	657	31761	6584
RD of Nutrient through organic based on P equiv. basis+ sun hemp green manuring	12.1	1.89	604	32096	661
Control (RDF: 40:25:25 NPK kg/ha) only inorganics	14.7	2.11	848	44796	23296
SEm ±	0.57	0.05	22.0	1522	1305
CD (P=0.05)	1.73	0.15	66.7	4617	3958

application of FYM @10t/ha + seed treatment with Azotobactor+PSB @ 25 g each/kg seed (Rs.16635/ha) closely followed by the application of FYM @ 5 t/ha+ seed treatment with Azotobactor + PSB @25 g each/kg seed (Rs.14796/ha). All other organic treatments resulted in to lower net returns.

CONCLUSION

Based on four years data on cotton yield and its parameters and economics it was concluded that application of FYM @10t/ha + Seed treatment with Azotobactor and PSB each @ 25 g/kg seed was found optimum in obtaining *arboreum* seed cotton yield comparable to the application of inorganic fertilizers alone (RDF: 40:25:25 NPK kg/ha) at the end of four years of organics application on the fixed site.

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Influence of organic nutrient management in rice based cropping system on productivity, quality and soil carbon dynamics

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In many countries including India, interest in organic production systems is increasing. The growth in organic production is estimated at 15-20% annually in India due to strong domestic and overseas demands. Organic farming (OF) systems are characterized by an ecological management system that aims to promote and enhance biodiversity, nutrient cycles and soil biological activity. Soil biological health is a central principle of organic agriculture and vital to sustainable agriculture. Large quantities of organic matter (OM) are used in organic production systems as a source of nutrients and also to enhance the physical, chemical and biological fertility of soils. In contrast, chemical fertilizer production system receives low and imbalanced inputs and soil fertility levels decline gradually so that the sustainability of such farming systems is questioned. Organic agriculture emphasizes recycling techniques and low external input and high output strategies.

Soil biological health is a central principle of organic agriculture and is vital to sustainable agriculture. Soils under organic production systems are generally reported to be rich in organic matter and biological activity (Marinari *et al*., 2006). With this background, an investigation was conducted to study the productivity, produce quality and carbon dynamics in an organic aromatic rice-wheat/vegetable cropping system *via-a-vis* integrated nutrient management and chemical fertilizer production system.

METHODOLOGY

A field experiment was conducted atICAR-Indian Agricultural Research Institute, New Delhi, India during 2009-2014 to study the productivity, quality and carbon dynamics in an organic rice-vegetable cropping system *via-a-vis* integrated nutrient management and chemical fertilizer production system.The soil of the experimental plot was sandy clay loam with pH 7.8, organic carbon 0.76%, available nitrogen 398.5 kg/ha, available phosphorus 28 kg P/ha and available potassium 286.4 kg K/ha. The experiment was conducted as per the guidelines of International Federation for Organic Agriculture Movement (IFOAM). This experimental field was under organic cultivation since 2003 and during 2003-08 rice- wheat cropping system was followed. In this experiment irrigated transplanted rice was grown in wet season (June to November) followed by irrigated vegetables and wheat crop in dry season (November to April). Wheat and vegetables were sown/planted using zero-tillage practice. The field experiment was laid out in split plot design where aromatic (*Basmati*) rice (cv. '*Pusa Basmati 1401'*) was grown in main plots and vegetables like cauliflower, broccoli, cabbage, carrot and cereal crop wheat were taken in sub-plots. Three crop nutrient practices viz. organic, integrated nutrient management (INM) and chemical fertilization were taken in rice as well as vegetables and wheat crops. In organic crop nutrition four organic inputs viz. Blue Green Algae (BGA), *Azolla*, vermicompost and farm yard manure (FYM) were applied in rice crop in combinations. In organic treatment, entire dose of FYM was applied as basal and vermicompost was applied in 2 equal doses as basal and at panicle initiation stage. BGA (composite culture of four species viz. *Anabaena sp.*, *Nostoc sp.*, *Tolypothrix sp.* and *Aulosira sp.)* applied @ 1.5 kg/ha. Fresh *Azolla microphylla* was applied @ 1.0 tonne/ha. Both*Azolla* and BGA were applied 3 days after transplanting and for proper growth of these bio-fertilizers, standing water (3-5 cm) was maintained in rice field. BGA and *Azolla* multiplied for 25-30 days and developed a thick mat of biomass and later this biomass decomposed due to shading effect of rice crop and left over biomass was incorporated mechnically. In integrated nutrient management (INM) 5 t/ha FYM was supplemented with 90 kg N/ha applied through urea. Here, FYM was applied as basal and urea in three split doses. In chemical fertilization 120 N/ha was applied through urea and applied in three splits. The same treatments were used in rice, wheat and vegetable crops except the *Azotobacter* biofertilizer which replaced *Azolla* in wheat and vegetable crops crop.

RESULTS

Results revealed that the rice grain yield under organic management *i.e*. application of four organic inoculants (Blue Green Algae, *Azolla*, Vermicompost and Farm Yard Manure) was the highest in all the three years (4.46 to 4.72 t/ha) followed by the yield under INM (4.32 to 4.58 t/ha) and chemical fertilization (4.09 to 4.36 t/ha). The difference in yield was significant in second and third year of cropping. Productivity of vegetables like cauliflower, broccoli, cabbage and carrot grown under organic management using organic inputs viz. biofertilizers (*Azotobacter/ Rhizobium*), vermicompost and FYM gave *atpar* yield as given under INM and chemical fertilization. Micronutrients viz. Fe, Zn and Mn concentration and uptake in rice grain and edible portion of different vegetables increased significantly due to organic farming over INM and chemical fertilization. The analysis of soil (0-15 cm) under the above three treatments on physical properties of soil indicated that organic management resulted in the higher values of field capacity (FC) and available water content (AWC) and water retention capacity of soil. Lower bulk density (BD) was observed in organic treatment as compared to INM and inorganic treatments. Higher amount of soil organic carbon was observed in organic treatment as compared to inorganic treatment. The MWD value also showed similar trend. Microbial biomass carbon was highest under organic treatment followed by INM. Likewise, maximum β–glucosidase activity (17.33 μgpNP/g/h) was observed in organic management. Soil organic matter (SOM) and soil organic carbon (SOC) content of paddy soil improved by 10.9% and 8.1%, respectively in organically fertilized soil compared to chemical fertilization. However, the SOM in INM treated soil and chemically fertilized soil was statistically *at par*. Applied organic fertilizers improved the soil organic carbon content by 3.5-4.1 fold compared to reference soil.

CONCLUSION

Yield of rice, wheat and vegetables with organic nutrient management was *at par* with INM and higher than chemical fertilization. Organic farming (OF) was profitable only when produce are sold at premium price. Macro- and micro-nutrient concentrations significantly increased in grains due to OF over chemical fertilization. Soil carbon content was considerably built up under organic farming. Soil physical and microbial quality improved due to organic farming**.**

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Symposium 3
Agriculture Diversification for Sustainable Resources

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An experimental study on the performance of medicinal rice varieties in western zone of Tamil Nadu

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Rice is the world's most important crop and is a staple food for more than half of the world's population. In Asia, more than two billion people are getting 60-70 per cent of their energy requirement from rice and its derived products. Rice is grown in 43.94 million ha with a production of 159.2 million tonnes and productivity of 3623 kg/ha in India. Many rice varieties with medicinal value are cultivated and used in certain pockets in states of Karnataka, Madhya Pradesh, Kerala, Tamil Nadu, Uttar Pradesh, Himachal Pradesh and Western Ghats and to treat skin disease, blood pressure, fever, paralysis, rheumatism, leucorrhea, lactation and used also as a health tonic. The famous *Njavara* rice of Kerala is widely employed in ayurvedic practice as body enriching item, to exclude toxins and delay premature ageing (Ahuja *et al.,* 2008). *Kavuni* is a rice variety native to Tamil Nadu, cultivated in certain pockets of Thanjavur, Thirunelveli, Kanniyakumari with basic two type's *viz., Black Kavuni* and *Red Kavuni*. These landraces are highly nutritive and are rich in minerals like potassium, sodium, calcium, micronutrients like iron and zinc. Though there is no scientific data on the medicinal properties, they are being used in ayurveda in treating diseases like arthritis, cervical spondylitis, skin diseases and neurological problems (Deepa *et al.*, 2008). Hence, the present study was planned to find the feasibility of medicinal rice cultivation of *Njavara* and *Kavuni* under irrigated rice ecosystem in western zone of Tamil Nadu.

METHODOLOGY

The field experiment was carried out in the wetland farm of Tamil Nadu Agricultural University, Coimbatore during *Navarai* (Oct 2013 to Feb 2014) and *Samba* (Aug 2014 to Jan 2015) seasons. The location of the experimental site is situated at 11° N latitude, 77° E longitude and at an altitude of 426.7m above mean sea level. All recommended package of practices were carried out as per the guidelines of CPG, 2012. In the net plot area, five sample plants were selected randomly and tagged for recording biometric observations. The experiment was conducted under RBD design with three medicinal

Table 1. Growth parameters of medicinal rice varieties under irrigated rice ecosystem (Pooled data of 2 years)

Treatments	Plant height (cm)	Tillers m^{-2}	Leaf Area Index (flowering stage)	Dry matter production (t/ha)
Black Kavuni	118.8	443	4.31	11.00
Red Kavuni	127.5	538	5.87	11.31
Njavara	110.3	419	4.24	8.10
SEd	0.9	13.68	0.21	0.19
CD (P=0.05)	3.5	58.87	0.88	0.84

Table 2. Yield attributes and Yield of medicinal rice varieties under irrigated rice ecosystem (Pooled data of 2 years)

Treatments	Productive tillers m^{-2}	Total spikelet $panicle^{-1}$	Filled grains $panicle^{-1}$	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
Black Kavuni	350	114	86	2,776	7,030
Red Kavuni	404	119	94	3,421	7,470
Njavara	271	84	62	1,411	4,261
SEd	22.63	1.78	2.94	214.85	417.81
CD (P=0.05)	97.38	7.66	12.67	924.42	1797.71

Table 3. Bio chemical parameters of medicinal rice varieties under irrigated rice ecosystem (Pooled data of 2 years)

Treatments	Amylose content (%)	Total phenol content (mg/100g)	Total protein content (%)	The β–Carotene (ìg /100g)
Black Kavuni	20.2	14.79	6.87	288.91
Red Kavuni	19.9	12.69	5.83	208.59
Njavara	18.5	10.0	6.25	450.25

*Data statistically not analysed

rice varieties *viz.,* Red *kavuni*, Black *Kavuni* and *Njavara* in the field experiment. The observations were recorded on growth parameters like plant height, tillers, dry matter production and Leaf Area Index. The yield attributes and yield were recorded at the time of harvest. Bio chemical parameters like amylose per cent, total phenol content, total protein and â - carotenes were recorded.

RESULTS

The results obtained from the field experiment conducted with the objective to study the feasibility of establishment of medicinal rice varieties under irrigated rice ecosystem are discussed here. Growth parameters like plant height, tillers and dry matter production of the medicinal rice varieties studied were higher in Red *Kavuni* compared to Black *Kavuni and Njavara. Red Kavuni* recorded higher plant height (127.45 cm), Tillers m^{-2} (538), Leaf Area Index (5.87) at flowering stage, Dry matter production (11.31 t/ha) respectively. Regarding yield attributes, *Red Kavuni* recorded maximum number of productive tillers m^{-2}, total spikelets panicle^{-1} and filled grains panicle^{-1}. In the present study *Red Kavuni* and *Black Kavuni* recorded higher yield of 3,421 and 2,776 kg ha^{-1}. *Red Kavuni* recorded higher straw yield of 7,470 kg ha^{-1}, but was on par with *Black Kavuni* 7,030 kg ha^{-1}. *Njavara* recorded lower grain yield and straw yield of 1,411 kg ha^{-1} and 4,261 kg ha^{-1} respectively. *Black Kavuni* recorded higher amylose content of 20.8 per cent, total phenol content of 11.83 mg/100g and protein of 6.82 per cent *Njavara* recorded higher â-carotene (508.09 ìg/100g).

CONCLUSION

In medicinal rice varieties, studied *Red Kavuni* recorded enhanced growth characters and yield attributes compared to *Black Kavuni* and *Njavara*. *Black Kavuni* and *Red Kavuni* recorded higher biochemical parameters. Hence, these two varieties can be suggested for cultivation in Coimbatore (western zone of Tamil Nadu) and also for other rice belts districts of Tamil Nadu and it would be more profitable for small and marginal farmers.

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Rejuvenated *Ber* based agri-horti. system for higher productivity and profitability under arid rainfed conditions

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Arid zones have major constraint of aberrant weather for sustainable production of annual crops and hence it necessitates specialized integrated production systems with adapted plants species. *Ber* (*Zizizphus mauritiana* Lam.) is one of such species of arid landscape supplying fruits, fodder, fuel wood and fencing and could find place in every farming system of the region as a vital facet without any constraints. However, over the time, productivity of *ber* trees start declining because of aging, poor orchard management, biotic and abiotic stresses, seedling plantation etc. Vigour and yield in such or-

Table 1. Total system productivity and net returns of Agri.-Horti. System

Treatment	Total System productivity (*Ber* equivalent yield t/ha)					Net returns(x 10^3/ ha)				
	1st *	2nd	3rd	4th	Pooled	1st	2nd	3rd	4th	Pooled
Spacing										
6X6	4.62	8.50	6.96	7.54	6.90	10.90	99.42	57.64	102.11	67.52
6X12	2.29	5.92	4.55	4.50	4.31	0.17	78.18	45.35	64.04	46.93
SEm±	0.06	0.16	0.12	0.23	0.08	1.10	3.22	2.43	5.75	1.78
CD (P=0.05)	0.33	0.98	0.74	1.40	0.25	6.67	19.58	14.80	35.01	5.80
Variety										
Seb	2.72	7.48	5.90	6.33	5.60	-9.20	94.15	54.29	90.95	57.54
Gola	4.57	8.19	6.78	7.18	6.68	27.85	108.48	71.87	112.17	80.09
Umran	3.07	5.96	4.60	4.54	4.54	-2.06	63.77	28.33	46.11	34.04
SEm±	0.08	0.16	0.15	0.15	0.07	1.63	3.15	3.00	3.78	1.50
CD (P=0.05)	0.27	0.51	0.49	0.49	0.20	5.31	10.28	9.78	12.31	4.31
Intercropping										
Green gram	4.72	9.22	6.93	7.46	7.08	28.08	125.37	70.88	114.84	84.79
Pearl millet	3.16	8.34	5.58	5.81	5.72	-1.77	108.58	45.91	75.66	57.10
Senna	2.48	4.06	4.75	4.79	4.02	-9.72	32.44	37.70	58.73	29.79
SEm±	0.09	0.19	0.15	0.15	0.08	1.83	3.81	2.99	3.77	1.60
CD (P=0.05)	0.27	0.56	0.44	0.44	0.21	5.33	11.12	8.73	11.00	4.49

*Years after rejuvenation

chard may be regained by rejuvenation. Simultaneously integration of dominant food crops of the region in such orchard may be an appropriate option to enhance overall system productivity and profitability for sustainable livelihood of the poor farmers.

METHODOLOGY

An experiment was conducted during 2011-2015 to assess the productivity and profitability of a rejuvenated *ber* based Agri.-Horti. system under arid rainfed conditions.A senile orchard planted in 1978 having twenty two cultivars,managed rainfed was rejuvenated by heading back from the ground level and few selected shoots budded with early, mid and late season's cultivar Gola, Seb and Umran, respectively, in the month of July. From second year onwards inter cropping with green gram, pearl millet and senna was carried out in the alleys (6 m and 12 m) of *ber* varieties in split plot design. Twenty seven trees of each variety were kept in each spacing with nine plants in each replication. Productivity, system productivity, biological feasibility and profitability of the system were assessed over the years.

RESULTS

The rejuvenated trees attained profitable yield level within three years of rejuvenation. Gola recorded highest productivity (5.73 t/ha) followed by Seb and Umran. Amongst the intercrops, productivity of green gram calculated as *ber* equivalent yield was 1.7 times higher over pearl millet and 4.2 times over senna. Increasing the alley spacing from 6m× 6m to 6m×12m improved the productivity of intercrops (as *ber* equivalent yield) by 24%. Partial LER analysis indicated that ber is dominant species over the annual crops. Amongst the intercrops the total LER was in the order ber with green gram > pearl millet > senna. This justifies that *ber*- green gram association is complimentary. Highest total system productivity (*ber* equivalent yield) was achieved after two year of rejuvenation. The total system productivity in 6m × 12m spacing was less 50.47% during first year followed by 30.3, 34.6 & 40% during subsequent years, respectively, compared to 6m × 6m spacing. Profitability also followed the similar trend. Second year onwards, the systems showed good net returns averaging 84.79 x10^3 /ha with green gram (Table 1).

CONCLUSION

From the experiment, it can be concluded that old senile orchards of *ber* can be rejuvenated successfully and productivity could be restored within three years. Intercrops mainly green gram can be introduced in the alleys of *ber* at the recommended spacing (6m x6m). Though the biological feasibility of intercrops is accompanying under wider spacing but total system productivity and profitability cannot be compensated by reducing the *ber* population by 50%.

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Evaluation of wheat based cropping sequence for diversification in South-western Punjab

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The south-western zone of Punjab is at the tail end of the canal irrigation system, it is prone to the uncertainty and inadequacy of canal water. The irrational and discriminate use of water over last four decades has led to water scarcity due to monoculture of rice and wheat in Punjab state. Therefore, there is need for integrated management of depleting water resources. One of the options includes diversification in the existing rice-wheat system with lower water requiring crops, which can be beneficial in the long run. Therefore, an experiment on evaluating different crop sequences under variable irrigation supplies was carried to find the suitable crop sequence.

METHODOLOGY

A field experiment was carried out for three years at research farm of PAU Regional Station, Bathinda to study the feasibility of different crop sequences viz., Bt Cotton-Wheat/Barley/Raya, Guar - Wheat/Barley/Raya and Moong bean-Wheat/Barley/Raya. The experiment was conducted on sandy loam soil in a split plot design with three replications. Irrigation according to IW/CPANE ratio to wheat (O-0.9,SO-0.7,SSO-0.5) and barley (O-0.7,SO-0.5,SSO-0.3) which came out to be 4,3,2 and 3,2,1 of irrigations under O,SO and SSO in wheat and barley, respectively in rabi season and cotton (O-0.7,SO-0.5,SSO-0.3) 4,3,2 irrigations in kharif were given. Whereas, the irrigation scheduling was followed according to number of irrigations in raya (O-3,SO-2,SSO-1), moong bean (O-3,SO-2,SSO-1) and guar O-2,SO-1,SSO-0) crops. All other cultural practices were followed as per the recommendations of PAU.

RESULTS

It was found that the cotton equivalent yield of guar-wheat (3035 kg/ha) was statistically at par with cotton-wheat (3276 kg/ha) system. The benefit cost ratio was higher in guar-wheat (2.36) than cotton-wheat (1.37) due to lower variable cost in guar, which resulted in nearly Rs. 26000/-increase over cotton-wheat rotation. Water productivity of guar-wheat cropping system was 0.358 kg/m3 which were the highest among other cropping sequences. Moreover, the organic carbon status of surface layer of soil in guar based cropping sequences significantly improved as compared to cotton based cropping system. Jan and Ahmed, 2013 in an experiment conducted at Pakistan on effect of preceding cropping pattern on wheat. They found that legumes retained more soil N compared to non-legumes and plots sown after groundnut, mung bean and cluster bean produced higher wheat yield than preceding millets, sorghum and sesame. Therefore, Guar-wheat cropping system can replace the existing cotton-wheat cropping system, which will encourage crop diversification along with sustenance of soil and water resources and higher economic returns in semi-arid region of Punjab. Buttar and Kaur, 2010 also reported increase in area under guar (cluster bean) under irrigated conditions, as it helps in diversification of paddy-wheat cropping system of Punjab.

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Varietal response of hybrids rice (*Oryza sativa*) under agro-climatic conditions of Allahabad (Vindhyan region)

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Rice is an excellent source of carbohydrate and protein of human diet. It is the staple food of more than two-third of world's population. The slogan "Rice is life" is most appropriate for India as this crop plays a vital role in our national food security and a means of livelihood for millions of rural people of India. Rice cultivation in India extends from 8^0 to 35^0 N and from sea level to as high as 3000 m elevation. A field experiment was carried out during the *Kharif* season of 2014 at the Crop Research Farm, Department of Agronomy, Allahabad school of Agriculture, SHIATS, Allahabad (U. P.) to evaluate the varietal response of rice hybrids under agro climatic conditions of Allahabad. The experiment was laid out in Randomized Block Design with three replications. The treatment variety NPH-8899 was found maximum number of plant height and treatment variety Indam-200-017 tillers/plant (15), plant dry weight (37.76), panicle length (29.87), test weight (23.23) variety US-382,DAT to 50% flowering, effective tillers/m^2 and grain yield (8.46 t/ha) , the highest benefit cost ratio (3.56) was found of (variety Indam-200-017).

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Scope for higher profits and crop diversification in sugarcane through intercropping

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The Indian sugar industry plays a leading role in global sugar market, it being the world's second largest producer after Brazil producing nearly 15 and 25% of global sugar and sugarcane, respectively. The area under sugarcane covers around 5 million ha which is nearly 3% of the gross cultivable area in the country. However, thecultivated land is diminishing rapidly due to urbanization, road construction, and land deterioration.This crisis demands alternate research to raise crop productivity and maximize the economicreturns per unit land for feeding the gigantic population. Sugarcane is a long duration crop andgave late net economic return. Intercropping in sugarcane received much attention and need toproperly manage for getting higher net return from same unit area. It is becoming popular amongfarming community due to resourcefully utilization of land.Intercropping has been known a tremendous practice to increase returnsand better resources utilization and fulfill the demand of diversified farms.Thepresent study was conducted with the following objective:To explore the yield feasibility of sugarcane yield under different intercrops and its economics.

METHODOLOGY

The On farm testing of intercropping in *kharif* planted sugarcane with onion, beans and soybean was conducted for two year during 2010-11 and 2011-12 on a medium to deep black soil on farmers fieldsof Bagalkot districtat Krishi Vigyan Kendra, Bagaklot, Karnataka with five replications (Each farmer's field was considered as one replication). The climate of the region is semi-arid with annual average rainfall of 650 ± 50 mmand more than 70% of the rainfall occurs during June-September. The soil is thevertisol series andthe soil texture is clay. Plot size was 1000 m^2 in strips. The treatments comprised; sole sugarcane, sugarcane + onion, sugarcane + beans and sugarcane + soybean. Sugarcane variety CO-86032 with seed rate of 30,000 three budded setts per hectare was planted in July-August during 2010-11 and 2011-12. The popular varieties of the onion (Arka kalian), beans(Private) and soybean(JS-335) were used for intercropping in sugarcane planted at a distance of 120 cm. Fertilizer was applied at the rate of 250, 75 and 190 kg NPK ha^{-1} to the sugarcane crop only. Data were averaged over the replications and year. The effects of intercropping were evaluated by using crop equivalent yield, land equivalent ratio and economics.

RESULTS

Sole sugarcane and different intercrops in sugarcane had effect on yield parameters (Table 1). Sole sugarcane had higher millable cane (14.12/m^2), higher cane diameter (2.05 cm) and higher stripped cane yield (101.7/ha) as compared to intercropping systems.LER of different intercrops were in range between 1.04 to 1.21 during study period. In other words, the intercrops yield advantages varied from 0.04% to 21%, respectively. It could be inferred, that advantage due to intercrops per hectare yields were equal to sole sugarcane yields obtained from 1.04 to 1.21 hectares. The highest LER of 1.21 was recorded for sugarcane + onion. Yield parameters namely number of millable cane, cane diameterand striped cane yield were noted significantly higher in sole SC compared than different intercrops in sugarcane. Significantly higher yield attributes in sole crop was due to availability of sufficient soil nutrients and there was no crop competition (Li *et al*., 2013). Among the intercrops, higher number of millable cane in beans was due to restorative in nature. The difference in cane diameter among different intercrops was attributed to nature of intercrops. Higherstripped cane yield was recorded in sugarcane + Beans rather than other intercrops was due to uptake and availability of residual nutrients which was done by the plants roots. The highest sugarcane equivalent yield (SEY) was recorded in sugarcane + onion intercropping system. The LER of different intercrops compared to their sole SC was found higher. This showed that different intercrops geometries were biologically more efficient as compared to their sole crops. The economic benefits got from different intercrops in sugarcane were compared with the sole sugarcane (Table 2). The data revealed that all the intercrop treatments increased the net return from sole sugarcane. The highest net return (Rs 191480/ha) was obtained from sugarcane + onion. Maximum benefit cost ratio (2.87) was noted at sole sugarcane while minimum benefit cost ratio in sugarcane + soybean (2.92) was observed.Higher values of net returns were obtained from different intercrops than sole sugarcane. Benefit cost ratio is another important economic parameter in which farmers are interested to see the gain in net returns with

Table 1. Effect of different intercrops on number of millable canes, cane diameter, stripped cane yield, crop equivalent ratio and land equivalent ratio of irrigated sugarcane (pooled data of 2010-11 and 2011-12).

Intercropping	No. of millable canes/m^2	Cane stem diameter (cm)	Stripped cane yield (t/ha)	Intercrop yield (t/ha)	Sugarcane equivalent yield	Land equivalent ratio
Sole sugarcane	14.15	2.05	101.7	-	101.7	1.00
Sugarcane + Onion	13.25	1.94	96.2	8.2	123.5	1.21
Sugarcane + Beans	13.95	1.98	99.2	6.2	112.1	1.10
Sugarcane + Soybean	13.10	1.97	96.2	0.8	106.2	1.04

Table 2. Economics of various intercrop combination in sugarcane (pooled data of 2010-11 and 2011-12).

Intercropping	Gross income (Rs/ha)	Total cost (Rs/ha)	Net returns (Rs/ha)	Benefit cost ratio
Sole sugarcane	244080	85000	159080	2.87
Sugarcane + Onion	296480	105000	191480	2.82
Sugarcane + Beans	269080	102000	167080	2.64
Sugarcane + Soybean	262880	90000	172880	2.92

Price (per ton) of sugarcane: Rs. 2400, Onion Rs. 8000, Beans Rs. 5000 and Soybean Rs. 30000 a given increase in total costs. Our findings supported the results of Rana *et al*., (2006) who reported that all the intercrops gave higher net return and lower benefit cost ratio compared to sole sugarcane.

CONCLUSION

The present on farm testing of the technology revealed that the sole sugarcane gave higher stripped cane yield than all intercrop treatments. Higher values of SEY and LER were noted in intercropping treatments.Maximum net returns were obtained in sugarcane + Onion than other intercrops and sole SC while maximumBCR was noted in sole sugarcane. Based on economics, it is recommended that resource poor farmers grow only solesugarcane while resource rich farmers prefer to grow sugarcane + Onion due to high returns.

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Profitable intercropping systems for drylands in scarce rainfall zone of Andhra Pradesh

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Two thirds of cultivated area in India is under rainfed farming which is often influenced by aberrant weather conditions, by which the poor rainfed farmer suffers with low productivity and meager net returns. The main aim of research in dryland agriculture is to increase net returns of the dryland farmer by improving the economic returns and by reducing the cost of production with minimum risk of crop failures, besides sustaining natural resources. Groundnut is the most predominant oilseed crop, mostly grown under rainfed situation during *kharif* season. Out of total area of 8 m ha in India, an area of 6.4 m ha is under rainfed situation. Most of the groundnut farmers are small and marginal besides being resource poor. Because of poor economic status, the risk bearing capacity of rainfed groundnut farmer is low. In Ananthapuramu district (scarce rainfall zone of Andhra Pradesh) has 90% area under rainfed conditions. Farmers cultivate groundnut solely under rainfed situation in large area during *Kharif* over an area of about 8 lakh ha and no scope for crop diversification. Intercropping and sequence cropping systems can make better use of space and the entire rainy season, respectively, compared with monoculture systems (Willey, 1979).

METHODOLOGY

A field experiment was conducted to study profitability of intercropping system with clusterbean in alfisols of scarce rainfall zone under rainfed conditions for three years during kharif, 2013-14, 2014-15 and 2015-16 at Agricultural Research Station, Ananthapuram of Andhra Pradesh. The experiment consisted of eight treatments viz., T_1: sole crop of clusterbean, T_2: sole crop of pigeonpea, T_3: sole crop of groundnut, T_4: sole crop of castor, T_5: clusterbean + pigeonpea (15:1), T_6: clusterbean + castor (15:1), T_7: groundnut + pigeonpea (15:1) and T_8: groundnut + castor (15:1) conducted in RBD with three replications. Sowing was taken up as per the treatments. Gross returns were calculated based on local market prices of groundnut, clusterbean, pigeonpea and castor and net returns by subtracting the total cost of cultivation from gross returns.

RESULTS

During the crop season an amount of 415,299 ,460 mm of rainfall was received in 19, 20, 36 rainy days during 2013-14,2014-15 and 2015-16 respectively against normal rainfall of 492.3 mm in 28.8 rainy days. During the crop season the crops were subjected to dry spell of 148,176, 126 days during 2013-14, 2014-15 and 2015-16 respectively. Mean data 3 years revealed that, among sole crops groundnut recorded higher mean groundnut equivalent yield followed by castor, pigeonpea and lower with clusterbean. In intercropping systems groundnut+ pigeonpea (15:1) recorded higher groundnut equivalent yield (1041 kg/ha), net returns (Rs. 31280/ha) and B:C ratio (1.48) followed by groundnut + castor intercropping system with groundnut equivalent yield of 975 kg/ha, net returns (Rs. 28292/ha) and B:C ratio (1.34) and sole groundnut crop with equivalent yield of 960 kg/ha, net returns (Rs.27057/ha), B: C ratio of 1.28, Where as sole crop of pigeonpea given higher B:C ratio of 1.34 (Table 1).Higher yields of both the component crops in the two systems, groundnut + pigeonpea and groundnut + castor systems coupled with the higher price of saleable produce of intercrops resulted in production of the highest groundnut equivalent yield in these intercropping systems. This suggests that intercropping pigeonpea or castor with groundnut are the most appropriate systems to achieve high yield during rainy season. Higher groundnut equivalent yield in groundnut + pigeonpea (7:1) intercropping system was reported by Jayaprada (1998) and Sampath Kumar *et al.,* (2001),while groundnut + castor was found to achieve a higher groundnut pod equivalent yield by several earlier researchers (Guggari *et al.,* 1994 and Jayaprada, 1998).Castor can be successfully intercropped with groundnut, blackgram, greengram (Pooran Chand and Sujatha, 2000).

CONCLUSION

Based on three years of study revealed that groundnut intercropped with pigeonpea or castor in the ratio of 15:1was found profitable with yield advantage over sole cropping. Consistently higher yields from groundnut intercropping could be obtained and the risk of low yields or crop failure associated with the traditional groundnut production system, under drought of unpredictable intensity and duration could be reduced.

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Agronomic interventions for enhancing productivity and profitability of sole mango (*Mangifera indica*) orchard

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Long juvenile period and wider spacing of mango plant can be efficiently utilized by growing of different intercrops, as at juvenile phase the sparse foliage permits required light for the under storey intercrops that makes the microclimate compatible for inter-cultivation (Musvoto and Campbell, 1995). Mango cultivars differ in growth habit and productivity and thus may have variable effect on the intercrop and system productivity. The nutrient use in mango is either below optimum or in unbalanced proportion. Intercropping of pulses fixes the atmospheric nitrogen, so the recycling of legume residue and residual effect of nutrients applied to intercrops helps in building up of soil fertility and improving soil health. This build up in the soil fertility may contribute to meet the nutrient requirement of associated mango trees and thus reducing the recommended dose of nutrient of sole mango plantation (Wilhelm *et al*., 2004). Though large numbers of intercrops are grown in mango orchard, very meager information is available pertaining to comparative performance of legume crops in combination with different cultivars of mango and their residual recycling on the system productivity and nutrient saving in mango plantation.

METHODOLOGY

A field experiment was conducted during rainy, winter and summer seasons of 2011–12 and 2012–13 at Indian Agricultural Research Institute, New Delhi, to evaluate performance of 3 cropping systems viz. cowpea [*Vigna unguiculata* (L.) Walp] (for green pods)– Indian mustard [*Brassica juncea* (L.) Czernj &Cosson], greengram [*Vigna radiata* (L.) Wilczek]–Indian Indian mustard and blackgram [*Vigna mungo* (L.) Hepper]– Indian mustard in intercropping association with 4 mango (*Mangifera indica* L.) cultivars viz 'Pusa Surya', 'Amrapali', 'Mallika' and 'Dashehari' grown under 3 fertility levels viz. control, 50 % recommended dose (RD) of NPK through inorganic + 50% RD of FYM and RD of NPK through inorganic + RD of FYM to mango. The experiment was carried out on 3-years-old existing mango orchard planted with spacing of 6m × 6m. Before the commencement of study no intercrops were grown in the interspaces of mango. Stover of each intercrop was incorporated after harvesting/threshing along with natural incorporation of mango litter-fall.

RESULTS

Effect of mango cultivars was not observed on the yield and yield attributes of rainy season intercrops viz. cowpea, greengram and blackgram. Non-significant effect of mango cultivars on the yield and yield attributes of intercrops may be ascribed to their almost similar plant height and spread and small size of plants at initial growth stage, which failed to induce marked and variable shading effect on the intercrops. Application of 50% RDF + 50% RD of FYM to mango induced marked increase in yield and yield attributes of cowpea over control during both the crop seasons except number of grains/pod and stover yield/ha during first year, while in case of greengram and blackgram significant effect of fertility levels were observed only during second year. Indian mustard also recorded statistically similar yield and yield attributes in association with different cultivars of mango during both the crop seasons. Indian mustard recorded the highest values of yield and yield attributes after cowpea followed by greengram and least after blackgram during both the crop seasons. On an average, increase in the seed yield of Indian mustard after cowpea was 3.14 and 8.80% when compared to yield recorded after greengram and blackgram respectively. System productivity of intercropping system in terms of Indian mustard seed equivalent yield, gross returns, net returns and B:C ratio recorded significant variation due to cultivars effect during second year and the highest values of these parameters were recorded with 'Amrapali' and the lowest with 'Mallika'. This behavior of system economics can be traced to the trend of system productivity of intercrops in association with different mango cultivars. Among the intercropping systems, cowpea–Indian Indian mustard record significantly the

Table 1. Effect of mango cultivar, cropping system and nutrient management on system productivity and economics of intercrops

Treatments	System productivity in terms mustard equivalent (tonnes/ha)		System net returns (×10^3/ha)		System B:C ratio	
	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13
Mango cultivar						
V1 (Pusa Surya)	3.67	3.82	54.0	68.9	1.39	1.47
V2 (Amrapali)	3.74	3.88	55.5	70.8	1.43	1.51
V3 (Mallika)	3.64	3.76	53.2	66.9	1.37	1.43
V4 (Dashehari)	3.71	3.85	54.8	69.8	1.42	1.49
SEm±	0.026	0.032	0.64	0.96	0.02	0.02
CD (*P*=0.05)	NS	0.111	NS	3.32	NS	0.07
Cropping system						
CS1 (Mango: cowpea mustard)	5.17	5.50	87.9	115.3	2.13	2.32
CS2 (Mango: greengram mustard)	3.09	3.13	41.1	50.4	1.14	1.16
CS3 (Mango: blackgram mustard)	2.82	2.85	34.1	41.7	0.94	0.95
SEm±	0.029	0.048	0.72	1.45	0.02	0.03
CD (*P*=0.05)	0.086	0.145	2.15	4.36	0.06	0.09
Nutrient management in mango						
F0 (Control)	3.61	3.68	52.4	64.6	1.35	1.38
F1 (50 % RD of NPK + 50% RD of FYM)	3.70	3.89	54.7	70.9	1.41	1.52
F2 (RD of NPK + RD of FYM)	3.76	3.92	56.1	71.9	1.45	1.54
SEm±	0.035	0.031	0.87	0.93	0.02	0.02
CD (*P*=0.05)	0.099	0.088	2.47	2.64	0.06	0.06

highest values of system productivity, gross returns, net returns and B:C ratio during both the crop seasons followed by greengram–Indian mustard. This variation in system productivity of intercrops due to the effect of mango cultivar may be attributed to their variable height and spread, resulting in variable competition for light and other sources with the intercrops. Significant effect of fertility levels to mango was also observed on the productivity and economics of intercropping systems. Recommended dose of organic and inorganic nutrients and their 50% produced statistically similar values of system productivity and economics but both were statistically superior to control (Table 1).

CONCLUSION

Based on two years study, it is concluded that cowpea, greengram and blackgram during rainy season and Indian mustard during winter season can be intercropped in the inter-row space of mango orchard during establishment phase without any harmful effect to base crop. From this practice farmers can earn on an average net returns around ₹70,000/ from the intercropping based on the market prices for inputs and outputs during 2011–13.

Keywords: Agri-horticulture system, Blackgram, Cowpea, Cultivars, Fertility levels, Greengram, Indian mustard, Intercropping, Mango

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Extended Summaries Vol. 1 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Studies on interactive effects of planting geometry, plant spacing, legume intercropping and residue management on maize-wheat cropping system under rainfed conditions

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Maize (*Zea mays* L.)-Wheat (*Triticum aestivum* L.) is the most important cereal based crop sequence of Himachal Pradesh and these two crops constitute 69.5 per cent of the total cropped area in the state. More than 90 per cent of the total area under these crops is rainfed. The productivity of these crops in the state is low due to moisture stress during growing stages of the crops owing to untimely and uneven distribution of rainfall in addition to other production constraints. The productivity of these crops can be increased considerably by manipulating the cultural practices like planting geometry, plant spacing, legume intercropping and application of crop residues as mulch for moisture conservation. This higher yield due to residue application is due to better moisture conservation which further resulted in optimum seedling emergence and better shoot and root growth (Sandal *et al*., 2009). In view of this, two field experimentswere conducted to access the interactive effects of planting geometry, plant spacing, legume intercropping and residue management on maize and their residual effect on following wheat crop in maize-wheat cropping system under rainfed mid-hill conditions.

METHODOLOGY

First field experiment was initiated during *kharif*season of 2010 and was continued for three years (2010, 2011 and 2012) at the Research Farm of Hill Agricultural Research and Extension Centre, Bajaura (1090 m amsl) to study the interactive effect of residue management, plant geometry and plant density on the yield of maize-wheat cropping system under rainfed conditions in a split plot design with 3 replications. Two residue management treatmentswere assigned to main plots and 2 row arrangement (regular rows and paired rows) and 4 plant spacing treatments (plant to plant spacing of 35 cm, 30 cm, 25 cm and 20 cm with row spacing of 60 cm) were tested in sub plots. An early maturing maize hybrid KH 101 was used in this trial while wheat variety VL 829 was used to study the residual effect of residue management in maize on succeeding wheat crop. The soil of the experimental site was sandy loam in texture with neutral pH (6.9). The available N (265 kg/ha) and P (15.2 kg/ha) were medium, while available K (293 kg/ha) was high in this soil. The second trial was initiated during the *kharif* season of 2013 and the plant spacing treatments in the earlier trial were replaced with two legume intercropping systems with black gram and soybean taken as intercrops. All the crops were raised with recommended management practices. The soil was sandy loam in texture with neutral pH (6.9). The available N (265 kg/ha), P (15.2 kg/ha) were medium, while available K (293 kg/ha) was high in this soil. The normal annual rainfall of Bajaura is 943 mm, only 44% of which is received during rainy season (June to September).

RESULTS

Table 1. Effect of residue management, row arrangement and plant spacing in maize on grain yield of maize and succeeding wheat in maize - wheat sequence

Treatment	Three year pooled maize grain yield (t/ha)	Three year mean wheat grain yield (t/ha)
Residue Management		
Residue @ 5t / ha	9.49	3.68
No Residue	8.98	3.26
CD (P = 0.05)	0.29	
Row Arrangement		
Regular Rows	9.30	-
Paired Rows	9.14	-
CD (P = 0.05)	NS	-
Plant Spacing (cm)		
60 x 35	8.36	-
60 x 30	8.93	-
60 x 25	9.31	-
60 x 20	10.34	-
CD (P = 0.05)	0.40	-

The data recorded in first trial conducted over three years (2010 – 12) has been given in Table 1. On pooled basis application of residue @ 5 t/ha resulted in significantly higher grain yield of maize as compared to when no residue was applied. Similar trend was observed during 2011 and 2012 while in 2010 the differences were not significant. This was probably due to very high rainfall received during *kharif* 2010 which resulted in little effect of moisture conserving technologies on maize yield. Row arrangement (regular/paired) had no significant effect on grain yield of maize during the entire period of study. Grain yield of maize was also influenced by plant spacing with significantly highest grain yield recorded with the closer spacing of 60 cm x 20 cm during all the three years of study while significantly lowest yield obtained from wider spacing of 60 cm x 35 cm.The residue management in maize also had a significant influence on the grain yield of succeeding wheat crop with residue application in maize increasing wheat yield by 12.9% as compared to when no residue was applied to maize. The data recorded in the second trial conducted during 2013 has been given in Table 2. Like in the first trial application of residue significantly increased the maize grain yield as well as maize equivalent yield though the intercrop yield was not affected. Row arrangement had no affect on grain yield of maizeas well as maize equivalent yield though it had a significant influence on the seed yield of intercrops with significantly higher yield recorded from regular rows as compared to paired rows. This higher yield obtained in regular rows was probably due to more number of rows of legume crops per unit area in this arrangement. Grain yield of maize was significantly influenced by intercrops with soybean intercropping reducing the grain yield of maize by 11.7% as compared to black gram intercropping. Amongst the intercrops, soybean gave significantly higher yield as compared to black gram. However the maize equivalent yield was significantly higher when soybean was intercropped with maize. This was due to the higher yield of soybean (0.60 t/ha) as

Table 2. Effect of residue management, plant geometry and legume intercropping in maize on grain yield of maize and succeeding wheat in maize - wheat sequence

Treatment	Maize Grain yield (t/ha)	Intercrop yield (t/ha)	Maize equivalent yield (t/ha)	Wheat grain yield (q/ha)
Residue Management				
Residue @ 5t/ha	7.31	0.32	8.12	3.39
No Residue	5.66	0.31	6.44	3.10
CD (P = 0.05)	0.59	NS	0.57	0.11
Row Arrangement				
Regular Rows	6.20	0.37	7.14	3.25
Paired Rows	6.76	0.26	7.42	3.24
CD (P = 0.05)	NS	0.04	NS	NS
Legume intercropping				
Blackgram	6.84	0.03	6.93	3.30
Soybean	6.12	0.60	7.63	3.18
CD (P = 0.05)	0.59	0.04	0.57	NS

compared to that of black gram (0.03 t/ha). Application of crop residue @ 5 t/ha in maize crop resulted in significantly higher wheat grain yield (3.4 t/ha) as compared to no residue application (3.10 t/ha).

CONCLUSION

On the basis of above results, it may be concluded that yields of both maize and wheat crops can be increased considerably under rainfed conditions by applying 5 t/ha crop residue on dry weight basis which helps in mitigating the adverse impact of climate change by improving soil moisture in a year of less rainfall in addition to improvement in soil health. Legume intercropping in maize has additional advantage and insurance against total crop failure and also improves soil fertility.

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Extended Summaries Vol. 1 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Diversification and intensification options for rainfed farming systems in semi-arid Bundelkhand region of Central India

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The rainfed agro-ecosystem of Bundelkhand is characterized by undulating and rugged topography, highly eroded and dissected land, poor soil fertility, scarce ground water resource, erratic rainfall leading to frequent droughts, poor irrigation facilities, heavy biotic pressure, inadequate vegetation cover and frequent crop failures resulting in scarcity of food, fodder and fuel (Palsaniya *et al.,* 2008). There are reports of mass migration, hunger and distress sale of animals in the region. In this context, an attempt has been made to identify suitable options for diversification and intensification of farming systems in rainfed Bundelkhand region.

METHODOLOGY

The average annual rainfall of the area is around 900 mm, bulk of which (>90%) is received during June to September. It has been observed that in a cycle of 5 years, 2 are normal, 2 drought years and 1 is excessive rainfall year (Tiwari *et al*., 1998). The rainfed systems have very low productivity (0.5-1 t/ha) which largely may be attributed to low rain water use efficiency (30-40 %) for crop production. Indiscriminate extraction of the ground water, scarcity of fuel and fodder, over grazing by livestock and unscientific land uses are further threatening to the livelihood of rainfed agro-ecosystems of this region (Palsaniya *et al.,* 2010). Therefore, under such a scenario, it is vital to conserve natural resources and provide livelihood security through diversifying and intensifying the rainfed farming systemswith appropriate interventions. Research and application of integrated farming system technologies offer excellent opportunities for crop diversification and intensification to sustain food production at higher levels, improve soil health through recycling, recharge aquifers and enhance household income. Besides improving the diversification and intensification there is urgency to develop and promote productive farming systems especially for such rainfed agro-ecosystems that can better adapt and even mitigate the ill effects of climate change. In this context, an attempt has been made to identify suitable options for diversification and intensification of farming systems in rainfed Bundelkhand region.Improved crop varieties and efficient cropping systems, inclusion of multipurpose tree species (MPTs), perennial based forage production system, in-situ and ex-situ rainwater harvesting and its efficient recycling, inclusion of goats, vermicomposting, biogas, mushroom, etc are some of the identified interventions for integration in farming systems in the rainfed Bundelkhand region. One hectare rainfed integrated farming system model was developed at IGFRI by incorporating above components for semi arid central Indian farmers.

RESULTS

A number of improved varieties and efficient inter and sequence-cropping systems were recommended based on soil type, rainfall and length of growing seasons to achieve appropriate land use and productivity. Since here we are harvesting rainwater through farm pond, more remunerative crop sequences like groundnut/soybean-barley (0.3 ha) and green gram-chickpea (0.2 ha) were taken with life saving irrigation. To minimize risk, provide stability to farm income and also utilize the marginal lands for production of food, fodder, fuel wood and fibre, a suitable alternative land use systems based on location specific experimentations should be incorporated in the rainfed farming systems.Ber based agrihorticulture system with sesame-chickpea crop sequence was incorporated in 0.2 ha while, *Leucaena leucocephala* + tri specific hybrid + stylo based alley cropping system was taken in another 0.2 ha area in the model. A 25 m x 20 m x 2.5 m rain water harvesting pond was dug in the model for rain water harvesting and recycling. This water is being used for providing life saving irrigation to crops.Six goats along with their kids can be maintained in this model. The model can further be strengthened by multilayer boundary plantation of Ardu, subabul and edible cactus and incorporation of composting/vermicomposting for nutrient recycling and mushroom for additional income generation.

CONCLUSION

On the basis of this study it can be concluded thatdiversification and intensification of rainfed farming systems with ber, sesame, chickpea, *Leucaena lecocephala*and stylo utilize the marginal lands for production of food, fodder, fuel wood and fibre.

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Extended Summaries Vol. 1 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Crops productivity of major production systems in different soils of Jagner block Agra district, Uttar Pradesh

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Jagner block of Kheragarh tehsil district Agra in Uttar Pradesh located between 26°44’ to 26°59’ N latitude and 77°25’ to $77^0$45’ E longitude is known for its red stone and mustard oil extraction. It belong to Agro-Ecological Sub Region 4.1 known as North Punjab plain and Ganga Yamuna Doab and Rajasthan upland, hot, dry semi arid eco sub-region (N8Dd3). Its geographical area is 29371 ha scattered in 57 villages. Net sown area is 20607 (70% of the total area) of which irrigated (by tubwell) is 15230 ha. Major crops grown are pearlmillet, sorghum, pigeon pea and soybean during kharif and wheat, lentil and mustard during rabi. Average productivity potential of south western semi-dry plain soils of Uttar Pradesh is 37 q /ha, the actual productivity of area attained is only 11.65 q /ha. During Land Resource Inventory (LRI) at 1:10,000 scales, nine soils were identified in five landforms. Crop productivity data in identified arable soils was collected from the farmers through an interview (6 each from small, medium and large land holding groups). Crop cultivation is practiced under rainfed, semi-irrigated, irrigated and lowlaying conditions. Sonykhera and Piprreta soils on gently sloping upper piedmont, under rainfed have very low productivity in the range of 1 to 2.5 q /ha as single crop either in kharif or in Rabi are possible. Nagla Madho soils on lower piedmont, have some facility of irrigation where water is carried from 1-2 kilometer away, has productivity of 3-4 q /ha. Soils of Birbhum, Nagla Rundh and Sarendhi series have irrigation facilities and productivity is medium to high with range of 5 to 30 q /ha. Low lying Mewla and Nonikhera soils are very deep, imperfectly drained, dark grayish brown, clay loam, occasionally flooded, problem of salinity and sodicty. In these soils water stagnates from July to August and only Rabi cultivation is possible with crop yield of 9.9 q/ha. Among the irrigation systems highest productivity 3.7 t/ha was recorded under irrigated system followed by low laying (9.9) single crop in *rabi*. Semi-irrigated was (0.40) and dry-land (0.24) t/ha. Among the soils Sarendhi recorded highest productivity 32.4 followed by Nagla Rundh and Birbhum under irrigated followed by low lying soils Mewla and Nonkhera productivity 9.89 and 9.9 q /ha, respectively. However, in semi- irrigated soil Nagla Madho productivity was 3.87 q /ha. Whereas soils Sonykhera and Pippreta of rainfed state was recorded lowest productivity 1.97 and 2.28 q /ha/year^{-1} respectively. We can recommend best alternative high yielding crops guar for rainfed, pigeanpea in kharif and gram in rabi for semi-irrigated, pigeonpea in kharif-potato/ tomato/wheat in rabi in irrigated and gram and wheat in rabi for low laying stage are utilizing the soil and environment resources efficiently.

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Influence of varieties and crop geometry on baby corn yield (*Zea mays*) in coconut gardens

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Baby corn is a crop recently gained consumer preference especially in urban areas and suburbans of Kerala. The possibility of introducing baby corn as a suitable intercrop in coconut gardens in homesteads in all seasons has been demonstrated successfully by Krishi Vigyan Kendra, Ernakulam. Generally maize varieties and hybrids developed are being cultivated as baby corn, and the authentic studies to indicate the varietal suitability of baby corn in farming situation of Kerala are meagre. Though the spacing requirement of grain and fodder corn has been standardized, information on optimum crop geometry to explore the available resources and the influence of spacing on baby corn productivity especially under intercropping situation in coconut based cropping system are lacking. In this context, the present investigation was carried out to find out the varietal suitability and spacing requirement of baby corn in coconut gardens of southern Kerala.

METHODOLOGY

The study was carried out at the Coconut Research Station, Balaramapuram, Thiruvananthapuram, in Kerala Agricultural University during the summer (March to May) and *Kharif* season (August to October) in 2015 to find out the varietal suitability and crop geometry of baby corn intercropped in coconut garden. The field experiments were laid out in Randomized Block Design with 9 treatments replicated thrice and the treatments comprised of combinations of three maize varieties (Rasi-4212, G-5414 and CO-6) grown for baby corn and three spacings (30 cm x 20 cm, 45 cm x 20 cm and 60 cm x 20 cm). The variety Rasi 4212 and CO-6 were corn hybrids while G-5414 was a baby corn hybrid. The varieties were planted in the interspaces of 53 years old coconut trees planted at 7.5 m x 7.5 m spacing as per the treatments and the gross plot size was 21.6 m^2. Harvesting of the baby corn was done after 1-3 days of silk emergence and the weight of baby corn with husk from each plot was recorded in kg and it was converted to t /ha.

RESULTS

The variety G 5414 produced significantly higher cob yield with husk during both seasons. Pooled analysis also indicated similar trend in case of cob yield with husk (Table 1). The percentage increase in cob yield with husk of the variety G 5414 was 22.8 per cent and 24.75 per cent over the variety CO-6 in summer and *Kharif* seasons respectively. Though the total dry matter production was higher with the variety CO-6, the dry matter partitioning to cob was found to be higher with the variety G 5414. According to Asaduzzaman *et al.* (2014), the increased availability of photosynthates may enhance the number of flowers resulting in more assimilating surfaces at reproductive developments which might contribute to better green cob formation due to adequate production of metabolites and their translocation towards cob. Since G 5414 is a baby corn hybrid, its hybrid vigour might have contributed to increased photosynthetic assimilation with better assimilate partitioning towards the economic part even though its growth

Table 1. Effect of varieties and spacings on yield of baby corn as intercrop in coconut garden (t/ha)

Treatment	Cob yield with husk		
	Summer	*Kharif*	Pooled mean
V_1 (Rasi 4212)	8.24	7.28	7.76
V_2 (G 5414)	10.97	9.98	10.47
V_3 (CO-6)	8.93	8.00	8.46
SEm±	0.463	0.484	0.32
CD (P=0.05)	1.388	1.454	0.934
S_1 (30 cm x 20 cm)	8.20	7.12	7.66
S_2 (45 cm x 20 cm)	10.90	9.63	10.27
S_3 (60 cm x 20 cm)	9.02	8.50	8.76
SEm±	0.463	0.484	0.32
CD (P=0.05)	1.39	1.45	0.93

attributes were not significantly higher compared to other varieties. The spacing 45 cm x 20 cm recorded significantly higher cob yield with husk during both seasons and the pooled analysis also showed similar results. The higher cob yield with husk at the spacing 45 cm x 20 cm could be attributed to the higher cob weight with husk at this spacing (Gosavi and Bhagat, 2009). The higher cob weight with husk at wider spacing may be due to the fact that plants grown at lower density would have exploited the natural resources more efficiently, besides responding to externally applied inputs, allocating the photosynthates in a better manner to the economic parts (Ramachandrappa *et al*., 2004). The baby corn hybrid G 5414 and a moderate spacing of 45 cm x 20 cm were superior in producing higher cob yield with husk in the intercropped condition in coconut gardens during summer and *Kharif* seasons in southern Kerala. The maize variety, CO-6 also performed well when grown at 45 cm x 20 cm spacing in coconut garden during both seasons.

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Study on *rabi* fennel (*Foeniculum vulgare* Mill.) based intercropping systems under different row spacing

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Fennel (*Foniculum vulgare* Mill.) commonly known as variyali or saunf is native of Mediterranean countries and belonging to the family of Apiaceae. Fennel is widely cultivated in the temperate and sub-tropical regions of the world. France, Germany, Romania, Russia, Italy, India and U.S. are the major fennel growing countries. In India, it is mainly cultivated in Gujarat, Rajasthan, Karnataka, Maharashtra, U.P., Punjab and Bihar. Gujarat alone accounts for more than 90% of the fennel production in the country.

METHODOLOGY

A field experiment was conducted on loamy sand soil of AgronomyInstructional Farm, Department of Agronomy, Chimanbhai Patel College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar during the *rabi* seasons of 2012-13 and 2013-14 to study "Study on *rabi* fennel (*Foeniculum vulgare* Mill.) based intercropping systems under different row spacing". The soil of the experimental plot was low in organic carbon and available nitrogen, medium in available phosphorus and potash.Twenty four treatment combinations comprising of four row spacing viz. S_1 : (45 cm), S_2 : (60 cm), S_3 : (75 cm) and S_4 : (90 cm) and six intercropping systems treatmentviz.IC_1 : Fennel sole, IC_2

Table 1. Effect of row spacing and intercropping systems on Seed yield, fennel equivalent yield and net return

Treatment	Pooled data		
	Seed yield (kg/ha)	Fennel equivalent yield (kg/ha)	Net return (/ha)
Row spacing			
S_1 : (45 cm row spacing)	1564	3712	244745
S_2 : (60 cm row spacing)	2154	4030	275429
S_3 : (75 cm row spacing)	2048	3640	245983
S_4 : (90 cm row spacing)	1631	3040	198998
SEm$\pm$	38	73	6171
CD (P= 0.05)	116	226	19014
Intercropping system			
IC_1 : Fennel sole	2287	2324	147822
IC_2 : Fennel + carrot (1:1)	1493	3882	253697
IC_3 : Fennel + cabbage (1:1)	1819	4816	343043
IC_4 : Fennel + cauliflower (1:1)	1685	3855	264116
IC_5 : Fennel + radish (1:1)	1635	4244	285323
IC_6 : Fennel + vegetable fenugreek (1:1)	2177	2512	153732
SEm$\pm$	35	50	4216
CD (P= 0.05)	99	141	11865
Interaction			
S x IC	NS	S	S

: Fennel + carrot (1:1), IC_3 : Fennel + cabbage (1:1), IC_4 : Fennel + cauliflower (1:1), IC_5 : Fennel + radish (1:1) and IC_6 : Fennel + vegetable fenugreek (1:1) were evaluated.

RESULTS

Seed yield of *rabi* fennel was significantly influenced by different row spacing. Row spacing treatment S_2 : (60 cm) produced significantly higher seed yield of *rabi* fennel 2154 kg/ha (Table 1). Increased seed yield of *rabi* fennel by row spacing treatment S_2 : (60 cm) was higher by 5.2, 32.1 and 37.7% over S_3 : (75 cm), S_4 : (90 cm) and S_1 : (45 cm), respectively on pooled basis.Fennel equivalent yield was significantly influenced by various row spacing. Fennel equivalent yield of 4,030 kg/ha was significantly higher when fennel sown at S_2 : (60 cm row spacing). It was higher by 8.6, 10.7 and 32.6% over S_1 : (45 cm row spacing), S_3 : (75 cm row spacing) and S_4 : (90 cm row spacing), respectively on pooled basis. It is indicated that significantly the highest net return of ₹2,75,429/ha was received when fennel sown at row spacing of S_2 : (60 cm) which was higher by 12.0, 12.5 and 38.4% over S_3 : (75 cm), S_1 : (45 cm) and S_4 : (90 cm), respectively on pooled basis.Seed yield of *rabi* fennel was significantly influenced by different intercropping systems. Intercropping treatment of (IC_1) : fennel sole produced significantly higher seed yield of *rabi* fennel 2287 kg/ha. The increased seed yield of *rabi* fennel by intercropping systems IC_1: fennel sole was higher by 5.1, 25.7, 35.7, 39.9 and 53.2% over IC_6 : fennel + vegetable fenugreek (1:1), IC_3 : fennel + cabbage (1:1), IC_4 : fennel + cauliflower (1:1), IC_5 : fennel + radish (1:1) and IC_2 : fennel + carrot (1:1) respectively, on pooled basis. Apart from the competitive effect, prevailing price become an additional important factors in choosing the components of intercropping systems. Thus, intercrops yield were converted to fennel equivalent yield. Fennel equivalent yield of 4,816 kg/ha was significantly higher with intercropping of IC_3 : fennel + cabbage (1:1). It was higher by 13.5, 24.1, 24.9, 91.7 and 107.2% over IC_5 : fennel + radish (1:1),IC_2 : fennel + carrot (1:1), IC_4 : fennel + cauliflower (1:1), IC_6 : fennel + vegetable fenugreek (1:1) and IC_1 : fennel sole respectively, on pooled basis. From the data, it is indicated that significantly highest net returns of 3,43,043/ha were received in intercropping of IC_3 : fennel + cabbage (1:1). It was higher by 20.2, 29.9, 35.2, 123.1 and 132.1% over IC_5 : fennel + radish (1:1), IC_4 :fennel + cauliflower (1:1), IC_2 : fennel + carrot (1:1), IC_6 : fennel + vegetable fenugreek (1:1) and IC_1 : fennel sole respectively, on pooled basis.

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Management of alternate crop, linseed (*Linum usitatissimum* L.) under south Gujarat condition

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Linseed oil has diversified uses and has great value of foreign trade. The oil cake is most valuable feeding cake for animals. The oil cake is also used as manure. The stem fibre is of high quality having high strength and durability. India ranks first in respect of acreage (0.53 m ha) accounting for 23.8% of the total and third in production (0.21 m tonnes). Madhya Pradesh occupies first position in India in respect of both area (0.16 m ha) and production (0.07 m tonnes)(Damodaran and Hegde, 2005). South Gujarat is a heavy rainfall zone and important cropping sequences are paddy-paddy and paddy-sugarcane. Water requirement of both these crops are very high which results in water logging and secondary salinization in these areas. Therefore, to overcome these problems there is need to find out alternate *rabi* crop with low water requirement. Linseed because of its less input requirement and suitability of in *rabi* season, may increase the crop areas in south Gujarat.

METHODOLOGY

A field experiment was conducted during *rabi* season of the year 2011-12 at College Farm, Navsari Agricultural University, Navsari (Gujarat). The soil of the experimental field was clayey in texture and showed low, medium and high rating for available nitrogen (117.00 kg/ha), phosphorus (30.63 kg/ha) and potassium (646.00 kg/ha), respectively. The soil was normal (pH 7.4) with normal electrical conductivity. Sixteen treatment combinations consisting of four levels of irrigation *i.e.*I_1(0.4 IW/CPE), I_2(0.6 IW/CPE), I_3(0.8 IW/CPE) and I_4(1.0 IW/CPE);IW=60mm and four row spacing *i.e.* S_1(15 cm x 10 cm), S_2(30 cm x 10 cm), S_3(45 cm x 10 cm) and S_4(60 cm x 10 cm) were tried in split plot design with three replications.

RESULTS

Almost all the growth and yield attributes, seed and stover as well as oil yield were recorded significantly higher under the treatment having irrigation level of 1.0 IW/CPE (I_4). The marked improvement in growth components with irrigations aimed at replenishing the soil moisture deficit to field capacity in the root zone at different stages of crop growth could be ascribed to potential role of water to modify soil and plant environment conducive for better growth and development of the crop. The remarkable increase in seed and stover yields under treatment of 1.0 IW/CPE (I_4) was mainly due to adequate moisture supply throughout the entire crop growth period which ultimately resulted in better growth, yield attributing characters, yield and also higher content and uptake of nutrients from seeds and stalks. Increase in seed yield and its attributes due to irrigation may be attributed to more photosynthesizing area resulting in production of more assimilates which got translated to yield attributes and finally to seed yield. Consumptive use of water increased with increasing number of irrigations. Increase in water application at higher IW/CPE ratio, decreased the crop water use efficiency considerably. Thus increased water supply through irrigation along with improvement in overall growth of crop seems to have increased both transpiration and water use for metabolic activities.The maximum net returns (Rs. 68427/ha) was accrued under irrigation treatment of 1.0 IW/CPE (I_4) with BCR of 4.62. Consumptive use of water(CU) increased with narrow spacing. The CU with various spacing viz. 15 cm x 10 cm (S_1), 30 cm x 10 cm (S_2), 45 cm x 10 cm (S_3) and 60 cm x 10 cm (S_4) were 169.7, 165.3, 160.8 and 156.4 mm, respectively. The crop water use efficiency (CWUE) with various spacing viz. 15 cm x 10 cm (S_1), 30 cm x 10 cm (S_2), 45 cm x 10 cm (S_3) and 60 cm x 10 cm (S_4) were 5.51, 5.44, 5.43 and 5.41 kg/ha-mm, respectively, showing marked reduction in CWUE under wider row spacing while narrow row spacing recorded higher water use efficiency. The net realization of Rs. 60693/ha was obtained under linseed sown at a spacing of 45 cm x 10 cm (S_3) with maximum BCR of 4.20. This was due to almost similar yield with narrow spacing and wider spacing under study. However cost of cultivation under treatments S_3 reported savings in seed as well as other operation costs which ultimately reflected into higher net realization and BCR.

CONCLUSION

Almost all the growth and yield attributes were significantly higher under the wider spacing (S_4). Whereas, plant height, seed yield and stover yield were recorded significantly higher with narrow spacing. Higher plant height might be due

Table 1. Effect of spacing and irrigations on economics of linseed

Treatment	Yield (t/ha)		Consumptive use of water (mm)	Crop water use efficiency (kg/ha-mm)	Gross realization (Rs/ha)	Total cost of cultivation (Rs/ha)	Net realization (Rs/ha)	BCR
	Seed	Stover						
I_1	0.86	1.40	83.6	10.45	69500	13638	55863	4.10
I_2	0.92	1.49	131.4	7.00	74345	14028	60318	4.30
I_3	0.97	1.58	176.7	5.48	78390	14418	63973	4.44
I_4	1.03	1.67	260.5	3.89	83235	14808	68428	4.62
S_1	1.00	1.62	169.7	6.75	80810	17658	63153	3.58
S_2	0.96	1.56	165.3	6.69	77580	15258	62323	4.08
S_3	0.93	1.50	160.8	6.70	75150	14458	60693	4.20
S_4	0.89	1.45	156.4	6.68	71925	14058	57868	4.12

to unavailability of sufficient space and sunlight which might have made the plant longer in search of sunlight, in narrow spaced crops. The wider spacing improved per plant yield attributes and yield, but yield per hectare recorded higher with narrow spacing which might be due to more number of plants per unit area.

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Soil organic carbon and nutrient pool under poplar based agro-forestry in sub-tropical Punjab (India)

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Poplar based agro-forestry is gaining ground as more remunerative and eco-friendly agriculture production system, because it has potential to sequester carbon (C) in soil and off-set carbon dioxide (CO_2) emission in the atmosphere. Soil samples were collected from profiles (0-60 cm) under chronosequence (5-25 years) of poplar plantation in a sub-tropical area in Ropar district of Punjab (India) to study changes in soil organic C (SOC), phosphorus (P) and potassium (K) pool. Soil organic C pool varied between 5.35 and 7.48 g/kg in surface (0-7.5 cm) and between 4.90 and 7.03 g/kg in sub-surface (7.5-15 cm) soil depth. In a plough layer (0-15 cm), SOC pool was significantly ($p<0.05$) higher by ~34, 61 and 83% than in 15-30, 30-45 and 45-60 cm soil depths, respectively. Surface (0-7.5 cm) soil depth had ~0.4 g/kg (~7%) higher SOC concentration, compared with 7.5-15 cm soil depth. Soil organic C decreased significantly with increasing soil depth, regardless of the duration of poplar plantation period (5-25 years). Organic C stocks in surface (0-7.5 cm) and sub-surface (7.5-15 cm) soil depth after 25-years of poplar plantation were significantly higher, compared with soil under poplar plantation for 5-15 years. Data pooled for soils under different duration of poplar plantation showed a decrease in bulk density (Db) with increasing organic C concentration. Available P and K concentration were significantly higher in the surface (0-7.5 cm), compared with sub-surface (7.5-60 cm) soil depths. Thus, it can be concluded that long-term adoption of poplar based agro-forestry system could enhance C sequestration and improve soil physical condition, as is indicated by decrease in soil Db.

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Sustainable and intensive cropping systems for humid ecologies of Rajasthan

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Diversification of the system through introduction of crops of diverse nature may be a good preposition to break the monotony of the predominant systems and to sustain productivity over a period of time. Top priority need to be given to highly productive and profitable cropping systems, which can meet the balanced food demand of burgeoning population and maintaining sustainability in crop production. Therefore, all efforts are being made to develop alternate cropping systems to maximize the production from available resources and prevailing climatic conditions for south-eastern areas of Rajasthan. Keeping in view a field experiment was carried out to evaluate sustainable and intensive cropping systems for humid ecologies of Rajasthan.

METHODOLOGY

The treatments comprised of eight sequential/intercropping systems viz., t_1- soybean-wheat (flatbed system), t_2- soybean (broad bed)+maize (furrow)+garlic (bb)-wheat (f), t_3- maize-mustard-greengram (grain+residue), t_4- maize+blackgram (bb)+sesbania (f)- gram (bb)+mustard (f)-greengram (g+r), t_5-maize+blackgram (1:1) - gram+linseed (6:1) -cowpea (veg+r), t_6- maize–garlic, t_7- cotton+blackgram (1:2)-greengram (g+r), t_8- cotton+clusterbean (1:2) (veg.+mulch) – greengram (g+r). The crops were grown and managed with their recommended package of practices for the zone.

RESULTS

The productivity and profitability of different diversified cropping systems were varied significantly compared to soybean-wheat system in humid ecologies of Rajasthan (Table 1). Results revealed that among the tested cropping systems, maximum soybean equivalent yield (11592 kg/ha) and net

Table 1. Productivity and profitability of diversified and intensive cropping systems for humid ecologies ofRajasthan (Pooled data of 6 years)

Cropping system	System productivity	System economics		
	Soybean equivalent yield (kg/ha)	Cost of cultivation (₹/ha)	Net return (₹/ha)	B:C ratio
Soybean-Wheat (Flatbed system)	4621	33368	78730	2.34
Soybean (BB)-Maize (F)+ Garlic (BB)+ Wheat (F)	7204	65600	129053	2.02
Maize-Mustard-Greengram (G+R)	4525	34647	71964	2.15
Maize+ Blackgram (BB)+ Sesbania (F)- Gram (BB)+ Mustard (F)-Greengram (G+R)	4772	37520	75262	2.03
Maize+ Blackgram (1:1) - Gram+Linseed (6:1) -Cowpea (Veg + R)	7078	39783	127406	3.28
Maize – Garlic	11592	77303	214069	2.82
Cotton+ Blackgram (1:2)- Greengram (G+R)	5221	38320	88981	2.33
Cotton+ Clusterbean (1:2) (Veg.+ mulch) – Greengram (G+ R)	4575	38320	73049	1.92
CD (P=0.05)	348	-	14542	0.58

returns (214069/ha) were found in maize-garlic cropping system and it was higher to the magnitude of 150.9 and 171.9 over soybean-wheat system, respectively. The next best treatment was soybean (broad bed)-maize (furrow)+ garlic (broad bed)+ wheat (furrow) closely followed by maize + blackgram (1:1)-gram + linseed (6:1)-cowpea (vegetable + mulch) cropping system by recording 55.9 & 53.2 and 63.9 & 61.8 % higher SEY and net return as compared to soybean-wheat cropping system, respectively. The maximum and significantly higher B: C ratio (3.28) was recorded with bio-intensive maize + blackgram (1:1)-gram + linseed (6:1)-cowpea (vegetable + mulch) cropping system to the tune of 40.2 % over existing soybean-wheat system and being on par with maize-garlic cropping system (2.82).

CONCLUSION

The results thus revealed that maize-garlic system was found more productive and remunerative cropping system followed by soybean (broad bed)-maize (furrow)+ garlic (broad bed)+ wheat (furrow) and maize + blackgram (1:1)-gram + linseed (6:1)-cowpea (vegetable + mulch) cropping system as a diversification and intensification options for soybean-wheat cropping system in south-eastern ecologies of Rajasthan.

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Can performance of maize (*Zea mays* L.) hybrids in sub-tropical India be ameliorated with the adjustment in sowing window?

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Maize, being the third most important cereal after wheat and rice is cultivated in both spring and autumn seasons in northern India and thus can be introduced in any cropping scheme. A number of factors govern the productivity potential of maize but, abiotic stresses (drought, salinity, extreme temperatures, flooding, pollutants and poor or excessive irradiation) are the major cause, limiting the crop productivity (Lawlor, 2002). Moreover, continuous cultivation of older maize varieties makes them vulnerable to biotic and abiotic constraints which then starts exhibiting undesirable agronomic performances such as late maturity and susceptibility to root and stalk lodging and thus slowly loses their actual yield potential. So the selection of good germplasms/hybrids with high yield potential needs to be explored for its adaptability in wider timeframe by adjusting the sowing datesin order to modify the environmental conditions of the growing season and, particularly, those of theoretical period of flowering. Early maize, sown during early spring (early February–March), has a long growing season asthe crop develops more slowly during its vegetative stage and has high radiation interception and biomass conversion rates, leadingto maximum productivity under non-limiting conditions (Otegui*et al.*,1995). However, there is also an increased risk of water deficitduring flowering for early sown maize in Punjab, when the yield sensitivity of this crop to water supply is maximum (Hall *et al.*, 1992) and the evaporative demand frequently exceeds the supply. On the other hand, *kharif* maize, sown during late June – July grows faster until flowering, explores lower levels of radiation and finds lower temperaturesduring reproductive stages and therefore it has lower yield potential.

METHODOLOGY

Field studies were carried out in loamy sand soil at the research farm of Maize section, Dept. of Plant Breeding and Genetics, P.A.U., Ludhiana during *Kharif* 2012. The experiment was laid out in split plot design with three replications andwas planned to assess whether the climatic aberrations have any kind of impact on productivity oftwo recently introduced maize hybrids against the standard check hybrid Parkash. So Parkash (an early maturing hybrid), PMH 4 (a medium maturing maize hybrid) and PMH 1 (a late maturing maize hybrid) was tested over a broader sowing window (45 days) with four dates of sowing viz. recommended date of sowing, advance sowing by 15 days, delayed sowing by 15

Table 1. Effect of climate aberrations on growth and yield attributing characters of maize hybrids.

Treatment	Cob length (cm)	Cob Diameter (cm)	No. of rows per cob	Grain yield (t/ha)	Net returns (Rs/ha)
Sowing Schedule (DoS)					
Advance sowing by 15 days	18.8	4.3	14.0	8.67	71436
Recommended sowing date (15 June)	18.3	4.2	13.7	8.72	72072
Delayed sowing by 15 days	18.6	4.4	13.5	8.79	72864
Delayed sowing by 30 days	17.6	4.3	13.4	8.66	71352
CD (P= 0.05)	0.8	NS	NS	NS	-
Hybrid (H)					
Parkash (Early)	18.3	4.2	13.3	7.8	61008
PMH 4 (Medium)	17.9	4.2	13.7	9.07	76272
PMH 1 (Late)	18.8	4.5	13.9	9.26	78504
CD (P=0.05)	NS	NS	0.4	0.55	-
Interaction [DoS x H]	NS	NS	NS	NS	-

and 30 days.A common recommended dose of 125 kg N, 60 kg P_2O_5 and 30 kg K_2O/ha was applied to all the three hybrids. Full phosphorus and potassium was drilled at sowing,while nitrogen was applied in three splits.One-third nitrogen was applied at sowing, another one-third was top dressed at knee high stage and the last one third was applied at pre-tasseling stage.The sowing schedule was kept in main plots and six rows of each cultivar was planted keeping row to row distance of 60 cm and plant to plant distance of 25cm in a sub plot size of 14.4 sq.m (6 rows x 4.0 m).

RESULTS

Advancing or delaying the sowing schedule by a fortnight had a different impact on the growth and yield attributing parameters of maize but it did not influenced the grain yield significantly (Table 1). The growth in terms of plant and ear height is not influenced by changes in sowing schedule. Yield attributing characters like cob diameter, rows per cob and the grain yield too were not influenced by delay or advancement in sowing time. The only significant change was noticed in length of cob. Delayed sowing by 30 days produced cobs with significantly smaller length by 1.2 cm and 1.0 cm as compared to advanced or delayed sowing by 15 days, respectively and was at par to the crop sown at recommended time. The non-significant differences in the grain yield of maize sown at different times indicated that the climatic aberrations especially due to rainfall, temperature and relative humidity over a wider sowing window of 45 days affected the crop relatively less and crop adaptability was very high to the changing climatic scenario. The net returns due to the prevalent environmental conditions within the tested sowing duration ranged from Rs 71,352/ha to Rs 72,525/ha representing similar behavior of the crop on all dates of sowing.Among the three hybrids tested, the long duration single cross hybrid PMH 1 out yielded (Table 1) others and gave maximum grain yield of 9.26 t/ha leading to net returns of Rs.78504/ha. The plant height and ear height is a genetically as well as environmental controlled factor and different hybrids differed significantly for plant height. The late maturing hybrid PMH1 recorded significantly higher plant and ear height than the PMH 4 and Parkash. But this character could not contribute towards yield enhancement of corresponding hybrids. Among the yield attributing characters, PMH1 recorded higher value of cob length and diameter but the level of significance could not be achieved. The plant characteristic which might have contributed in maximizing the yield seemed to be number of rows per cob which the hybrid PMH1 and PMH 4 being at par to each other registered significant edge over the hybridParkash.The net returns of PMH 4 and PMH 1 exceeded standard hybrid Parkash by Rs 15264/- and Rs 17496/- respectively. The interaction effects between the date of sowing and the maize hybrids were not significant for any of the character.

CONCLUSION

In the present study, grain yield of maize were similarwhen the sowing was advanced by 15 days or when it was delayed by 15 and 30 days indicating the wider adaptability of tested hybrids over a broader time frame.Among the hybrids, PMH-1and PMH-4 gave significantly better yield than the standard check hybrid Parkash.

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Effect of diversification of rice-wheat system on productivity and economics

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Rice is the predominate crop in Rewa region of Madhya Pradesh. It is difficult to replace the rice by any other crop in rainy season due to soil and climatic condition. Hence, only option left is to replace the wheat and gram crop in winter season for diversification of rice based cropping system. Rice based cropping systems have not been evaluated for Rewa region of Madhya Pradesh (Anonymous, 2008). Keeping above facts in view the present experiment entitled "studies on crop diversification based on rice for sustainable production in Rewa region of Madhya Pradesh.

METHEDOLOGY

The present field investigation entitled "Studies on crop diversification based on rice for sustainable production in Rewa region of Madhya Pradesh" was made under all India coordinated research project on farming system at Kuthulia Farm of JNKVV Rewa M.P. during 2009-10. The soil of experimental field was silty clay loam in texture, neutral in reaction (pH 7.25), medium in organic carbon (0.56%) and low in available nitrogen and phosphorus and high in potash (315kg/ha). The total rain-fall received during kharif season was 755.6 mm distributed in 38 rainy days. The ten cropping systems i.e. Rice-wheat; rice-gram, rice-berseem, rice-potato, rice-garlic, rice-linseed, rice-green pea, rice-maize, rice-gram + linseed and rice-mustard were taken for study. The rice varieties were Kranti in wheat and gram ,Pro Agro 6444 in garlic, Pro Agro 6201 in berseem, potato ,pea and gram, linseed and Pusa Basmati in linseed ,mustard and maize cropping.

RESULTS

The Hybrid rice proagro 6444 garlic cropping sequence gave the highest gross monetary return rupees 276299/ha followed by rice proagro 6201 berseem cropping system Rs 162097/ha and rice proagro 6201 –pea (green) Rs 1,37037/ ha. Rice gram 1, 19185/ha and rice wheat 1, 16384/ha. The hybrid rice proagro 6444 garlic cropping system gave maximum net monetary return Rs 210444/ha and B: C ratio 3.19 followed by hybrid rice proagro 6201 berseem cropping system. The rice proagro 6201 pea cropping system gave net monetary return Rs. 101702/ha which was superior to existing cropping pattern rice-wheat and rice – gram which were recorded minimum net monetary return .Rice –Pea cropping systems gave higher rice equivalent yield was also reported by . The growing of berseem for fodder and seed production in succession to rice proagro 6201 also produced rice equivalent yield 22.1 t/ha (Table 1). It may be due to fact that rice variety proagro 6201 gave higher yields and then excellent opportunity to grow the succeeding berseem.The similar were also reported by. Rice *Kharif* wheat and rice Kranti – Gram cropping systems are predominant cropping systems in Rewa re-

Table 1. Productivity and economics as influenced by crop diversification in rice-wheat cropping system

Treatment	Rice equivalent yield (t/ha)	Cost of cultivation (/ha)	GMR (₹/ha)	NMR (₹/ha)	B:C ratio
Rice (Kranti) – wheat Kanchan	14.9	38910	116384	77474	1.99
Rice (Kranti) – Chick pea (JG - 322)	15.4	37610	119185	81585	2.16
Rice (Pro Agro 6201)- Berseem fodder & seed	22.2	46645	162097	115452	2.47
Rice (Pro Agro 6201)- Potato (Kufrichandramukhi)	16.9	64075	125200	61125	0.95
Rice (Pro agro - 6444)- Garlic	38.0	65855	276299	210444	3.19
Rice (Pusa - Basmati) – Linseed (JL – 332)	8.0	32220	38111	5891	0.18
Rice (Pusa - Basmati) – Maize (JM – 8)	10.4	38570	91085	52575	1.36
Rice (Pro Agro 6201)- Pea (Arkel)	18.6	35335	137037	101702	2.87
Rice (Pro Agro 6201)- Chick pea + Linseed (3:1)	12.9	35805	97943	62138	1.73
Rice (Puse Basmati) – Mustard (Pusa bold)	16.3	34045	120767	86722	2.54
CD (P=0.05)	1.1	-	-	-	-

gion of Madhya Pradesh which produced the rice equivalent yield 14.85 t/ha and 15.42 t/ha respectively (Table 1). Rice Kranti gram cropping system gave higher rice equivalent yield than rice- wheat system.

CONCLUSION

The rice variety Pro Agro 6444 gave maximum yield 80.87 g/ha which was significantly superior ion rice garlic system as compare to rest of the varieties in different cropping system followed by Pro Agro 6201 in rice berseem, rice potato and rice-pea cropping system. Rice-garlic cropping system gave maximum rice equivalent yield 379.75 g/ha net profit Rs. 276299/ha and B: C ratio 3.19 which was significantly superior to all the cropping systems followed by rice-green pea, rice-mustard and rice berseem cropping system.

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Assessment and projections of spatio-temporal distribution of carbon stock in agro and other ecosystems over India

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Biomass and carbon storage in agro and other ecosystems play important role in the global carbon cycle.In addition to high spatio-temporal variability, terrestrial C sequestration in the aboveground alsofaces uncertainties that lead to complexities in its assessments. It is well known that changes in land use will also have impacts on carbon flow. However the terrestrial C sequestration studies over India (Fallen *et al*., 2007) have been restricted to individual ecosystems like, agriculture, forestry etc. The objective of this study is to develop a methodology to estimate bi-monthly spatial distribution of carbon stock in agro and other ecosystems and also carbon stock projection based on IPCC AR5 climate scenarios.

METHODOLOGY

In our study we rely onhigh-resolution (4km)daily rainfall, temperature and soil moisture from dynamically downscaled daily climate data, IPCC AR5 climate simulations and projections, gridded harvested area (10km) for 175 crops, SPOT and MODIS vegetation data(1 km) for the period 2001-2015. The carbon stored in agro and other ecosystems is broadly classified into trees and crops.The conceptual methodology is shown in Figure 1.

The double logistic curve has been used extensively to model vegetation phenology, as its shape closely resembles the EVI signature of plants during a growing season. From our fitted functions we define green-up in each year (for different crop seasons) as the point when the fitted curve reaches 10% of its maximum amplitude for that year; senescence was defined as the equivalent point on the declining portion of the function. Green season length was computed each year as the number of days between green-up and senescence (Lobell *et al*., 2012).

RESULTS

Temporal variation of aboveground biomass of different ecosystems has been associated with seasonal and interannual regimes.Resultshaveshown that the conversion of forest to other vegetation types, cultivated area changes associated with rainfall and reduction over time of biomass within vegetation types contributed significantly to decreases in total standing carbon stock during the period. The variability in spatial distribution of carbon stock is related to the variability in seasonal cycle of climate. The methodology described will help to understand and project possible changes in C-stock in various ecosystems with change in climate and in developing land-use strategies including agriculture.Figure 2 shows that the cropland vegetation over a Koppal district of Karnataka is decreasing by about 10-12%. Hence it is necessary to estimate the spatio-temporal distribution of carbon stock and its association with climate.

CONCLUSION

This brings out the potential of different land use systems

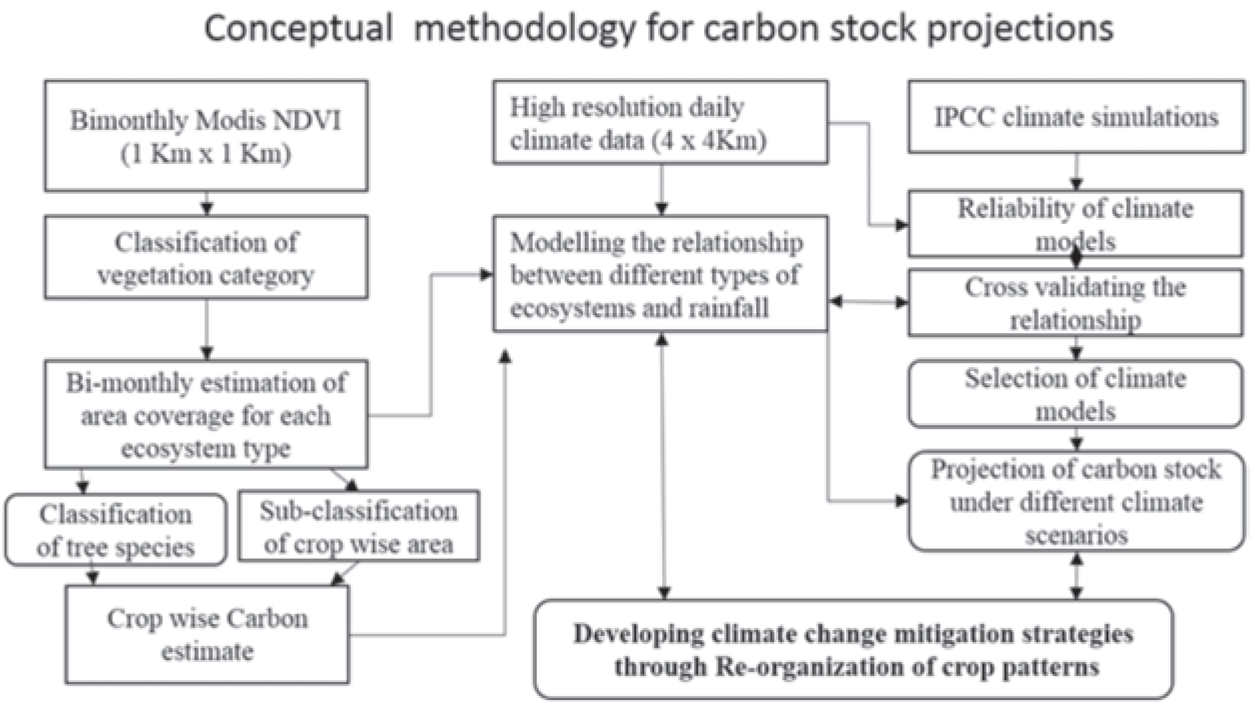

Fig. 1. Dynamic model for estimating and projection of carbon stock.

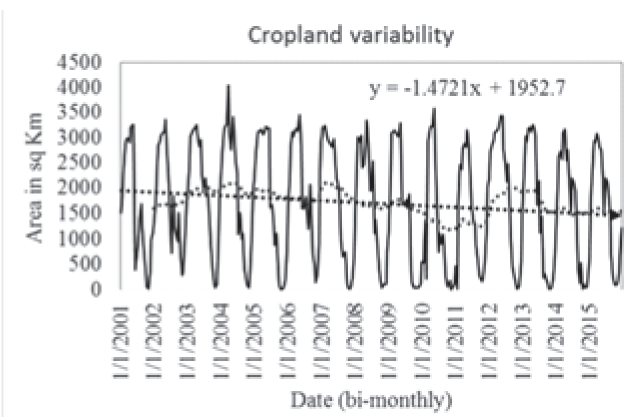

Fig. 2. Bi-monthly variation (black) in crop land vegetation during 2001-2015. The linear trend (red dotted line) and yearly moving average shows significant reduction in cropland vegetation.

influenced by varying factors for their C-sequestration potential in different regions, thereby providing useful climate change mitigation and carbon storage strategies.

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Prospects of medicinal and aromatic plants for crop diversification and enhancing farm income in jute based cropping system

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Jute fibre plays a vital role in Indian economy in terms of its significant contribution to industry and generation of employment and foreign exchange earnings. Though the yield of raw jute has doubled since independence, a wide disparity in the yield level still exists among the jute growing states as well as the agro-climatic zones within the states. In addition to it, the compound annual growth rate of synthetic fibres in India is higher than natural fibres. Despite bio-degradability and eco-friendliness of jute fibres, it is facing stiff competition from its cheaper synthetic counterparts (Mahapatra *et al.*, 2012). And this is where crop diversification with high value crops in traditional jute-based cropping system comes into place. An attempt was made for crop diversification to make jute farming profitable by integrating medicinal and aromatic plants (MAPs) in jute based cropping system incorporating kharif rice in rotation as rice is the staple food in the region. MAPs with their demand for industrial use, and alluring market price, are increasingly perceived as diversification crops in Indian Agriculture, as they improve land use efficiency and economic gains and minimize risks to farmer's income at the same time (Rao, 2011).

METHODOLOGY

Present experiment was conducted at Experimental Farm of the ICAR-Central Research Institute for Jute and Allied Fibres, Barrackpore during 2014-15 and 2015-16 to study the economic feasibility and production potential of growing spices and medicinal crops in jute-based cropping system. The experimental site is located at 88^{O} 26‘ E longitude and 22^{O} 35‘ N latitude 9 m above mean sea level. The experiment was laid out in split plot design with three replications and two fertility levels i.e. recommended dose of fertilizer (60-30-30 kg N-P_2O_5-K_2O/ha) and RDF + 5t FYM respectively. The experimental soil was sandy loam in texture with pH 6.8, high in organic carbon 0.66%, medium in available nitrogen (290 kg/ha) , high in available P_2O_5 (36 kg/ha) and K_2O (234 kg/ ha). The jute variety JRO-204 was sown during April followed by transplanting of rice in the month of August. After harvest of paddy, five medicinal and aromatic plants viz. asalio (Lepidium sativum), ashwagandha (*Withania somnifera)*, isabgol (Plantago ovata), menthol mint (*Mentha arvensis*) and senna(*Senna alexandrina*) were evaluated along with potato as prevailing traditional crop to assess the most profitable jute-rice-sequence. The data for both the years were recorded and pooled.

RESULTS

The component crops were taken up after the harvesting of kharif rice and were harvested. The data for both the years were pooled and presented in (Table 1). The maximum total jute equivalent yield was recorded in jute-kharif rice-potato cropping sequence which was 25% more than jute-kharif rice-isabgol in case of medicinal and aromatic plants cropping sequence. This was followed by jute-kharif rice-menthol mint . Similar findings were recorded in case of gross return of the system where traditional cropping sequence jute-kharif rice-potato resulted maximum gross return of Rs. 2,60,198 followed up by jute-kharif rice-isabgol (Rs.1,93,033). However jute-rice-ashwagandha gave the highest net return of Rs. 96,537 which was 23% higher than traditional cropping sequence. Considering the system as whole, though the total jute equivalent yield was highest in traditional cropping sequence (potato), the benefit cost ratio was minimal (1.39). This was 35% less than the jute-kharif rice-ashwagandha, which recorded the maximum benefit: cost ratio of 2.15. Thus the introduction of high value crops like medicinal and aromatic plants in the conventional jute-rice-cropping sequence resulted in increased productivity and farm income.

CONCLUSION

The result indicated that jute-kharif rice-ashwagandha recorded the maximum benefit: cost ratio of 2.15, thus improving the productivity and profitability of the system. Cultivation of medicinal and aromatic plants in jute based cropping system not only enhances the farm income but also maintains ecological sustainability. Thus integration of medicinal and aromatic plants with traditional jute-based cropping system is more profitable and remunerative, bringing more income generating ventures.

Table 1. System economics of medicinal and aromatic plants in jute fibre based cropping sequence (Pooled)

Treatment	Total jute equivalent yield (t/ha)	Gross Return (Rs/ha)	Net Return (Rs/ha)	B:C Ratio
Cropping System				
C1=Jute-kharif rice-asalio	7.05	180063	93221	2.08
C2=Jute-kharif rice-ashwagandha	7.12	180961	96537	2.15
C3=Jute-kharif rice-isabgol	7.57	193033	93731	1.96
C4=Jute-kharif rice-menthol mint	7.37	187942	81451	1.78
C5= Jute-kharif rice-senna	6.28	160008	76354	1.91
C6=Jute-kharif rice- potato	1.02	260198	73973	1.39
CD (P=0.05)	9.002	1492	1167	0.14
Fertility Level				
F1 (RDF)	7.35	187722	80294	1.83
F2 (RDF+ 5t FYM/ha)	7.53	192440	83555	1.85
CD (P=0.05)	5.92	749	680	0.08
Interaction (C x F)				
CD (P=0.05)	15	1835	1665	0.20

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Diversification of rice-wheat cropping system under irrigated medium land ecology of Jharkhand

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In general, rice- fallow is the predominant cropping system in Jharkhand owing to lack of irrigation facility. Wherever irrigation is available, rice-wheat system is practiced and intensification of the system is the need of the day. Diversification of rice based cropping system by inclusion of high value crops as well as addressing the nutritional needs of the farming community can help to achieve round the year employment, income and nutritional security.Choice of the component crops needs to be suitably maneuvered to harvest the synergism among them towards efficient utilization of resource base and to increase overall productivity (Anderson, 2005). Keeping this in view, the present investigation was undertaken to identify remunerative rice based cropping systems under irrigated medium land condition in Jharkhand.

METHODOLOGY

A field experiment was laid out in randomized block design with seven rice based cropping systems with three replications during 2005-06 at Birsa Agricultural University, Ranchi and after completion of eightcrop cycles; the data has been presented for the year 2013-14.The soil of the experimental site was acidic in nature (pH 6)and low in organic car-

Table 1. Agronomic practices followed in different crops

Crops and varieties	Seed rate (kg/ha)	Spacing (cm)	Fertilizer dose (kg/ha)		
			N	P_2O_5	K_2O
Rice var. Sahbhagi	50	20 x 10	80	40	20
Wheat var. K 9107	125	20	100	50	25
Potato var. Kufri Ashoka	3000	50 x 20	120	80	100
Mustard var. Pusa bold	8	30 x 10	80	40	20
Linseed var. T 397	25	30 x 10	50	30	20
Green gram var. Pusa Vishal	30	30 x 10	20	40	20

Table 2. Yield, nutrient use efficiency and net return in different cropping systems

Treatments	Crop yield (kg/ha)			System yield (REY) kg/ha	NUE (%)	Net return (Rs/ha)
	Kharif	Rabi	Summer			
Rice- wheat	2946	3472	-	7807	24.78	46325
Rice- mustard- greengram	3426	1088	713	9729	27.03	53409
Rice- linseed- greengram	3734	761	946	8945	27.95	49026
Rice- potato- greengram	3830	21231	1339	26172	50.33	174884
Rice- wheat+mustard (5:1)-greengram	3254	2458+ 216	744	10359	26.23	52479
Rice- wheat+linseed (5:1)- greengram	3542	2566+137	792	10559	26.73	55924
Rice-potato+wheat (1:1)-greengram	4255	20118+1626	1171	27308	52.52	181899
SEm±	192	-	-	345	-	6234
CD(P=0.05)	590	-	-	1060	-	19138

REY= Rice equivalent yield; NUE= Nutrient use efficiency

bon(3.8 g/kg) and low to medium nutrient status (225, 20 and 115 kg NPK/ha). The cropping systems were rice-wheat-fallow, rice-mustard-green gram, rice-linseed-green gram, rice-potato-green gram, rice-wheat+ mustard (5:1)-green gram, rice-wheat+ linseed (5:1)-green gram and rice-potato+ wheat (1:1)-green gram. Details of agronomic practices for different crops are shown in Table 1. Rice crop was transplanted during *kharif* and all the *rabi*crops were grown at their optimum time except wheat in potato+ wheat system where wheat was sown at the time of earthing up in potato and hence, was late sown. Green gram was sown as soon as the preceding crop was harvested.

RESULTS

During *kharif* season, maximum rice grain yield was recorded under rice-potato+ wheat (1:1)-green gram system which remained *at par* with rice- potato–green gram and both were significantly superior to that under rice-wheat system. The higher rice grain yield in these systems may be attributed due to residual effect of the nutrients applied to potato during *rabi* and beneficial effect of legumes grown in summer season. During *rabi* season, potato grown as sole as well as intercropped with wheat out yielded all other crops. Higher yield of green gram was obtained when grown after sole potato may be due to early sowing of green gram (15-20 days)in comparison to other *rabi* crops.Rice equivalent yield in the rice-potato+ wheat (1:1)- green gram systemwas also highest due to higher yields of individual crops in this system. In case of net return, rice-potato+ wheat (1:1)-green gram (Rs. 1,81,899/ha) and rice- potato – green gram (Rs. 1,74,884/ha), both being statistically similar, were superior to rest of the cropping systems (Table 2). System productivity, land use efficiency, employment generation, nutrient uptake and nutrient use efficiency were also higher in rice-potato+ wheat (1:1)- green gram. Prasad *et al.* (2013) also reported higher productivity and profitability of rice-potato + wheat (1:1)-green gram and rice-potato-green gram system under irrigated medium land condition.

CONCLUSION

Based on the above findings, it may be concluded that rice-potato+ wheat (1:1) –green gram system is the most remunerative system, being biologically efficient, resource conservative and highly profitable cropping sequence under irrigated medium land situation of Jharkhand.

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Raised and sunken bed land configuration for crop diversification in the lower Gangetic alluvial lowland of West Bengal

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The lower Gangetic plains (LGP) of West Bengal belongs to subtropical humid climatic zone receives an average of about 1600 mm rainfall of which 75% is concentrated during rainy season (June to September). During rainy season poor drainage and low use efficiency of applied nutrients are the major constrains for crop production in medium and lowland conditions. Crop failure due to flash flood and stagnation of water is a very common phenomenon in wet months. Even in the winter, crop establishment suffers from late monsoon. Root zone soils of most of the agricultural lowland farm in this region remain over-saturated for a considerable period in a year. Therefore, especially in low lands after harvest of *kharif* rice, it is very difficult to grow arable crops like vegetables due to excess moisture. Diversification and intensification of rice-based cropping systems are the most important agronomic tools to enhance the productivity of the system as well as to increase the resource use efficiency. In LGP, land shaping with raised bed and sunken beds (RSB) are noticed in a very scattered way and also without any definite design. Different kinds of vegetables like tomato, brinjal, pea, gourd, parwal, ridge gourd, green coriander, different leafy vegetables etc. are grown year round on the raised beds, whereas in sunken beds no crops are generally taken. In few cases fish production is also found. Though 100% of land area is not used for crop production, this practice enhances the land productivity as well as reduces the chance of crop failure.

METHODOLOGY

To improve upon the low land rice-rice system as well as to develop a sustainable remunerative and resource efficient production system RSB structures were developed in the year 2012 at Central Research Farm, Bidhan Chandra Krishi Viswavidyalaya, Gayeshpur, Nadia, West Bengal located at 21º83´981´´N latitude and 87º42´323´´E longitude. The study area falls under sub-humid tropical climate zone with an average annual rainfall of about 1600 mm, out of which about 75 per cent is received during South-West monsoon season (June to September. The soil of the experimental field was sandy clay loam (Inceptisol) in texture under low land ecosystem. In the experimental area 5 numbers of raised beds and sunken beds units (1:1 ratio) were developed alternately by cutting and filling method. The area of each unit was 400 m^2 [5 m (width) X 40 m (length) X 2]. The surface layer from area marked for sunken bed was removed and deposited on the adjacent area identified for raised bed to a height of about 50 cm. Along with these 5 units one normal field of 400 m^2 was taken adjacent to RSB units. The details of 6 cropping systems undertaken in this study during 2014-15 have been

Table 1. Crops taken under different systems

Treatment	*Kharif* Raised bed	*Rabi* Sunken bed	Summer	*Kharif*	*Rabi*	Summer
RSB1	Amaranths+Ridge Gourd	Raddish+ Brinjal (3:2)	Okra+Cowpea(2:3)	Fish	Fish	Fish
RSB2	Maize (Green cob)+ Amaranths	Capsicum+ Carrot(2:3)	Maize(Greencob)+ F.bean(1:2)	Rice+Fish	Dolichos Bean+Fish	Swamp Taro+fish
RSB3	Bottle Gourd+Amaranths	Tomato+ Spinach(2:4)	Bittergourd	Rice+Fish	Bottle gourd+ fish	Rice+Fish
RSB4	Pumpkin+Amaranths	Potato+ Coriander leaf	Pumpkin	Rice+Fish	Poi+Fish	Rice+Fish
RSB5	Pointed Gourd+ E.F.Y(1:2)	Pointed Gourd + Spinach	Pointed Gourd+ E.F.Y(1:2)	Rice+Fish	Dolichos Bean + Fish	Rice+Fish
Normal rice-rice	Rice	-	Rice			

Table 2. Rice equivalent yield (REY) of different systems

Treatment	Rice equivalent yield (REY) (kg/plot) Raised bed	Sunken bed	Total	Cost of production (₹/400 m²)	Net return (₹/400 m²	B:C ratio
RSB1	423	203	626	4482.75	5134	2.15
RSB2	249	201	450	3948.75	2675	1.68
RSB3	303	214	517	4586.25	2995	1.65
RSB4	311	196	507	5103.75	2185	1.43
RSB5	283	188	471	4586.25	1813	1.40
Normal rice-rice	-	-	377	4230	300	1.07

given in the Table 1.

RESULTS

Results of the experiment revealed that the highest REY (626 kg/400 m^2) was recorded under Amaranths+Ridge Gourd-Raddish+ Brinjal (3:2)- Okra+Cowpea (2:3) in raised bed and fish cultivation in sunken bed followed by Bottle Gourd+Amaranths-Tomato+ Spinach (2:4)- Bittergourd in raised bed and rice+fish in sunken bed. The lowest yield was observed under normal rice-rice system (377 kg/400 m^2). Similarly the highest net return (₹5134/- in 400 m^2) as well as B:C ratio (2.15) was recorded under same system (Amaranths + Ridge Gourd-Raddish + Brinjal (3:2)- Okra+Cowpea(2:3) in raised bed and fish cultivation in sunken bed) and the lowest net return (₹300/- per 400 m^2) as well as B:C ratio (1.07) was noticed in rice-rice system (Table 2). This may be the due the fact that land configuration with RSB system allowed to utilize the low land ecosystem for more remunerative vegetable crops round the year in comparison to rice-rice system. The results of this experiment are supported by the findings of Das *et al.* (2014).

CONCLUSION

Adoptions of permanent RSB system of cultivation with proper cropping sequences in lowland ecosystem not only increased the production and productivity of vegetables and fish but also enhanced cropping intensity, employment, and income substantially.

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Identification of need based cropping system for Godavari delta Andhra Pradesh

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Godavari delta is the Rice bowl of Andhra Pradesh, which is one of major contributors of rice production in the country. The production and productivity of rice growing areas are fluctuating every year due to different biotic and abiotic constraints. Besides climate change, continuous cultivation of rice for longer periods with low system productivity, and often with poor crop management practices, results in loss of soil fertility due to emergence of multiple nutrient deficiency and deterioration of soil physical properties (Tripathi, 1992), and decline in factor productivity and crop yields in high productivity areas (Yadav, 1998). Rice-Rice-pulse is one of the predominant cropping system in Godavari delta. Due to lack of

Godavari inflows and shortage of canal water during *rabi*, rice could not be taken up in the *rabi* season and so there is immense need to develop viable rice based cropping system. Due to late release of canals, *kharif* rice plantings are also delayed (up to mid August) and the growing season extends up to December/January months. The next crop (*rabi)* is further delayed and plantings were done during January and its duration extends up to April/May. Therefore sowing window of *rabi* crops play a great role in deciding the performance and yield potential of *rabi* crops. Suitable rice based cropping has to be evaluated to assess the stability in production.

METHODOLOGY

A field experiment was conducted at Andhra Pradesh Rice Research Institute & Regional Agricultural Research Station, Maruteru during *Kharif* and *Rabi*, 2014-15 seasons with an objective to test the productivity and profitability of various cropping systems with a view to identify the most remunerative cropping systems suitable for Godavari delta region of Andhra Pradesh under heavy soils. During *Kharif* season the entire experimental area is divided into two blocks along with common check plot and transplanting was done with two duration group rice varieties 1) medium duration rice variety MTU 1075 which is of 135-140 days duration and 2) long duration rice variety MTU 1112 which is of 150-155 days duration and a common check rice variety MTU 1061 (145-150 days duration). During *Rabi* season these two blocks were further divided in four sub blocks and common one check with a view to overcome the delay plantings and to ensure timely sowing of ID crops. Method of sowing during *rabi* season was dibbling according to the treatment under zero tillage condition. First block sowings were completed 15 days early to second block sowings during *Rabi* season. Experiment was laid out in randomized block design with eight treatments in two blocks and one common check and replicated thrice. The experimental soil was clay loam in texture and slightly alkaline, low in organic carbon (0.43%) and available nitrogen (188 kg/ha), medium in available phosphorus (34.4 kg/ha) and high in available potassium (225.4 kg/ha).

RESULTS

During *Kharif* season medium duration rice variety MTU 1075 recorded highest grain yield of 6427 kg/ha followed by check variety MTU 1061 (6245 kg/ha) which were significantly superior over late duration rice variety MTU 1112 (5919 kg /ha). The impact of rice crop on succeeding ID crops yields were analysed with *rabi* season data. Highest grain yield of ID crops were recorded with first block plots where medium duration rice variety MTU 1075 was grown during previous season compared to long duration rice variety MTU 1112. Maize and sorghum crops performed well and recorded 1405 kg /ha and 993 kg/ha grain yields compared to other ID crops (Table 1). Maize after *kharif* rice and sorghum after *Kharif* rice cropping system performed well among rice-ID crops cropping systems. But, among the treatments highest Rice grain equivalent yields of 1802 kg /ha was observed with rice-blackgram cropping system followed by rice-maize cropping system. Highest total system productivity was recorded with rice-rice crop sequence (8.83 t/ha/yr) followed by rice-blackgram crop sequence (7.87 t/ha/yr) which is on par with rice-sorghum crop sequence (7.50 t /ha/yr). By taking into consideration of total system benefit: cost ratio, highest B:C ratio of 1.28 was observed with rice-blackgram followed by rice-sorghum (1.24) which is significantly higher than rice-rice mono cropping system (1.10). The productivity and profitability of various cropping system could be enhanced by intensification or diversification of predominant cropping systems through inclusion of fodders and pulses. It was found

Table 1. Influence of various rice based cropping systems on yield, system productivity and economics

Treatment No.	*Kharif*	*Rabi*	Grain yield (kg/ha) *Kharif*	Grain yield (kg/ha) *Rabi*	System Productivity (t/ha/yr)	System Gross Returns (Rs/ha/yr)	System Net Returns (Rs/ha/yr)	B:C Ratio
Medium duration rice (135-140 days)								
T1	Rice (var. MTU 1075)	Maize	5810	1405	7.10	88,783	33	1.00
T2	Rice (var. MTU 1075)	Sorghum	6427	993	7.50	91,760	18,010	1.24
T3	Rice (var. MTU 1075)	Soybean	5882	229	6.47	76,166	7,916	1.12
T4	Rice (var. MTU 1075)	Blackgram	6064	501	7.87	81,555	17,805	1.28
Long duration rice (150-155 days)								
T5	Rice (var. MTU 1112)	Maize	5737	817	6.49	81,109	-7,641	0.91
T6	Rice (var. MTU 1112)	Sorghum	5628	736	6.42	78,816	5,066	1.07
T7	Rice (var. MTU 1112)	Soybean	5919	254	6.57	76,905	8,655	1.13
T8	Rice (var. MTU 1112)	Blackgram	5701	365	7.02	75,461	11,711	1.18
	Check (145-150 days)	*Check (120 days)*						
T9	Rice (var. MTU 1061)	Rice (var. MTU 1010)	6245	2584	8.83	1,07,787	10,037	1.10
SEm ±	119.2	106.8	0.21	1942	1943	0.03		
CD (P=0.05)	360	323	0.65	5874	5874	0.08		

that cropping sequences including legumes performed fairly well with regard to rice productivity besides building soil fertility.

CONCLUSION

The experimental results indicated that, monocropping of rice-rice cropping system not only escalating the system cost of cultivation by means of increasing pest and disease complex and also loss of soil fertility due to monocropping. Adoption of selected cropping systems like rice-blackgram, rice-sorghum and rice-maize will not only enhances the cropping intensity but also improves soil fertility. A scientific approach in selection of varieties and crop management practices will usher in greater dividends and more importantly sustains the soil for future generations.

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Vegetable based cropping systems for prosperity and nutritional security

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Agriculture continues to be a major source of livelihood in India. However, due to poor crop management practices, limited resources and lack of know-how the productivity and income from farms is low as evident from baseline survey reports. Therefore, major effort has been on identification and introduction of suitable crop varieties with location specific management practices and diversification to vegetable crops for better remuneration (Singh, 2008). The major crop interventions include introduction of improved crop varieties, intercropping, crop diversification and seed production. The horticulture sector includes fruit crops, vegetable crops, potato and tuber crops, ornamental crops, medicinal and aromatic crops and spices and plantation crops. It contributes in poverty alleviation and nutritional security. Vegetable crops are highly income intensive if improved management practices are adopted along with development of appropriate market linkages. They are also rich source of nutritional security. Horticulture is not only an integral part of food and nutritional security, but also an essential ingredient of economic security. Vegetable cultivation is considered one of the major sources of food security and income generation among the rural community. The role of horticulture is changing rapidly from traditional to high income generating activity. The process of transition from low-input largely subsistence horticulture to a more intensive market-oriented version presents many challenges. Objective of study was to develop horticultural crop based model for improving profitability and nutritional security of small and marginal farmers.

METHODOLOGY

Experiments were conducted at Indian Institute of Farming Systems Research, Modipuram, Meerut to develop horticultural crop based model for improving profitability, enhancing productivity and nutritional security of small and marginal farmers particularly of western plain zone of Uttar Pradesh. Three modules, viz. Fruit based (CS 1, 0.3 ha), vegetable crops based (CS 2, 0.22 ha) and field crop based (CS 3, 0.4 ha) were evaluated under this project by using randomised block design replicated for years. Under fruit crop based system (CS-1), mango, guava and banana were grown as the main crops whereas cucumber, radish, carrot and onion as the intercrop in mango, brinjal, veg pea and okra as intercrops in guava and turmeric as intercrop in banana respectively. In vegetable based system (CS-2) turmeric, bottlegourd-cauliflower-tomato and brinjal-potato were grown while under crop based system (CS-3), Rice-wheat and sugarcane-ratoon were evaluated and compared.

RESULTS

On comparison of three cropping systems viz., CS 1- Fruit based system (0.3 ha), CS 2- Vegetable based system (0.22 ha) and CS 3- Agronomic crop based system (0.4 ha), CS-3 recorded the highest net returns worth Rs.2,63,912/ha followed by CS-1 with net returns of Rs. 2,24,928/ha. Maximum net returns of Rs 2,02,657/ha was recorded for Cucumber-Radish-Carrot-Onion system followed by Turmeric (Rs 1,47,780/ha) and Brinjal-Potato-Beans system (Rs 68,035/ha) among vegetable based cropping systems and hence showed that these systems have performed best and rendered higher returnsmainly due to contribution by cash crops. Fruit based system (CS 1) gave highest net returns per ha as there was additional returns from vegetables which were used as intercrops in the juvenile fruit trees The highest economic efficiency of Rs 617.93/ha/day was recorded for CS-1 followed by CS-2 (Rs.565.51/ha/day) which shows that diversification with vegetables is more remunerative than cereal based monocropping systems (CS-3). Similar results were reported by Kashyap *et al.* (2015).

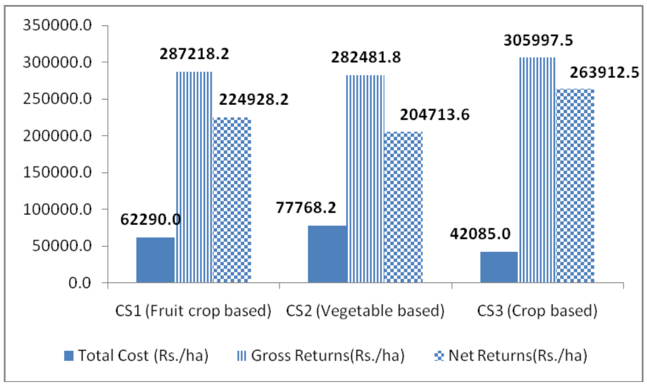

Fig. 1. Economics of the different cropping systems under study

CONCLUSION

Results obtained from the study revealed that diversification of existing cereal based mono-cropping systems with more remunerative vegetable based system is capable of providing higher returns and monetary gains to the farmers of the western plain zone of Uttar Pradesh.This will not help in providing additional income to the farmers through cash crops but also in achieving nutritional security through diverse food products other than cereals.

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Effect of manures and fertilizer on paddy for growth and yield under casuarina (*Casuarina equisetifolia*) based agri-silviculture system

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Agri-silviculture system which is gaining ground in most developing countries, which ensures an intensive utilization of the land. It provides employment means of subsistence to people. This system provides the basic requirement of fodder, fuel, pulp and green manure for agricultural crops (Sanchez, 1995). Farmers of our country integrate fast growing trees on their farm land in association with agricultural crops. The higher income from agroforestry unlike monocropping of agricultural crops is a major reason for farmer to plant more trees in association with agricultural crops.The role of trees in soil erosion control and productivity maintenance on a sustained basis has been proved (Viswanath *et al.,* 2005).

METHODOLOGY

The present study was conducted during 2012-2013 in already established 15 years Casuarina plantation spaced at 10

Table 1. Effect of fertilizer and manures on yield and yield attributing characters of paddy crop under *Casuarina equisetifolia* based agri-silvicltural system and open area.

Treatment	Grains/panicle		Test weight (g)		Grain yield (t/ha)		Straw Yield (t/ha)	
	Agri silviculture system	Open area	Agri silviculture system	Open area	Agri silviculture system	Open area	Agri silviculture system	Open area
T_1	130	132.0	22.8	23.0	2.65	2.68	3.52	3.63
T_2	175	179.0	24.2	24.5	3.84	4.07	5.57	5.94
T_3	166	168.0	23.8	24.1	3.36	3.41	4.65	5.12
T_4	161	163.0	23.5	23.8	3.22	3.25	4.42	4.58
T_5	165	169.0	23.6	24.2	3.30	3.58	4.51	4.93
CD (P=0.05)	10.43	11.04	NS	NS	0.206	0.23	0.320	0.30

m x 3 m at N. D. University of Agriculture and Technology, Kumarganj, Faizabad ($26^0 27'$ N latitude and 82^0 12' Elongitude at an elevation 113 m above mean sea level). The annual rainfall during 2012-2013 was 1148 mm.Paddy variety- Sarjoo-52 was taken in RBD experimental design with four replications in 5treatments: T_1.Control (Open area) T_2. NPK (120:60:40 kg/ha) T_3.FYM (24 t/ha) T_4.Paddy straw (24 t/ha)T_5.Pressmud (10t/ha). Paddy crop was estimated in terms of yield parameter(Grains/panicle, test weight (g), grain and straw yield (t/ha) by quadrate method at the time of harvest. Five quadrates of 1 m^2 were selected per replication between rows of Casuarina. The yield of produce (grain) was extrapolated to be expressed in t/ha. All cultural practices were adopted as per recommended for cultivation of paddy.

RESULTS

The yield and yield attributing characters of paddy variety Sarjoo-52 exhibited significant differences under different treatments. The number of grains/ panicle, grain yield (t/ha) and straw yield (t/ha) were recorded significantly lesser in T_1 –treatment control (where trees were planted but fertilizer and manures were notapplied) under agri-silviculture system due to more shade and competition for moisture and nutrients between annual and perennial plants. The result indicated that the significantly higher number of grains/panicle(175),grain yield (3.840 t/ha) and straw yield (5.57 t/ha) were recorded in T_2–NPK (120:60:40 kg/ha) under agri-silviculture system, which found significantly superior over other treatments due to maximum amount of inorganic fertilizer was applied in that treatment, whereas the maximum test weight (24.20 g) was found in T_2- treatment NPK-(120:60:40), In case of open area higher value was recorded in T_2- treatment (24.50 g). But variations were found non-significant in both agrisilviculture system and open area.The vegetative and reproductive growth was promoted by increasing N rates. Treatments T_3, T_4 and T_5 were found statistically at par. While in case of open area, comparatively significantly higher number of grains/ panicle(179), grain yield (4.07 t/ha) and straw yield (5.94 t/ha) were recorded in T_2–NPK (120:60:40 kg/ha) because no shade and competition for moisture and nutrients between annual and perennial plants. Reduction in yield of paddy crop under system may be because of fact that shade negatively affects grain yield. The reduction in yield depends on the direction of tree line, its composition, height, spacing and quantity of light intensity. Similar finding was also reported by Sirohi *et al*. (2012).

CONCLUSION

The maximum grain yield (3.84 t/ha) and straw yield (5.57 t/ha) of paddy were obtained in T_2 (NPK 160:60:40) under *Casuarinaequisetifolia*basedagri-silviculture system.While in open area higher value was observed i.e. grain yield (4.07 t/ ha) and straw (5.94 t/ha) was noted in same treatment T_2.

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Identification of Bio-intensive complimentary cropping systems for higher productivity, profitability and efficient resource use

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A concept of complementary intensive intercropping system was conceived to deal improvement in productivity with input use efficiencies, reduction in cost of cultivation and creating gainful employment issues (Gangwar, 1983). The growing of morphologically and physiologically different two or more than two crops in association under different land configurations which complements each other and subsequent crops on one hand and saves the resources on the other is defined to be "Bio-intensive complimentary cropping system". Under these systems, not only the higher productivity and total biomass yield both above & below ground along with improving the yield of crops, by improving soil health, more judicious use of water, nutrients, may result in resource saving too. To study all these aspects the present study was undertaken.

METHODOLOGY

The experiment was conducted for two consecutive years (2012-13 and 2013-14) at the research farm of Indian Institute of Farming systems Research, Modipuram, Meerut (U.P.). The soil of the experimental plot was sandy loam containing initial level of 125.4 kg/ha available nitrogen, 24.5 kg/ha P_2O_5 and 126.2 kg/ha K_2O. Ten bio-intensive complementary cropping systems involvingland configurations, in situ green manuring, residue incorporation, zero/minimum tillage and inter cropping approaches were laid out in RBD replicated thrice. The details of treatments are indicated in table 1.Recording of the observations and computation of different economic values were done by following standard procedures.

RESULTS

Raising of maize for cobs +vegetable cowpea in 1:1 ratio on broad beds (BB) and *Sesbania* in furrow during *kharif* and mustard in furrow and 3 rows of lentil on broad beds in *rabi* while 3 rows of green gram on beds in summer produced highest REY of 26.58 t/ha with productivity of 72.81 kg/ha/

Table 1. Bio-intensive complimentary cropping systems for higher productivity and profitability as alternative to rice-wheat (Pooled data of 2 years)

Treatments	Grain/fodder yield (t/ha) *Kharif*	*Rabi*	Summer	REY (t/ha)	Net returns (/ha)	Productivity (kg/ha/day)	Profitability (/ha/day)
Rice-wheat	5.18	5.17		11.29	100651	30.93	276
Hybrid rice-lentil(b)+wheat (firb)-cowpea (v+r)	6.34	0.19+4.19	0.78	12.84	117859	35.17	323
Maizec)+veg. cowpea(bb)+sesbania (f)-lentil(bb)+ mustard(f)-green gram (mt) (g+r)	12.19+1.14	1.37+1.98	1.68	26.58	259936	72.81	712
Maize (g)+black gram (1:1)-veg. pea (firb)+mustard (f)-green gram (g+r)	2.42+0.48	0.82+0.97	1.59	14.32	89377	39.23	245
Maize (c)+sesbania-toria+g. sarson(tpt)- greengram (zt) (g+r)	11.63	1.39	1.52	19.40	169236	53.15	464
Sorghum+cluster bean (f)-maize(c)+black gram (1:1)-methi-cowpea (v+r)	25.54+ 12.61+0.45	2.26	0.77	22.46	210610	61.53	577
Pigeonpea+black gram (1:1)-wheat+mustard (6:1)(zt)-cowpea (f) (zt)	1.46+0.54	4.96+0.47	23.55	16.26	168332	44.55	461
Pigeonpea-wheat+methi (6:1)(zt)-cowpea (f) (zt)	1.88	4.85+0.34	26.13	15.35	160820	42.05	441
Maize+cowpea (f)- maize(c)+black gram- wheat+ methi (6:1)-green gram(g+r)	27.78+11.46+0.37	5.03+0.23	1.36	24.13	254107	66.11	696
Sorghum(g) + cowpea (v) -oat (f)-pearlmillet(f)+ cluster bean (v)	2.48+2.21	52.84	47.82+0.25	14.64	109588	40.10	300

day and profitability of Rs. 712/ha/day was better than other systems. The complementary effects were reflected in the system as in broad bed and furrows (BBF) system, the furrows served as drainage channels during heavy rains in *kharif* which were utilized for *in-situ* green manuring with 32 t/ha green foliage incorporated after 45 days of sowing. The timely sown mustard crop in these furrows resulted a good harvest 1.98 t/ha and a bonus yield of lentil (1.37 t/ha) could be harvested on one hand and 35% of irrigation water was saved. In the summer season green gram could yield 1.68 t/ha as grain while incorporation of green gram foliage of about 4 t/ha in the soil further helped the system favourably. Bio-intensive system of raising maize +cowpea (f)-maize (C) +black gram-wheat+ methi (6:1)-green gram (G+R) was second best which resulted in REY of 24.13 t/ha with productivity of 66.11 kg grain/ha/day and profitability of Rs. 696/ha/day. This system proved to be the second best in the order of merit. The lowest REY (11.29 t/ha) with productivity of 30.93 kg grain/ha/day and profitability (Rs. 276/ha/day) was obtained under the conventional rice-wheat system (Table 1).

CONCLUSION

Thus, the results indicated that the rice-wheat system can be diversified by maize (Cob)+vegetable cowpea (BB)+sesbania (F)-lentil(BB)+mustard (F)-green gram (MT) (G+R) system followed by maize+cowpea (f)-maize (Cob)+black gram-wheat+methi (6:1)-green gram (G+R).

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Agri-horticulture systems for hyperthermic sandy loam soils in saline groundwater rain-fed semi-arid regions of north-west India

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Arid and semi-arid regions throughout world suffer from water scarcity because of scanty and uneven distribution of rainfall (Armitage, 1984). Large tracts of these regions usually lack supplemental irrigation facilities, except for the low yielding very deep saline groundwater aquifers, and thus remain underutilized or fallow throughout year. In India, about 127.3 mha areas lie underutilized round the year (MoA, 2012; Dagar *et al*., 2013). Groundwater surveys in the country, especially in Rajasthan, Gujarat, Haryana and Punjab; suggest that 32-84% of the total groundwater development for irrigation is poor in quality (GoI, 1998). In the past, efforts towards utilisation of saline groundwater aimed at enhancing the production of only arable crops. However, some studies have also suggested productive use of saline groundwater for irrigation in medicinal/aromatic and plantation crops (Tomar *et al*., 2010). Therefore, a study comprising assessment of some agri-horticulture systems was taken up to identify low water requiring agri-horticulture systems for improving farm income and ecological sustainability in rain-fed saline groundwater regions.

METHODOLOGY

A long-term (2003-2013) field study on assessment of low water requiring salt tolerant agric-horticulture systems [karonda (*Carissa carandas*), bael ((*Aegle marmelos*) and aonla (*Emblica officinalis)* with barley and mustard during winter and pearl-millet and cluster-bean during rainy season as companion crops in tree row inter-spaces] was conducted at Bir Reserved Forest (29° 10'N longitude and 75° 44'E latitude with an altitude of 240 m above mean sea level), Hisar (Haryana), India. The experimental site soil is calcareous sandy loam hyperthermic camborthids and climate is semi-arid monsoon type. The experiment was laid out in RBD by transplanting 6-7 months old saplings of 3 horticultural species in re-filled auger holes (0.2 m in diameter and 1.2 m deep) at 4 m intervals (2m in case of *karonda*) in sill of the furrows (0.15 m deep and 0.6 m wide) made at 5 m distance. The saplings were basin irrigated using low (ECiw 4-5 dS/m and SAR 18) salinity water as per the need for the 3 months during July- Sep. 2003. Afterwards these were irrigated as per the treatment using the water of low salinity, alternate irrigation with water of low and high (ECiw 8.5-10.0 dS m^{-1} and SAR 21) salinity and irrigation with water of high salinity. These were compared with control treatment of low salinity water irrigated arable crops without trees. Pearl-millet (*Pennisetum typhoides* cv HHB 68) - barley (*Hordeum vulgare* cv BH 375), cluster bean (*Cyamopsis tetragonoloba* cv HG 365) - barley and cluster bean - mustard (*Brassica juncea* cv CS54) rotations were taken up during 2003-04, 2004-2007-08 and 2008 to 2012-13, respectively. *Kharif* season crops were sown after onset of monsoon but a pre-sowing 6 cm irrigation of low saline water was given in before sowing of *rabi* (winter) and *kharif* crops in delayed monsoon years. Soil samples were collected from three random spots in each treatment plot initially and twice (April November) every year and analysed for electrical conductivity (ECe) and pHs while tube well water samples were collected and analysed every month for EC, pH, SAR and RSC. Survival, growth and fruit-yield of horticultural species were recorded after bearing season and in April every year while fresh and dry biomass and grain/seed yields of all the companion crops were recorded from respective treatment plots at harvest and converted to tonnes per hectare.

RESULTS

In different saline (low, alternate and high) water irrigation treatments, survival of karonda, bael and aonla varied from 92-98, 87-95 and 58-69%, respectively in 1st year. While after 3 years, it remained 100 and 90-98% of 1st year in karonda and bael, respectively but reduced to 90, 86 and 80 in low, alternate and high salinity water irrigation treatments, respectively. Karonda and bael started bearing after 3 years and recorded 0.95, 89 and 46 and 2.32, 1.85 and 0.96 t/ha in low and alternate and high saline water irrigation, respectively. After 5 years, most of the trees of all the three species started bearing fruits. As such in alternate and high salinity water irrigation, fruit yields of karonda, bael and aonla reduced by 18 and 27.5, 31.7 and 54.8, and 24 and 41.6%, respectively over low saline water irrigation and followed the similar trend with improved yields thereafter. During initial two years, amongst companion crops the grain yield of pearl-millet decreased 13-25% when the crop was irrigated adopting T_3 and T_4 treatments as compared to T_2, but no significant reduction was observed in its stover yield and grain and straw yield of *rabi* season barley crop. Barley recorded the mean grain and straw yield of 2.46 and 2.95 t/ha, respectively. The yield of cluster-bean in subsequent years decreased when irrigated with high salinity water or alternate use of low and high salinity water. Influence of canopy of the fruit trees was also observed on the yield of cluster-bean crop. Reduction in yield of the companion crop was more when cultivated with bael because of larger canopy of the trees as compared to aonla and karonda. Since 2008, barley was replaced by mustard crop during *rabi* season. Like barley and cluster bean, mustard also showed reduction in yield due to higher salinity and under bael due to larger canopy impact. After the harvest of *rabi* crops, salinity build up in upper 0-1.2 m soil depth was recorded with alternate salinity water irrigation, more so when irrigated with water of higher salinity. However, except for below normal rainfall years soluble salts leached down in the profile. Karonda followed by bael with peral-millet – mustard agri-horticulture systems were more remunerative than aonla based systems.

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Soil-site suitability evaluation for groundnut in soils of Porbandar Taluka, Gujarat for improved livelihood and sustainable agriculture in the region

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Groundnut is an important oilseed crop, possessing a high nutrition value as it contains 40-48% oil, 26% protein, 12% starch, 5% soluble sugar and 2% crude fiber. Production potential of any crop is principally affected by soil-site parameters as conditional by climate, topography, fertility and management level (Sehgal, 1987). Therefore, it is necessary to interpret the soil-site characteristics of any place in terms of their suitability for the important crops grown in the region. Information on soil-site suitability of Groundnut crop in different landforms of Porbandartaluka is skimpy. Hence, it is desirable that the Groundnut crop should be grown as per the suitability in different kinds of soils as well as climate and physiography. Keeping above theory in mind the study "soil-site suitability evaluation for groundnut in soils of porbandartaluka, Gujarat for the improved livelihood and sustainable agriculture in the region" has been done.

METHODOLOGY

The study area falls under AESR 5.1 (Central Kathiawar peninsula, hot dry semiarid ESR with shallow loamy clayey black soil, medium AWC) along the Arabian Sea coast. It lies between $21^0$13'to $21^0$58'N and $69^0$22' to $70^0$01' E. The temperature regime is megathermic in hill slope, upper piedmont and lower piedmont and iso-megathermic in piedmont plain and coastal area. Average rainfall of last 10 years of the block is 877 mm with the length of growing period (LGP) is 90-120 days.Soil survey of the taluka has been conducted on 1:10000 scale using existing, digital base maps and IRS P6 imagery. Sixteen representative soil series including twenty eight mapping units of three landforms viz., soils of hill & pediment, soils of piedmont & alluvial plain and soils of coastal plain were selected for present study. Physical and chemical characteristics were estimated by using standard procedures. Suitability classes were determined with regards to the number and intensity of limitations. The soils were evaluated in different suitability classes *viz.*, S1: Highly suitable, S2: Moderately suitable, S3: Marginally suitable and N1: Currently not suitable

RESULTS

Soils of hill and pediment are shallow to moderately shallow, excellent drained, very dark brown to dark brown, gravely loam to gravely clay loam, clayey and loamy skeleton particle size, strongly calcareous, high in organic carbon, strongly alkaline, moderate to severely eroded, gently slope (3-8%) with 40-50% coarse fragments and A-C horizon sequence. Soils of Piedmont and alluvial plain are shallow to very deep, well drained, very dark brown to brown, strong to violently calcareous, clayey to fine in texture, fine particle size class, medium in organic carbon, slightly to moderately eroded, very gently slope (1-3%) with 10-15% coarse fragments and A-Bw-BC horizon sequence. Soils of coastal plain are shallow to very deep, excessively to poorly drained, brown to yellowish brown, sandy to fine in texture, calcareous, low to high in organic carbon, slightly eroded and slight to strong salinity and sodicity with nearly level (1-3%) to gently slope (3-8%) and 10-50% coarse fragment and A-Bw-Bss/C/Bck-Bc/A/Cr/Ck-R/C horizon sequence.The average yield of groundnut in Porbandar district is 1.4t/ha, which is 10-15% more than the state average. A large area of coastal plain landform falls under not suitable class due to shallow depth, less organic carbon, high EC and high salinity/sodicity, whereas rest of the area soil properties represents the moderately and marginally suitable classes for the cultivation of groundnut crop.

CONCLUSION

Climate or soil properties mainly influence the yield of groundnut crop, so with this study we can conclude that each soil properties affect the yield of crop up to a certain extent in a particular region. So we have to improve or take care most important limiting factor for getting maximum yield from the available resources in a particular climate and soil regime.

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Diversification of rice-wheat cropping system under resource conservation and nutrient management

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Efforts for diversification of agriculture with reduced tillage and adoption of alternative cropping systems could be a successful tool due to assured profitability and lower risks with the system. Tillage increases soil degradation and erosion (Cerda *et al*., 2009), reducing soil productivity and soil organic carbon (Lal, 2004), whereas reduced or no till practices can increase soil organic carbon in the surface soil layer (Lopez- Bellido *et al*., 2010). Crop diversification allows the efficient utilization of resources like land, water and nutrient which is based on the suitable crop selection procedure for increasing production and productivity. This study aims at exploring suitable possibilities of diversification of the rice-based cropping sequence to sustain agricultural productivity and mitigate the demand of food grains for small holders in Bihar.

METHODOLOGY

A field experiment was conducted during 2010-11 to 2014-15 at Bihar Agricultural University, Sabour, Bhagalpur to determine agronomically efficient and economically viable rice based cropping systems under resource conservation practices and nutrient management. The soil was loam in texture, low in fertility status (201 kg available N/ha, 16 kg available P/ha, 160 kg available K/ha), having pH 7.5, organic C 0.64%, bulk density 1.44 g/cc with 19% field capacity, 7.6% permanent wilting point and 0.35 cm/hr infiltration rate. Four rice-based cropping systems were evaluated under different tillage systems (different resource conservation practices) and fertilizer doses to determine sustainable and economically viable cropping systems. The experiment was laid out in split plot design with three replications. The main plots consisted of minimum and conventional tillage systems whereas the subplot treatment consisted of a combination of four rice based cropping systems viz. rice–wheat–mung bean (grain + residue incorporation), rice–potato–Onion + maize (relay cropping), rice–maize + potato–cowpea (fodder) and rice–cabbage–maize + mung bean (Grain + residue incorporation) and two levels of fertilizer i.e., 100% RDF (recommended dose of fertilizer) through inorganic fertilizer and 75% + 25% RDF through inorganic and organic respectively. Rice (*Oryza sativa* L.) cv PHB–71 (Hybrid) was grown during rainy (*Kharif*) season as transplanted rice. However wheat (*Triticum aestivum* L.) cv HD-2733, potato (*Solanum tuberosum* L.) cv Kufri Ashoka, maize (*Zea mays*) cv Pioneer hybrid (30V92) and cabbage (*Brassica oleracea*) cv Disha hybrid were grown during rabi season. Cowpea (*Vigna unguiculata*) cv Mitali as fodder, mung bean (*Vigna radiata*) cv SML-668, onion (*Allium cepa*) cv Patna Red as summer crops were raised under irrigated conditions with recommended package of practices. Maize + potato, Maize + Onion and Maize + Mung bean were sown with a spacing of 60×20 cm while the intercrops were sown with a spacing of and 60×20 cm, 15×10 cm and 30×10 cm respectively. Seeds of maize in onion + maize relay cropping were dibbled in 4:1 row proportion, 15 days before onion harvesting. For comparison between crop sequences, the yields of all the crops were converted into rice equivalent yield. Three years mean data was analyzed for computing economics of the systems. The B:C ratio was then determined as the ratio of net return to cost of cultivation of the system.

RESULTS

Among the four rice based cropping sequence tested, rice-potato-onion + maize (cob) cropping gave the highest mean rice-equivalent yield (30.65 t/ha/year) and net returns (‘ 1, 29, 293/ha/year), followed by rice-potato + maize-cowpea with rice-equivalent yield (27.53 t/ha/year and net returns (‘ 1, 21, 019/ha/year). Rice-wheat-mungbean cropping system recorded the least net return of ‘ 99, 934/ha which indicated that inclusion of vegetable crops like potato, onion and maize in the cropping systems not only increases the system productivity but also fetched premium prices in the market, thereby increasing the net return which was in parity to findings of Sharma *et al.* (2014). Conventional tillage and incorporation of 75% RDF through inorganic source and 25% through vermicompost significantly increased REY and net return by 6.4% and 7.4 % over minimum tillage and recommended dose of fertilizer applied indicating the role of major nutrients in attaining remunerative system productivity in lieu of changing climate scenario. However, the benefit cost ratio was the highest (2.23) in rice–wheat–mungbean, followed by rice–cabbage–maize + mung bean (1.83) which was significantly lower than the highest value. Tillage practices and fertilizer

Table 1. Effect of tillage practices and fertilizer rates on yields, net return, nutrient uptake and fertility status under different rice-based cropping systems (mean over 5 years)

Treatment	REY (t/ha)	Net return ($x10^3$ /ha)	B:C ratio	Nutrient uptake (Kg/ha)			OC (%)	Available nutrients (kg/ha)		
				N	P	K		N	P_2O_5	K_2O
Tillage Practice										
Minimum Tillage	23.13	106.5	1.80	341.2	97.2	351.5	0.61	197.2	33.6	167.2
Conventional Tillage	24.62	118.7	1.86	347.2	103.8	377.6	0.60	195.1	32.5	166.6
CD (P=0.05)	0.48	4.98	NS	6.61	1.89	9.75	NS	NS	NS	NS
Cropping system										
Rice - wheat - mung bean	17.17	99.9	2.23	249.7	64	268.8	0.62	208.1	35.1	179.7
Rice - potato - onion + maize (cob)	30.65	129.3	1.73	373.6	113.5	396.4	0.59	184.8	31.0	156.3
Rice - potato + maize - cowpea (F)	27.53	121.0	1.76	392.2	116.2	406.7	0.60	187.5	32.2	161.0
Rice – cabbage- maize+mung bean	20.13	100.2	1.83	361.3	108.3	386.3	0.61	204.4	33.8	170.6
CD (P=0.05)	0.68	7.04	0.09	9.34	2.67	13.8	0.04	4.63	2.13	4.52
Fertilizer rate										
RDF	23.13	109.5	1.83	325.4	95.8	350.1	0.59	193.7	31.7	164.2
75% RDF + 25% through vermicompost	24.61	115.6	1.82	362.9	105.3	379.1	0.62	198.7	34.3	169.6
CD (P=0.05)	0.65	6.56	NS	10.16	2.73	10.28	NS	4.42	2.05	4.38
Initial soil value		0.56	200.7	26.5	219.5					

rates had no significant effect on B: C ratio. Rice-potato + maize-cowpea (F) cropping system was found to be most exhaustive cropping system which removed the maximum quantity of N (392.2 kg/ha), P (116.2 kg/ha) and K (406.7 kg/ha), followed by rice-potato-onion + maize (cob) relay cropping which removed 373.6 kg N /ha, 113.5 kg P /ha and 396.4 kg K /ha. The lowest uptake of 249.7 kg N, 64.0 kg P and 268.8 kg K /ha was recorded under rice-wheat-mung bean cropping system. Higher N, P and K uptake in these systems might be due to greater biomass production of the crops and more content of nutrients, which also confirms to the findings of Sharma *et al.* (2014). Organic carbon and available P balance was positive in all the treatments where as a slight decreasing trend over initial soil fertility status was observed in available N and K pool in all the cropping systems. Rice-wheat-mung bean cropping system helped in enhancement of soil organic carbon and available NPK levels. Minimum tillage and application of 75% recommended doses of fertilizers + 25% N through vermicompost helped in improving organic carbon and available NPK status in comparison to conventional tillage and recommended doses of fertilizers, respectively.

CONCLUSION

It can be concluded that farmers with adequate resources can diversify the existing rice-wheat cropping system with rice-potato-onion + maize (green cobs) and rice-potato + maize-cowpea with 75% RDF + 25% through vermicompost for getting higher productivity and profitability under irrigated conditions of Bihar.

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Extended Summaries Vol. 1 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Effect of harvesting time on essential oil content and composition of *Artemisia maritima* in the cold desert region of the western Himalayas

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Artemisia maritima L. (syn. *A. brevifolia* wall.) commonly known as sea wormwood is perennial aromatic shrub distributed in western Himalayas at altitudes of 7000-9000 feet. It grows abundantly in north-west Kashmir, dry temperate regions of Himachal Pradesh and to a certain extent in Chamoli district of Garhwal Himalayas (Uttarakhand) (Chauhan *et al.,* 2010). It is a deciduous shrub growing to 0.6 m height and a hardy crop which flowers from August to September. It grows fairly on the dry and sandy slopes of Lahaul–Spiti and Kinnaur district of Himachal Pradesh between 2700m and 3400m. The plant is commercially utilized in India for santonin which is anthelmintic and very effective against round worms (Ascaris spp.). The essential oil of *A. maritima* has anti-infective, antibacterial, antifungal, antispasmodic and bronchodilatory activities (Chauhan *et al*., 2010). 1, 8-cineole, camphor and borneol are the major compounds present in its essential oil. There is no information regarding its harvesting time hence this study was conducted to find out the effect of harvesting time on essential oil content and compounds of *A. maritima* from its natural population grown in cold desert region of western Himalayas.

METHODOLOGY

A. maritima fresh plant samples were harvested from natural population from Tandi, Keylong Distt. Lahaul and Spiti, HP (3800 m amsl, 32.6'92° N, 77.3'84° E), during fourth week, in the afternoon, in different times of the growing phase of the plant at monthly interval (from June to October 2015). Fresh aerial parts (stem and leaves) of *A. maritima* (500 gm) were chopped and were subjected to hydro-distillation for 4 hrs in Clevenger type apparatus. The essential oil was dried over anhydrous Na_2SO_4 and stored in a sealed vial prior to chemical analysis. The compound analysis of oil was done by GC–2010 gas chromatograph with FID detector and a ZB–5 capillary column and GC–MS (QP2010 Shimadzu, Tokyo, Japan) equipped with AOC 20i Auto sampler and ZB–5 capillary column was used for oil analysis. Sample injection volume 2 µL (dilution: 5 µL oil in 2 mL dichloromethane, HPLC grade) was used. The retention index was calculated for all volatile constituents using homologous series of n–alkanes (C_8–C_{24}). The components of oil were identified by matching their mass spectra with those stored in the computer library namely Wiley, New York mass spectral (MS) library, National Institute of Standards and Technology, NIST (Stein, 2005), their retention indices (RI).

RESULTS

The fresh samples of *A. maritima* yielded upon hydro-distillation pale yellow oil which has an agreeable odour. Essential oil content varied between 0.22% - 0.35% on the weight of fresh leaf material in the season that lasts from June to October 2015. July to September is the best period for harvesting higher essential oil (Fig. 1). The results of the GC-MS analyses are given in Table 1, compounds being listed in order of their elution time on the ZB–5 column. A total of 15

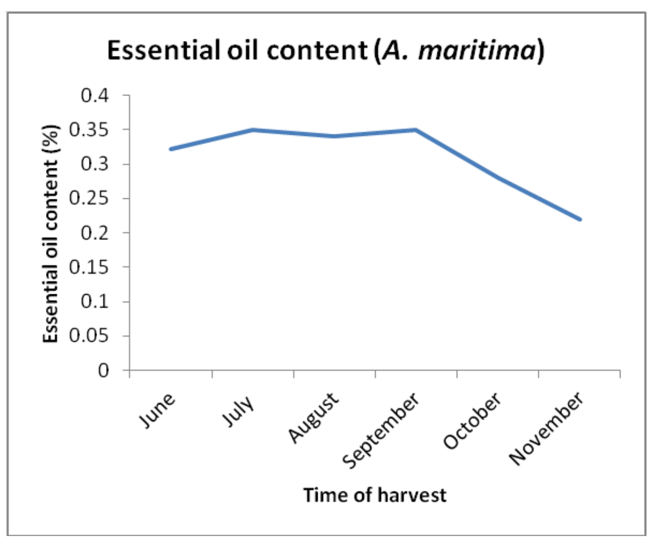

Fig. 1. Effect of different harvesting times on essential oil content of *Artemisia maritima*

Table 1. Major identified compounds of *A. maritima* essential oil in different months

Main compounds	Time of harvest					
	RI	June	July	August	September	October
Santolina triene	922	1.33±1.06	9.80±0.05	0.80±0.78	7.73±4.29	-
Camphene	970	1.64±0.13	1.86±0.01	1.69±0.13	1.79±0.31	1.65±0.14
Sabinene	991	5.28±0.81	2.80±0.00	2.06±0.16	0.85±0.33	1.07±0.40
â-myrecene	1009	2.38±1.04	4.70±0.04	1.02±0.22	10.97±1.49	2.39±2.65
1,8-cineole	1057	50.41±1.23	34.84±0.40	44.22±1.10	35.71±14.21	58.08±7.12
Linalool	1080	1.09±0.22	0.94±0.02	0.81±0.29	0.45±0.24	0.48±0.11
Camphor	1125	2.70±0.02	2.63±0.06	5.20±0.43	4.60±2.27	2.17±0.33
á-terpineol	1206	9.13±1.23	8.31±0.09	11.59±0.65	7.95±0.76	8.42±0.15
Bornyl acetate	1314	5.73±0.46	7.01±0.08	10.69±1.09	11.06±1.18	6.99±1.40
Germacrene-D	1516	2.36±0.11	1.99±0.01	1.38±0.26	0.78±0.55	0.52±0.25
Total		84.11±6.72	76.62±0.61	80.73±0.48	82.42±2.25	82.20±1.90

RI: Retention Indices; Data represents area percent in an average of two replicates (±SD)

compounds have been identified, and these compounds ranged from 76.62±0.61% to 84.11±6.72% for June to October, respectively. The major oil compounds in *A. maritima* were 1, 8-cineole, bornyl acetate and santolina triene, respectively. 1, 8-cineole compound was highest (58.08±7.12%) in the month of October (Table 1).

CONCLUSION

In conclusion, it can be stated that components of the essential oil of *A. maritima* show fluctuations in their relative amounts throughout the period under study. The plant can be harvested in the month of July to September for getting higher essential oil, however, for higher 1,8 cineole the plant is to be harvested in the month of October. The population of *A. maritima* is abundantly available in barren land but the local people are not making its effective use due to lack of knowledge of processing techniques and processing equipment. The standardization of process technology for extraction of essential oil from plant parts and testing of *A. maritima* essential oil for medicinal/insecticidal properties will further make proper utilization of fragmented land holdings.

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Improved varieties and technologies for vegetable crops to integrate in crop diversification: a study from Andaman Islands, India

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Vegetable crops are rich in dietary micronutrients and health building substances. Their addition as new crops to existing agricultural system is remunerative due to high yield potential per unit area and time along with better market price. In India, vegetable crops are grown on 9.39 million ha area with annual production of 162.89 million tonne which can supply only 145g per capita per day as against recommended dietary allowance (RDA) requirement of 300 g. Rise in purchasing power, awareness about health benefits of vegetable crops and year round availability are factors to trigger the demand of the vegetables in every household. Day to day demand of vegetables is increasing irrespective of season which sometimes lead to price escalation and impact the inflation. The wide gap between RDA and per capita availability of vegetables in Indian diets needs to be narrowed down through doubling the production by 2020 not only through cluster approach for less-perishables but also scattered approach for highly perishables. Improved varieties/hybrids, increased area, advancements in production & protection technologies and effective post-harvest management & marketing are important determinants in vegetable sector which need further R & D investments to achieve the targets of doubling the vegetable production. Breeding efforts have resulted into appropriate varieties/hybrids not only for main season but also off-season growing conditions. These improved varieties/hybrids for off-season are helpfulfor farmers to grow alternative and high value crops by replacing or adjusting their traditional cropping system. Heat tolerant tropical carrot 'Pusa Vrishti'; heat-tolerant tropical cauliflower 'Pusa Meghna', 'Pusa Kartiki', 'Pusa Ashwini', 'Pusa Kartik Sankar'; summer radish 'Pusa Chetki'; kharif onion 'N-53', 'Agrifound Dark Red', 'Baswant-780' and 'Arka Kalyan' are best possible options for crop diversification for*Kharif* season in North Indian plains. In *Rabi*(winter) and *Zaid* (summer) seasons, a range of varieties/hybrids are available in different vegetable crops for inclusion in crop diversification scheme. Developments in raised bed technology, intercropping, use of drip irrigation, training & pruning practices, weedicides, site specific tillage practices and effective insect-pest & diseases management modules favours integration of vegetables in crop diversification schemes. Cauliflower is one of the most cherished vegetable crop in India (0.43 million ha area and 8.57 million tones production). Genetic improvement has created four groups in Indian cauliflower (early; mid-early; mid-late; snowball) which makeit feasible for year roundgrowing particularly in North Indian plains. Cauliflower cultivation has spread to tropical regions including Andaman and Nicobar Islands but, its cultivation is restricted to rain free and cooler months (December to March) in these regions. The Andaman and Nicobar Islands have tropical climate and an emerging tourist destination. Caulifloweris one of the most preferred and priced (Rs. 40-120/kg) vegetable in Andaman Islands. It is grown on 280 ha with production of 1450 MT and very low productivity (5.18MT/ha). It is a high risk crop due to intense rains, high temperature and high relative humidity with high insect-pest incidence. Local production of cauliflower takes place only during December – March months while rest of months, the demand is met from mainland India. Although, genetic improvement of Indian cauliflower facilitated its spatial and temporal expansion but requires technological adjustments with suitable varieties for economic realization.To understand feasibility of introducing cauliflower into existing cropping system in the islands, the study was conducted during 2011-14 with six experiments on different components. The integrating components in the study were growing seasons (4; early and late rainy and main and late dry), improved varieties (16), protected structures (4; polyhouse, rainshelter, shadenet, open), planting methods (single row, double row, pot culture), spacing levels (4; S_1- 50 x 40 cm; S_2 - 50 x 30 cm; S_3 - 45 x 30 cm; S_4 - 40 x 30 cm)and crop combinations (cauliflower+palak; cauliflower+radish; Cauliflower+brinjal; cauliflower+chilli). The experiments were conducted in randomized block design at ICAR-Central Island Agricultural Research Institute, Port Blair, Andaman and Nicobar Islands during 2011-14. Cauliflower performed very well in cooler months of dry season (December- February; 19.7 – 24.7 t/ha) while during hot months of dry season (March – April; 6.2 - 8.0 t/ha) it was poor. 'White Marble' and 'White Shot' were found promising varieties for year round cultivation in open and protected structures. Among the four spacing level, the highest yield was recorded from 45 x 30 cm for 'White Marble' (22.5 t/ha) and 'White Shot' (17.7 t/ha) which was significantly (p<0.05) higher than other spacing levels. The raised bed + double row system (30.7 t/ha) and polybag culture (37.7t/ha) were suitable for open and protected structures, respectively. Due to heavy rains from May to November months, the farmers in the islands have limited opportunity for growing vegetable crops in open *i.e.* December – April months, hence suitable and economically remunerative crop combinations are necessary. For this, an experiment with crop combinations likecauliflower + chilli, cauliflower + brinjal, cauliflower + palak and cauliflower + radish were tested and found that the combinations had negative effect on yield of both component crops. This suggests further investigations to find appropriate crops for combinations or devise suitable technological modules for intercropping. Experiments on cauliflower in protected structures revealed that rainshelter protects cauliflower curds from impact of heavy rains and soft rot during rainy season, agro-shadenet (50%shade) from high temperature and insect-pest attacks in hot months, insect proof net house from insects during main season and polyhouse structures were found to be suitable for crop growth and yield during rainy season. The information helped in covering around 90 % of area under the identified varieties of cauliflower and taking it as important remunerative component in crop diversification and integrated farming system in the islands.However, varieties/hybrids developed in some of the vegetable crops which suits to the criteria of crop diversification, but appropriate technological modules are required for promising vegetable crops for their integration in crop diversification schemes to improve the economics of the farming sector.

Extended Summaries Vol. 1 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Diversification of Bt cotton based cropping system through transplanting of cotton for enhancing productivity and resource use efficiency

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Cotton–wheat cropping system is the second most important wheat based system in the South Asia (4.5 M ha) and India (2.6 M ha) and contributes significantly to the food security in the region. Being a cash and grain cropping system, it is highly remunerative with assured returns.However, with the conventional method of crop establishment and crop management, the productivity and profitability of the cotton–wheat system is low. The sustainability of the direct seeded cotton–wheat system in the Indo-Gangetic Plains (IGP) is at risk dueto exhaustive nature of cropping system, inadequate crop stand of cotton, delay sowing of wheat. Raising seedlings of cotton in May–June under controlled conditions and their transplanting on the onset of monsoon may be a way out to ensure optimum plant stand and reduce cost of cultivation through saving in irrigation and seed (Rajpoot*et al*. 2014). Transplanted cotton also offer opportunity to adjust 3rd crop in the existing and exhaustive direct seeded cotton -wheat cropping system as a summer legume viz., summer mung, vegetable cowpea and fodder cowpea in the window period April to June during summer. It increases the system productivity, profitability and improves soil, animal and humanhealth. As maturity of cotton extend upto end of November or early December, wheat sowing become late. In such situation, high density planting system (HDPS) of Bt. cotton shortening of growing season 15-20 days leads to timely sowing of wheat and alternate crop like onion, cauliflower, guar, reddish are better option to maximize the profit. Onion has very high export potential beside local consumption.

METHODOLOGY

A field experiment was therefore conducted at Indian Agricultural Research Institute, New Delhi during the *kharif* season of 2014-15and 2015-16 in a split plot design with three replications. of two crop establishment methods of cotton (direct sowing and transplanting) in main plots during the *kharif* and three planting density for cotton (90 × 60 cm, 75 × 45cm and 60 × 45 cm) in sub plots. In the *rabi* and summer season each sub plot was divided into two plot to adjust wheat, onion and summer mung, fodder cowpea respectively in the crop

Table 1. Effect of planting density and diversified Bt cotton based cropping system on system productivity, irrigation water productivity and profitability (pooled data of 2 years)

Treatment	Cotton equivalent system productivity (t/ha)	Irrigation water productivity (kg/ha/m^3)	Cost of cultivation (× 10^3₹)	Net return (×10^3₹)
Planting density				
90×60	5.67	69.1	102.4	145.9
75×45	5.91	72.2	105.4	152.6
60×45	6.61	81.4	107.8	179.7
SEm±	0.02	0.27	-	1.12
CD (P = 0.05)	0.07	1.07	-	4.42
Cropping system				
Direct seeded cotton- Wheat	3.87	61.4	84.0	103.8
Transplanted cotton- wheat- Mung bean	4.47	62.1	98.0	112.5
Direct seeded cotton- Onion	7.16	82.3	111.5	186.4
Transplanted cotton- onion- fodder cowpea	8.75	91.1	127.4	234.8
SEm±	0.12	1.35	-	4.68
CD (P = 0.05)	0.34	4.01	-	13.9

sequence. For nursery raising, glass of 15 cm height were filled with soil and farm yard manure in the ratio of 3:1. Two seeds were sown in each poly glass and they were watered alternate day till their transplanting in the field. Transplanting of one month old seedling was done in similar land configuration and spacing as followed for direct sowing. Seedlings were transplanted at the centre of ridge by making pit of desired dimension.

RESULTS

Cotton planted at 60 × 45 cm planting density recorded significantly higher cotton equivalent system productivity (t/ha) (6.61/5.91/5.67 t/ha) and net return (179.7× 10^3 ₹)/ ha. Among the cropping systems, transplanted cotton- onion- fodder cowpea recorded significantly the higher cotton equivalent system system productivity (8.75 t/ha) and net return (234.8× 10^3)/ ha followed by direct seeded cotton- onion, transplanted cotton- wheat- mung bean and direct seeded cotton- wheat, respectively.Irrigation water productivity of cotton planted at60 ×45 cm planting density (81.4 kg seed cotton/$m^3$of water) was 17.8% higher than that of 90 × 60 cmplanting density (69.1 kg seed cotton/$m^3$of water) of cotton. Among cropping systems, transplanted cotton- onion- fodder cowpea (91.1 kg seed cotton/$m^3$of water) proved to be statistically superior most in terms of irrigation water productivity, followed by direct seeded cotton- onion,transplanted cotton- wheat-mungbean and direct seeded cotton- wheat, respectively.

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Introduction and domestication of ginseng (*Panax ginseng*) in cold desert of Western Himalayas

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Panax ginseng Meyer (araliaceae) commonly known as Asian Ginseng is native to China and Korea. It is a perennial herb cultivated for its highly valued root in the international market. It grows in cool and temperate climate in the mountainous region. Its cultivation is difficult because of its long cultivation period and its demand for deep shade and nutrient-rich, slightly acidic, deep, and well-drained soils. It is a slow growing, glabrous, perennial herb reaching a height of 30–60 cm at the age of 5 years. Its roots are 2 to 4 inches long and one-half to 1 inch or more thick. The plant bear three to five palmately compound stalked leaves each with five leaflets with a cluster of 6 to 20 white to greenish white flowers in an umbel. It form oval berries turning red when ripe each containing two to three grayish white wrinkled seeds (Kim *et al.,* 2015). The main active ingredients in roots of Asian ginseng are saponin triterpenoid glycosides called "ginsenosides" (or panaxosides) that are thought to be responsible for the herb's claimed medicinal properties (Kim *et al.,* 2011). It acts as an adaptogen and is used to increase physical endurance and lessen fatigue, to improve the ability to cope with stress, to boost immune system and to improve concentration. It is also used for anemia, diabetes, gastritis, neurasthenia, erectile dysfunction, impotence and male fertility, fever, hangover, asthma, bleeding disorders, loss of appetite, vomiting, colitis, dysentery, cancer, insomnia, neuralgia, rheumatism, dizziness, headache, convulsions, disorders of pregnancy and childbirth, hot flashes due to menopause, and to slow the aging process.Due to its vast use in various systems of medicine it can act as boon to farmers of high altitude area.CSIR-Institute of Himalayan Bioresource Technology (IHBT), Palampur,

Table 1. Growth parameters of *P. ginseng*domesticated in cold desert region of western Himalayas

Plant Age	Plant height (cm)	Number of leaflets/plant	Number of leaves/plant	Plant spread (cm)	
				N-S	E-W
1 year old	9.0±2.3	1.0±0.0	12.4±0.9	9.2±2.4	10.6±1.1
2 year old	14.2±1.9	2.4±0.5	16.6±2.4	17.4±3.0	17.8±3.3
3 year old	27.0±3.5	4.6±0.5	23.4±2.7	26.0±3.3	25.2±1.8
4 year old	45.2±4.9	5.0±0.0	24.2±1.5	40.2±3.1	42.0±6.4
5 year old	47.0±2.9	5.0±0.0	25.2±0.4	45.4±3.9	43.4±3.0

HP, India has made efforts to introduce this plant in cold desert region of western Himalayas. The commercial production of ginseng would soon be possible in tribal district Lahaul and Spiti of Himachal Pradesh as successful trials for its domestication were conducted by the CSIR- IHBT, Palampur during 2010 to 2016.

METHODOLOGY

P. ginseng was introduced for the first timeby laying demonstration plotsin Lahaul and Spiti (3800 m amsl,32.6'92° N, 77.3'84° E), district of Himachal Pradesh, India. Soil of experimental area was silty loam in texture, acidic in reaction (pH 6.48), high in organic carbon (1.22 %), low in available N (195.31 kg/ha) andlow in available P (5.29 kg/ha). Seeds of ginseng were brought from China during July 2010. Before sowing, seeds were subjected to stratification, which is a process of long period of storage of seed in moistold sawdust with a warm/cold treatment.The stratified seeds were sown first time during October 2010 in nursery bed for the first time and then every year up to 2015.One year old healthy rooted plantlets were transplanted in rows to maintain a distance of 15 to 20 cmduring October every year from 2011 to 2016. The growing plants are provided with 50% shade.Shade was imposed using green shading nets of 50% above the wooden frames and fixed at a height of 3 m above the ground to provide 50% reduction in light. Green agro shade nets with standard size of three metres width and 50 metres length made with high-density polyethylene (HDPE) plastics was used. Proper ventilation is necessary for ginseng so north and east directions were kept open to ensure free ventilation. In winters mulching was done by covering the beds with 4-6 cm layer of forest leaves to protect the underground roots from freezing temperature and frost injury. Beds were kept free from weeds by regular weeding and hoeing. Three to four irrigations were given during summers. Field data in terms of plant height, plant spread [North-South (N-S) and East-West (E-W) direction] and number of leaves was recorded during different yearcrop growth.

RESULTS AND DISCUSSION

Plant height of *P. ginseng* increased with the increase in age of crop (Table 1). Plant height ranged from 9.0 to 47.0 cm. Number of leaflets/plant increased continuously reaching maximum from one to five in five year old crop. Similar trend was seen in case of number of leaves/plant and plant spread in both N-S and E-W directions.Number of leaves/plant ranged from 12.4 to 25.2. Plant spread in N-S direction ranged from 9.2 to 45.4 cm, however, in E-W direction it ranged from10.6 to 43.4 cm. Ginseng plants established well in cold desert region of western Himalayas as plant growth increases with age of the crop and starts producing good amount of seeds in five year old crop. Soldati and Tanaka (1984) also reported similar results showing that growth parameters and ginsenoside content increases with the increase in age of crop and was seen maximum in 4 and 5 year old crops. Choi (2008) also reported an increase in growth parameters with increasing age in Korean *P. ginseng* plants.

CONCLUSION

It can be concluded that soil and climate of Lahaul valley in Lahaul and Spiti district of Himachal Pradesh is suitable for the commercial cultivation of *P.ginseng.* Plant establishes well in cold desert region of western Himalayas as growth parameters of plant increases with the increase in the age of crop and reaches maximum maturity at the age of five years along with production of good amount of seeds and roots. There is need to develop agro technologies of this plant for harvesting maximum yield.

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Effects of cotton establishment methods and direct and residual Zn fortification on productivity and profitability of *Bt*-cotton–based cropping systems

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Cotton the "Queen of fibre", popularly known as "White Gold" is grown mainly for fibre all over the world. In India, introduction of Bt-cotton in 2005-06 led to considerable rise in area and productivity and restored the cotton-wheat production system from a short period of slow growth.Cotton-wheat cropping system is a grain plus cash cropping system which improves the economy of farmers through cultivation of cotton as an industrial commodity and wheat as a component of food security. Overall, thus, the cotton-wheat production system is of immense practical significance as it fits well within the existing cropping systems. This system of crop production is contributing largely to improve the economic condition of a large number of peoples (> 8 million) engaged in farming, processing trade and textile industry (Mayee *et al*., 2008). However, high ambient temperature especially of soil, and frequent light showers during sowing period of crop, results in sub-optimal plant population due to crust formation. Besides this, May sown crop required frequent irrigation and weeding, which increases cost of cultivation of the crop. Under this situation, transplanting of cotton on the onset of monsoon can be tried to maintain optimum growth and plant stand under high temperature conditions and reduce irrigation water and weeding requirement of the crop.Sometime in northern part of India, temperature falls early in the month of November and December, resulting in delayed maturity of cotton. In such situations, delayed sowing wheat results in low yield and forced harvesting of cotton result in yield reduction due to un-opening of bolls. In such situation, alternate crop like onion, cauliflower, guar, reddish are better option to maximize the profit. Zinc is a micronutrient most commonly limiting crop yields in Indian soils.Zinc deficiency in crop production can be ameliorated through agronomic manipulations or genetic improvement.

METHODOLOGY

The field experiments were conducted across the rainy (*kharif*) and winter seasons (*rabi*) of 2013–14 and 2014–15 at the research farm of the Division of Agronomy, Indian Agricultural Research Institute, New Delhi to evaluate the effects of cotton establishment methods and direct and residual Zn fortification on the system productivity and profitability of cotton based cropping systems. Ten treatment combinations having 2 methods of cotton establishment (Direct sowing and transplanting) in the main-plots and 5 Znlevels (control, 2.5 kg Zn/ha, 5.0 kg Zn/ha, 7.5 kg Zn/ha and 0.5% zinc sulphate foliar spray) in the sub-plots of 3 times replicated split plot design. In the succeeding winter season, sub-plots were divided into 2 sub-sub-plots to study the residual effect of treatments given to cotton on wheat and onion. Residual effect of Zn levels on onion and wheat was also compared with direct effect of Zn and for that foliar spray treatment of cotton was replaced with 5.0 kg Zn/ha to wheat and onion. Direct sowing of cotton (SP 7007, BG II) was done by dibbling method on May 27 and 28 during 2013 and 2014, respectively. For nursery raising, polyglass of 15 cm height were filled with soil and farm yard manure in the ratio of 3:1. Two seeds were sown in each poly glass on May 27 and 28 during 2013 and 2014, respectively and they were watered alternate day till their transplanting in the field. For transplanting field was prepared before the onset of monsoon and transplanting was done on July, 3 and 20 during 2013 and 2014, respectively. Crop received recommended dose of 150 kg N, 60 kg P_2O_5 and 4**0** kg K_2O through Urea, Di-ammonium phosphate and Muriate of potash. Foliar spray of 0.5 % Zinc sulphate was done at 60 and 90 DAS using 400 and 600 litres water/ha respectively.

RESULTS

Statistically similar seed cotton yield was recorded under methods of crop establishment in both the year (Table 1). Zinc levels significantly influenced seed cotton yield in both the years and application of 5.0 and 7.5 kg Zn/ha being at par recorded significantly higher seed cotton yield over 2.5 kg Zn/ha and control. Foliar application of 0.5 % zinc recorded seed cotton yield on par with 2.5 kg Zn/ha and significantly inferior to 5.0 and 7.5 kg Zn/ha. On an average, application of 5.0 kg Zn/ha recorded9.2, 14.5 and 8.3 % increase in yield over control.System productivity of transplanted cotton–wheat cropping system (CWCS) was found non-significant with direct sown CWCS during both the cropping seasons. Direct and residual effect of Zn levels was also found to induce marked variation in the system productivity of cotton-wheat system. Successive increase in Zn level caused significant increase in system productivity up to 5.0 kg Zn/ha. On an average, system productivity recorded 7.7 % increase due to direct effect of 5.0 kg Zn/ha applied to wheat and 4.8, 10.0 and 9.9 % increase due to residual effect of 2.5, 5.0 and 7.5 kg Zn/ha over control, respectively. This may be due to deep and extensive root system of cotton crop compared to wheat that might have helped the plants in taking up nutrients more efficiently. System productivity of transplanted cotton–onion cropping system (COCS) was markedly higher than direct sown cotton-onion cropping system (COCS) during both the years. Both the seed cotton yield and bulb yield of onion were comparatively higher under transplanted COCS as compared to direct sown COCS, which jointly contributed for significant variation in the system productivity. Direct and residual effect of Zn levels was also found to induce marked variation in the system productivity of cotton-onion cropping system. Successive increase in Zn level caused significant increase in system productivity up to 5.0 kg Zn/ha. System productivity recorded 4.9, 11.2 and 10.4 % increase during 2013-14 and 4.1, 14.8 and 16.8 % during 2014-15 due to direct and residual effect of 2.5, 5.0 and 7.5 kg Zn/ha over control respectively. Foliar application of Zn to cotton and direct application of 5.0 kg Zn to onion also induced perceptible increase in system productivity, which was 10.4 % and 17.0 % higher over control during 2013014 and 2014-15, respectively. This behaviour of system productivity is attributed to the direct and residual effect of Zn levels on the productivity of component of crops of the system. On an average, COCS recorded 49.5 % increase in system yield over CWCS. The system economics (net returns and benefit cost ratio) was found significant during 2013–14 and non-significant during 2014–125 due to methods of cotton establishment and zinc fertilization in both the years. Residual effect of 5.0 and 7.5 kg Zn/ha applied to cotton recorded higher net returns which were at par during both the years. Direct effect of 5.0 kg Zn/ha recorded statistically higher net returns which was significantly higher than control during both the years. Net returns of cotton–onion cropping sequence were significantly higher than cotton–wheat cropping sequence. On an average, cotton–onion cropping sequence recorded an increase in net returns was ₹157665 over cotton–wheat cropping sequence, respectively. Cotton–onion cropping sequence recorded significantly higher benefit cost ratio (2.70 and 2.02) than cotton–wheat cropping sequence (1.25 and 1.28) during both the cropping years.

CONCLUSION

It is concluded that crop establishment methods in *Bt*-cotton had non–significant but positive influence on system productivity and profitability. On the other hand, successive increase in Zn level caused significant increase in system productivity up to application of 5.0 kg Zn/ha. Residual effect of 5.0/7.5 kg zinc/ha applied to Bt cotton was significant on productivity and profitability of succeeding wheat/onion and it was on par with direct application of 5.0 kg zinc/ha applied to wheat/onion.

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Extended Summaries Vol. 1 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Performance of mung bean and cluster bean under castor- based cropping system

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Castor is a valuable non-edible oilseed crop playing an important role in agricultural economy of arid and semi arid regions. At present, the world trade of fossil fuel is being controlled by Gulf. Similarly, India should also monopolise castor trade on the globe. Although, 67% India's' share in the world production of oilseeds is contributed only by castor with higher production and. productivity, without being complacent there is need to further strengthen the production and export of oil by careful management and planning. Due to rapid increase in population, urbanization and industrializa-

Table 1. Performance of castor based intercropping system

Technology Assessed	Seed yield (kg/ha)	Equivalent yield (kg/ha)	Net Return (Profit) in Rs./ha	B:C Ratio
Sole Castor	1900	2058	30588	1.67
Intercropping with mung bean (1:3)	1600 kg/ha + 900 kg/ha	3070	62291	2.36
Intercropping with cluster bean (1:3)	1600 kg/ha + 1000 kg/ha	3002	61391	2.34

tion the per capita land availability is going to decrease, thus this limitation imposing more pressure to produce more food, feed, fibre, fuel and fodder per unit area to meet basic need. So, horizontal increase in crop production is not possible, but the only way to increase crop productivity on per unit area basis is possible through multiple cropping. Intercropping seems to be the only way to increase productivity and intensity of land use.The benefits in terms of enhanced produce per unit area and time accrue due to duration differences, rooting systems and crop canopy/stature variations in intercropping system as opposed to sole cropping with its limitations. The objective of this study was to investigate the effect of intercropping of castor with mung bean and cluster beans yield and to work out the economics of different treatments.

METHODOLOGY

A biennial field trial was carried out at farmers field of village Gignau of Bhiwani district situated at 28^0 20' to 29^0 05' and longitude 75^0 28' to 76^0 25' during two consecutive years (20013-14 to 2014-15) to explore the possibility of increasing productivity from castor based intercropping system by optimizing pulse and planting pattern combination. The varieties/ hybrids were DCH 177, Satya and HG 563 of castor, mung bean and cluster bean, respectively. The crops were sown in North-South oriented rows during first fortnight of July during both years. During investigation two pulses intercrop viz., cluster bean & mung bean were evaluated under castor. There were three treatments.

RESULTS

The present study showed (Table 1) that intercropping had positive influence with pulse like cluster bean and mung bean. Intercropping proved more economical than sole castor. Intercropping with cluster bean was more beneficial than with mung bean. The sole cropping of castor gave 2058 kg/ha grain yield and net returns of Rs.30588/ha. Among intercropping systems, intercropping with mung bean gave higher equivalent yield of castor (3070 kg/ha) and returns (Rs.62291) than the intercropping with cluster bean 3002 kg/ ha equivalent yield of castor and (Rs. 61391) due higher prices of mung bean than cluster bean.

CONCLUSION

Available information indicates that castor can be successfully intercropped with mung beanand clusterbean. Thus, economically viable, tailor made, simple and easy to adopt agronomic technology for intercropping of castor crop with different leguminous crops. So it was concluded that intercropping with pulses in castor based cropping system could be best alternative to increase income of farmers.

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Effect of bio intensive cropping systems on productivity, economics and soil health in central plateau zone of Maharashtra, India

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The cropping systems play an important role in crop diversification and intensification by selecting the important crops and inclusion of cash crop for making the best use of leftover of each crop in synergistic manner Gill *et. al*. (2014). The cropping system are location specific as these are designated on the basis of climate , soil types, irrigation facilities, market demand , input supply, labour availability and farmer choice to adopt the systems. The best cropping systems should be cost effective, increasing the efficiency of inputs and suit the local climate based on soil, water, temperature and rainfall etc. which is suitable for increasing the productivity per unit area. Crop diversification and intensification can bring much agronomic and ecological benefit for enhancing the crop productivity, income /unit area by utilising the fallow land for short term with high value crop which ensure nutritional security, sustain income, reduce weeds and pest infestation, create employment opportunities, reduce risk from aberrant weather by different planting and harvesting times and provide ample opportunity of high value crop to meet requirement of the farmer. Hence, to enhance productivity and profitability the present investigation was carried out to find efficient bio intensive productive and remunerative cropping system.

METHODOLOGY

A Field experiment was conducted at AICRP on Integrated Farming Systems, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani (M.S.) during 2013-14 to 2014-15 for two successive years to study the effect of bio intensive cropping systems on productivity, economics and soil health in central plateau zone of Maharashtra. The experiment was comprised of eight different treatments out of which three predominant cropping system and five are the bio intensive cropping system plan on broad bed furrow system at 1.5 m distance with bed size 1.2 m and one with narrow bed planting of 90cm for planting of crop (Table 1). The experiment was laid out in RBD with three replications. The soil of experimental site was clayey in texture having pH 8.1, low in available nitrogen (169.7 kg/ha), medium in phosphorus (11.5 kg/ha), and high in available potassium (354.6 kg/ha). These crops were grown with recommended packages of practices under irrigated conditions. For comparison among different cropping systems, the yield of all the crops in the sequences were converted in to soybean equivalent yield on price basis ,productivity values in term of kg/ha was calculated dividing the production of the sequences by 365 days and profitability was obtained from net return of the sequences divided by

Table 1. Soybean equivalent yield, Production Efficiency, GMR, Cost of cultivation, NMR, Monetary advantage on the basis of NMR, B:C ratio, Land Use Efficiency and Mean Soil fertility status as influenced by different crop sequences (Pooled mean over two years)

Treatment	Soybean equivalent yield (Kg/ha)	Production Efficiency (kg/ha/day)	GMR (x 10^3 ₹/ha)	Cost of cultivation (x 10^3 ₹/ha)	NMR (x 10^3 ₹/ha)	Monetary advantage on the basis of NMR (₹/ha/day)	B:C ratio on the basis of NMR	Land Use Efficiency (%)	Available N Kg/ha	Available P Kg/ha	Available K Kg/ha
Soybean - Sorghum	4142	18.01	141.7	55.6	90.6	384	1.6	62.9	177.2	12.9	365.7
Cotton - Ground nut	5887	21.57	201.5	67.8	133.6	490	2.1	74.7	183.0	13.1	364.6
Soybean – Wheat – Cowpea (veg.)	5406	18.97	185.1	59.8	125.3	448	2.1	78.8	186.6	13.2	367.7
*Cotton (F) + Soybean (B) - Green gram (B) + Amaranthus (F) Broad Bed Furrow at 1.5 m	5854	24.92	200.0	62.8	137.2	448	2.5	62.3	174.7	13.2	368.0
*Pigeon pea (B) + Soybean (B) (in furrow Sesbania) - Green gram (B) + Cluster bean (F) Broad Bed Furrow at 1.5 m	4628	16.30	158.4	74.3	84.1	238	1.5	69.3	188.6	13.6	375.7
*Maize + Soybean in furrow - Sesbania (F) - Chick pea (B) + Wheat (F) – Cowpea (residue) (B) + Okra (F) Broad Bed Furrow at 1.5 m	6254	19.55	215.1	73.9	141.1	349	2.2	88.5	175.8	11.8	365.7
*Pearl millet (F) + Soybean (B) - Chick pea (B) + Mustard (F) - Cowpea (veg.) Broad Bed Furrow at 1.5 m	5739	25.17	196.7	67.9	128.8	417	2.4	73.3	173.3	12.2	359.1
**Maize (F) + Soybean (B) - Chick pea (B) + Rabi Sorghum (F) – Cowpea fodder (B) + Okra (F) Narrow Bed Furrow at 90 cm	6238	19.29	214.9	78.9	135.9	385	2.0	89.6	167.0	12.3	367.4
SEm±	139.2		2.02		2.02				2.16	0.37	8.08
CD (P=0.05)	341.6		11.70		11.70				7.20	1.12	2.59
Initial value									169.75	11.58	354.65

total duration of the sequences. The total rain fall received during 2013-14 and 2014-15, 1158 mm, 569.7mm, respectively,

RESULTS

The result indicated that the crop sequence of Maize + Soybean in furrow Sesbania (F) - Chick pea (B) + Wheat (F) – Cowpea (residue) (B) + Okra (F) recorded the higher soybean equivalent yield (6254kg/ha),GMR (Rs. 215111) and NMR (Rs. 141136) and B:C ratio 3.17 followed by Maize (F) + Soybean (B) - Chick pea (B) + Rabi Sorghum (F) – Cowpea (B) + Okra (F) . The lowest GMR (Rs. 147177) and NMR (Rs. 90662) was recorded in Soybean - Rabi Sorghum cropping sequence. Mandal et.al. (2011) reported that diversified cropping systems (Peanut-brinjal-brinjal, rice-potato-pumkin and cucumber- cabbage- basella) required higher cost of cultivation but also produced higher rice equivalent yield, higher net return and higher net return per rupees invested.

The maximum benefit cost ratio on basis of NMR was recorded in cropping sequence Pearl millet (F) + Soybean (B) - Chick pea (B) + Mustard (F) - Cowpea (veg.) Broad Bed Furrow at 1.5 m 2.4 followed by Maize + Soybean in furrow Sesbania (F) - Chick pea (B) + Wheat (F) – Cowpea (residue) (B) + Okra (F) 2.2 , respectively. The maximum land use efficiency was found in Maize (F) + Soybean (B) - Chick pea (B) + Rabi Sorghum (F) – Cowpea fodder (B) + Okra (F) (89.6 %), followed by Maize + Soybean in furrow Sesbania (F) - Chick pea (B) + Wheat (F) – Cowpea (residue) (B) + Okra (F) (88.5 %). The maximum monetary advantage on the basis of NMR was found in cotton –groundnut Rs 490 /ha / day followed by Cotton (F) + Soybean (B) - Green gram (B) + Amaranthus (F) (Rs. 448 /ha /day). Similar result reported by Walia and *et al.,* 2015

Soil Nutritional availability in terms of N, P and K was significantly influenced by different cropping sequence. Highest N, P and K after harvest of crop was recorded in treatment Pigeon pea (B) + Soybean (B) (in furrow Sesbania) - Green gram (B) + Cluster bean (F) Broad Bed Furrow at 1.5 m

CONCLUSION

The finding of present investigation inferred that planting of crop in broad bed furrow of 1.5 m distance with bed 1.2 m with cropping systems Maize + Soybean(B) in furrow Sesbania (F) - Chick pea (B) + Wheat (F) – Cowpea (residue) (B) + Okra (F) recorded the higher soybean equivalent yield (6254kg/ha),GMR (Rs. 215111) and NMR (Rs. 141136)and B:C ratio 2.2 and higher profitability.

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Symposium 4

Integrated Farming Systems for Smallholder Farmers

Extended Summaries Vol. 1 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Potential integrated farming system model under north Gujarat agro climatic situations

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An integrated farming system consists of a range of resource-saving practices that aim to achieve acceptable profits and high and sustained production levels, while minimizing the negative effects of intensive farming and preserving the environment (Lal and Miller, 1990; Gupta *et al.*, 2012).

OBJECTIVE

To assess relative efficiencies of different IFS components in terms of economic returns and employment generation for the family.

METHODOLOGY

A field investigation on one hectare integrated farming system model was carried out at Centre for Research on IFS, SDAU, Sardarkrushinagar (Gujarat) during 2010-11 to 2014-15. The component of the IFS model examined comprised: Crops (0.70 ha), multistoried horticultural crops (0.25 ha), Boundary planted trees, two Mahesani breed buffaloes and vermicompost unit (0.025 ha), nursery for raising vegetable seedlings (0.01 ha) and farm pond for ground water recharge (0.015 ha). Four predominant cropping systems were evaluated *viz.* C_1: Castor + Greengram, C_2: G'nut - wheat - multicut fodder pearlmillet, C_3: Greengram - mustard – pearlmillet and C_4 Hy.Napier + cowpea (F) – lucerne + F. chicory.

RESULT AND DISCUSSION

Results revealed that integrated farming system provides opportunity to increase the economic yield per unit time by intensification of cropping and integration of allied agricultural enterprises. Integrated farming systems of crops with allied enterprises, implemented in on-station situations provided highest net income ₹3,61,416 with ₹990 per day income during the year 2014-15.

Five years results revealed that income from crop husbandry component is dominant over all other enterprises during all the years except during year 2013-14 and 2014-15 in which livestock + vermicompost and boundary plantation, respectively. (Table1). Research studies have demonstrated the technical feasibility and economic viability of integrated farming systems.

Besides facilitating cash income, integrated farming system generates additional employment for family labour and minimizes the risk associated with conventional cropping system. It also sustains soil productivity through the recycling of organic nutrient sources from the enterprises involved. The advantage of using low-cost or no-cost material at farm level for recycling is reduced production costs, with improved farm income.

The data of last five years revealed that IFS brought increased revenue, which might be due to resource recycling. The net return fluctuate year wise due to establishment of model. The net return in the year 2014-15 from inclusion of allied enterprises in IFS is about 3,61,416/ year. In the year 2014-15 crop component contributes highest 32.00 % (1,15,952/year from 0.7 ha) followed by income from boundary plants 53.42 % (1,93,086), livestock 4.60 % (16,645) and multi-storeyed horticultural unit 9.88 % (35,733/year from 0.25 ha). One hector IFS model generates 990/year with year the round flow of income. On an average 306 man days employment were generated with daily engagement of 0.84 labour.

Integration of different farming systems were also found

Table 1. Net return (x 10^3/ha) of different IFS components

SN	Name of IFS components	2010-11	2011-12	2012-13	2013-14	2014-15
1	Cropping systems	124.7	113.1	96.5	93.4	116.0
2	Horticultural unit	61.9	23.9	23.4	24.2	35.7
3	Boundary plantation	-	6.8	9.2	10.5	193.1
4	Livestock +Vermicompost	-	44.7	32.7	110.8	16.6
Total	186.6	188.4	161.8	238.8	361.4	

beneficial by Ramrao *et al.* (2005), Sharma *et al.* (2008) and Channabasavanna *et al.* (2009) in their research of different States.

CONCLUSION

IFS is also an eco - friendly approach in which waste of one enterprise becomes the input of another thus making efficient use of resources. It helps in improving the soil health, weed and pest control, increase water use efficiency and maintains water quality. As this system minimizes the use of harmful chemical fertilizers, weed killers and pesticides and thus safeguards the environment from the adverse effects. One ha IFS model generates 990/day with engagement of 0.84 labour per days.

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Integration of fish in lowland rice under different geometry

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Rice-fish sequence is one of the approach of farming system for rainfed lowland rice ecology particularly in the eastern coastal India. Rice production is variable in these areas due to lack of appropriate technology used in rice production systems under rainfed lowlands with the integration of fish. Variation in planting density by different row spacing's or differential row arrangements at the same planting density may affect crop yield as well fish growth in the rice field. Hence, a field experiment was conducted to evaluate the effect of different crop geometry on the rice productivity and development of fish under concurrent rice-fish system.

METHODOLOGY

Experiment was conducted during the wet season of 2014 at National Rice Research Institute, Cuttack (20°252N, 85°552E; 24 m above mean sea level) in the south-eastern part of India. The climate is tropical with an annual rainfall of 1330 mm during the year of study of which about 76% was received in the wet season. The soil was sandy clay loam in texture with pH 6.2, electrical conductivity 0.5 dS/m, total C 7.5 g/kg, total N 0.6 g/kg, total P 0.8 g/kg and total K 1.2 g/kg. The depth of trench was 45 cm on one side of each plot simulating rice –fish system. The experimental design was a split plot with three replications under different crop geometry in the absence and presence of fish: S_1: random planting, S_2; skip one row after every three rows with 15 cm x 15 cm;; S_3: 15 cm x 15 cm (44 hill/m^2); S_4: 20 cm x 15 cm (33 hill/m^2); S_5: 25 cm x 15 cm (26 hill/m^2). Nile Tilapia was stocked 30 days after transplanting by weighing (8.2 ± 0.9 g) the required number of fish per rice field.

RESULTS

Significantly higher grain yield was recorded under rice-fish (4.92 t/ha) system over rice alone. Planting with skipping one row after every three rows at 15 cm x 15 cm resulted in significantly higher grain yield (4.94 t/ha) and it was at par with the planting density of 25 cm x 15 cm (Table 1). Weed biomass was also affected by presence of fish and planting

Table 1. Effect of fish in the rice field and crop geometry on yield, yield parameters and growth of fish

Treatment	Panicle/m²	Panicle length	1000 grain weight	Grain yield	Harvest index	Total fish yield	Specific growth rate (g/m²)	Survival %
Main Plot								
M_1 – Rice-Fish	306[a]	22.8[a]	26.8[a]	4.92[a]	0.44[a]	-	-	-
M_2 – Rice-Mono	272[b]	22.3[a]	25.8[a]	4.18[b]	0.41[b]	-	-	-
Sub-plot								
S_1- Random Planting	284[a]	21.3[c]	22.0[c]	3.82c	0.39[b]	202.76[b]	1.51[c]	44.1[d]
S_2- Skip one Row after every 3rd row with 15 cm x 15 cm	287[a]	23.1[a]	30.4a	4.94a	0.43[a]	288.07[a]	1.99[a]	65.8[a]
S_3- (15 cm x 15 cm)44 hills/m²	312[a]	22.0[b]	24.6[c]	4.54[b]	0.46[a]	209.47[b]	1.60[c]	50.8[c]
S_4 - (20 cm x 15 cm) 33 hills/m²	292[a]	22.7[b]	27.2[ab]	4.72[a]	0.43[a]	227.13[b]	1.79[b]	59.2[b]
S_5 - (25 cm x 15 cm) 26 hill/m²	269[b]	22.8[b]	27.5[b]	4.86[a]	0.41[ab]	280.96[a]	1.91[a]	65.0[ab]
Mean	289	22.6	26.3	4.55	0.43	241.68	1.76	57.0

*Mean value with different superscript in the same column are significantly different (P=0.05)

density being significantly higher with rice alone (31.9 g/m²) and lowest with planting density of 15 cm x 15 cm with skipping one row after every 3rd row (18.6 g/m²) at 75 DAT. The presence of fish resulted in a significant increase (17-20 %) in the grain yield, reduction of total weed biomass, and significantly ($P \leq 0.05$) lower dissolved oxygen and PO_4 concentrations. It was also found that the effect of planting density on fish production was related to a 'growth effect' resulting from increased availability of oxygen and food. The net fish production, specific growth rate and survival rate was significantly higher with the wider spaced crop.

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Integrated rice- fish- horticulture farming system for enhancing productivity and sustainability of rainfedlowland ecosystem

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Rice–fish-farming systems constitute a unique agro-landscape across the world, especially in tropical and sub-tropical Asia. The introduction of fish rearing to rice farming creates an integrated agro-ecological system (Lu and Li, 2006). Rice +fish+ vegetable crops production system is economically viable, technically feasible, could improve food security and yield stability, ecologically sound/friendly, socio-culturally acceptable and adaptable. It also showed its great potential to help alleviate flooding- and salinity-associated problems through increased cropping intensity, productivity, yield and income, reduced risk of crop and financial failure, greater employment opportunities, reduced cost of production (Lopez *et al*., 2004) and can ensure food, nutrition and livelihood security for the farming communities, particularly the largest group of small and marginal farmers (Mahapatra *et al*., 2007). Among the farming system options available for rainfed rice ecologies, rice - fish –horticulture farming system is one of the best economically viable and acceptable choice. The sub-tropical regions of north-eastern India offer a great scope for rice-fish-horticulture farming. Keeping in view of the available resources and needs Regional Rainfed Lowland Rice Research Station, Gerua has developed an eco-friendly rice-fish farming system technology for the region.

Table 1. Economics and employment generation under integrated rice –fish-horticulture farming system (5000 m^2 area)

Components	Gross return (Rs.)	Cost of cultivation (Rs.)	Net return(Rs.)	B:C ratio	Employment generated(MDYS)
Crop component(Rice-pulse/vegetable-rice)	41,040	24,945	16,095	1.64	88
Fish	29,600	15,785	13,815	1.90	56
Horticulture					
Vegetables	23,250	10,795	12,455	2.15	36
Fruits	9,800	3,965	5,835	2.47	18
Floriculture	3,220	1,645	11,575	1.96	6
Total	1,07,770	57,495	50,335	1.87	204

METHODOLOGY

A low lying rice field measuring 0.5 hectare area, holding 20-60 cm water in *kharif* season but free from frequent flood was renovated and developed to integrated rice-fish-horticulture model at RRLRRS, Gerua, Assam. Field design of the system included wide dykes all around, a pond refuge connected to side trenches (micro-watershed-cum-fish refuge) and one guarded outlet. The components are rice in main field (60% area), fish in the refuge pond, trenches (18%) and also in rice field at appropriate water level and horticulture on pond dyke (22%). During 2013-14 and 2014-15 interventions made on main rice field were rice- utera lentil/linseed - rice cropping system. Fingerlings of composite fish culture (rohu, catla, mirgal and common carp) were released @ 6000/ha after transplanting of *sali* rice. Vegetable, ornamental crops, tuber crops and fruit crops were cultivated on the pond dyke throughout the year. About 25 Assam lemons, 8 coconuts, 12 Areca nuts, 30 Banana, 4 Guava, 2Mango and 20 teak plants were on pond dyke. Eight hanging platforms were available for raising cucurbits throughout the year.

RESULTS

Rice varieties Ranjit and Anjali recorded grain yield of 5.9 t/ha and 3.2 t/ha during *sali* and *ahu* season, respectively. Fish production was 425 kg/ha. Promising vegetables on pond dykes included okra, yard bean and elephant foot yam during *Kharif* and French bean, cabbage, cauliflower during *rabi* season. Pumpkin, bottle gourd and country bean found promising on hanging plate forms. The multitier cropping system Areca nut + coconut + Assam lemon + Elephant foot yam found promising on pond dyke. The Gross and net income from the various components of the integrated farming system was calculated as Rs.1, 07,770 and Rs. 50,335, respectively from 0.5 ha of area. The system recorded the productivity of 1, 62,480 kg/ha of Rice Equivalent Yield per annum and employment generation was 204 man days from 0.5 ha of area.

CONCLUSION

The study revealed that rice-fish technology could be a viable and environment friendly farming option for considerable increase in farm productivity, income and employment in rainfed lowland of Assam

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Resource optimization and profitability maximization in marginal farm holdings through integrated farming system model by linear programming

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Agriculture in Eastern India is dominated with rice cultivation under rainfed situations resulting in low crop productivity and profitability. Rice cultivation has become unsustainable due to enhanced production cost, climatic risks, declining land, water, biodiversity, environment and other natural resource base, together with shrinking farm returns and reduced crop productivity. This necessitates diversification of farming in Eastern India. Integrated farming systems (IFS) involving animals (livestock, fish, etc.) and cropping (cereals, pulses, etc.) are recognized as an alternatives for preserving ecosystems and enhancing livelihood security. A study was therefore undertaken under Eastern Indian conditions to develop IFS models for marginal farm holdings (0.8 ha) and compare performance of pond-based integrated farming system model comprising rice-onion cropping system, multilayer pisciculture, poultry and mushroom with conventional cropping system of rice-green gram. Field experiments were conducted at five cluster of villages located in five different blocks viz. Khajuripada of Kandhamal district, Dhenkanal Sadar and Odapada of Dhenkanal district, Golamunda and Narla of Kalahandi district of Odisha under rainfed medium land situations during 2010 to 2013.

METHODOLOGY

Linear Programming based model is formulated with the objective of maximization of net farm income subjected to constraints related to resource availability such as land (ha), capital (), labour (man-days); enterprise options such as crop (ha) rice-greengram (X_1), rice-onion (X_2), pond dyke horticulture (X_3), fishery (X_4) in ha, poultry (X_5) (1 unit equivalent to 0.0045 ha) and mushroom (X_6) (1 unit equivalent to 0.0045 ha) were considered for modeling purposes. Mathematical model was developed using linear programming (LP) for one of the marginal farmers' situations. The data generated during 2010-11 to 2012-13 by conducting integrated farming system experiment in farmers field situation was used for modeling purposes(Behera and Rana, 2014) and has been used as the basis for formulation of model and its objective function and constraints. Mathematical model using LP is explained as below:

$$\text{Max } Z=\sum_{j=1}^{n} C_j X_j \qquad (1.0)$$

subject to

$$\sum_{j=1}^{n} aijX_j \leq bi \quad \text{i=1 to m} \qquad (1.1)$$

and X_je" 0 j = 1 to n (1.2)

Z = total net return

X_j = the level of the j^th activity

C_j = the net return of the j^th activity

aij = the quantity of the i^th resource required to produce a unit of jth activity.

bi = the amount of the i^th resource available.

Based on the information, a generalized model was developed as given below. In this model different farm constraints were imposed taking the real farmers situations in the study area.

Max Z = $15925 \times X_1 + 76262 \times X_2 + 1216900 \times X_3 + 81947 \times X_4 + 2467975 \times X_5 + 11282998 \times X_6$;

$X_1+X_2+X_3+X_4+X_5+X_6-R_1=0$;

$40322 \times X_1 + 89913 \times X_2 + 349900 \times X_3 + 229374 \times X_4 + 10366563 \times X_5 + 14152302 \times X_6 - R_2 = 0$;

$255 \times X_1 + 450 \times X_2 + 1650 \times X_3 + 600 \times X_4 + 12888 \times X_5 + 31333 \times X_6 - R_3 = 0$;

R_1- Land, R_2- Capital, R_3- Labour

$X_1>=0.05$; $X_1<=0.1$; $X_2>=0.40$; $X_2<=0.70$; $X_3<=0.04$; $X_3>=0.02$; $X_4<=0.1$; $X_4>=0.06$; $X_5=0.0045$; $X_6=0.0045$; $R_1<= 0.8$; $R_2<=195000$; $R_3<=588$;

Based on the information, the integrated farming system models were developed for marginal farmers.

RESULTS

The size of different enterprises of 0.8 ha IFS model with corresponding net return and employment generation were

Table 1. Area, net return and labour requirement under farming system components (0.8 ha IFS model)

Components of Farming System	Area allocation (₹/ha)		Production cost (₹)		Labour requirement (₹human days)		Net return (₹)	
	CCS	IFS	CCS	IFS	CCS	IFS	CCS	IFS
Rice	0.8	0.7110	22568	21291	150	130	7196	15541
Greengram	0.8		9690		54		5544	
Onion		0.7110		42659		190		54473
Papaya in pond dyke at a linear distance of 2.0 m		60 plants		2476		10		5287
Banana in pond dyke at a linear distance of 2.1m		56 plants		2172		9		8170
Drumstick in pond dyke at a linear distance of 2.5 m		48 plants		2350		14		10881
Fish		0.0800		13763		36		4917
Poultry (100 birds in one batch- 5 batches in a year)		0.0045		46650		58		11104
Mushroom (960 beds of paddy straw and 450 beds of oyster in a year		0.0045		63686		141		50774
Total	1.6	1.511	32258	195047	204	588	12740	161147

Table 2. Integrated farming system models developed in single objective framework using linear programming technique

Model	Decision variables and enterprise combination	Objective function/ Farm returns (₹)	Actual resource use Land (ha), Capital (₹) and Labour (Human days)	Actual resource available Land (ha), Capital (₹) and Labour (Human days)
IFS 1	$0X_1 + 0.633X_2 + 0.04X_3 + 0.06X_4 + 0.0045X_5 + 0.0045X_6$	163,739	Land = 0.742 Capital = 195,000 Labour = 585.8	R1<= 0.8 R2<=195000 R3<=588
IFS 2	$0.05X_1 + 0.458X_2 + 0.04X_3 + 0.06X_4 + 0.0016X_5 + 0.009X_6$	191,274	Land = 0.62 Capital = 2,00000 Labour = 605	R1<= 0.8 R2<=200000 R3<=605

Enterprise, X1: Rice- green gram, X_2: Rice-onion, X_3: On-dyke horticulture, X4: Fishery, X_5: Poultry bird 1 unit (0.0045 ha), X6: Mushroom 1 unit (0.0045 ha)

Resources, R_1: land, R_2: capital, R_3: labour.

reflected in Table 1 for computing the maximum net return using linear programming technique. Integrated Farming system model IFS 1 generated an income of ₹1,63,739 with a combination of rice-onion (0.633 ha), pond dyke horticulture (0.04 ha), fishery (0.06 ha), one unit of poultry (0.0045 ha) and one unit of mushroom (0.0045 ha) (Table 2). In this case his available capital and labour resources are fully utilized and land is underutilized. In order to further enhance the income, capital and labour become the constraints. Under this situation, if the farmer can arrange more capital for farm activities, his income can be further enhanced. Similarly, IFS 2 generated a net income of ₹1,91,274 with combination of rice-greengram (0.05 ha), rice-onion (0.458 ha), pond dyke horticulture (0.04 ha), fishery (0.06 ha), one unit of poultry (0.0016 ha) and one unit of mushroom (0.009 ha) if the farmer wishes to take up greengram during rabi in rice-fallows in 0.05 ha. Under this situation, if farmer wishes to spend 2, 00,000 as capital and 605 labourers, he can generate the maximum return of ₹1,91,274 but his land is underutilized. In order to further enhance the income by utilizing the entire area, capital and labour became the constraints. Under this situation, if the farmer can arrange more capital for farm activities, his income can be further enhanced. Modin- Edman *et al*. (2007) developed various tools for use in analysis of farming system models. Behera and Rana (2014) used linear programming for predicting maximum profit by using data on IFS models adopted by marginal, small, medium and large farmers.

CONCLUSION

Small and marginal farmers having consolidated patch of land can adopt these models. Labour is not constraint for implementation of the IFS model, but the capital need has to be met through credit from banks. However the above model can be applied to any farm size situations depending upon resource availability and taking constraints into considerations.

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Influence of pruning and agronomical management on biomass production of *Dalbergia sissoo* and yield of paddy: an agroforestry approach

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Paddy (*Oryza sativa* L.) is the most widely consumed staple food for the large part of the world's human population. Madhya Pradesh is the second largest state in terms of area and is thickly covered by the forest which account for one third of the state's geographical area. Nitrogen is very essential for the growth and development of this crop, which is absorbed during the vegetative growth stages contributing in growth during reproduction and grain filling stage through translocation. (Norman *et al*., 1992). *D*. *sissoo* attains a height up to 30 meters. It has multiple uses such as fuel, timber, fodder, shade and nitrogen fixing ability. Pruning is a common silvicultural practice to increase wood production, improves tree shape and potential uses to obtain poles and fire wood without decrease in wood productivity. It involves removal of live or dead branches or multiple leaders from the tree. Pruning of tree component is a powerful approach to regulate light, nutrients and other resource competition (Frank and Eduaro, 2003). The pruning can effectively change the micro-climate under canopy such as increased air temperature, soil water content and decrease the relative humidity. It also decreases tree taper and increases the volume increment. Agroforestry may be one of the solutions to increase forest area to one third of the total geographical area of the country. The agroforestry system (tree + crop) is more productive and sustainable than agriculture. Pruning has become has an essential practice for reducing both above and below ground competition with associated crops (Fownes and Anerson, 1991; Sinclair and Luther, 1998). Keeping above facts in view, that shade is an important factor affecting production, a study was under taken to test the effect of pruning of *Dalbergia sissoo* at different intensities on the biomass production with agronomical management on productivity of paddy under agroforestry system.

METHODOLOGY

The field experiment was conducted at Forestry Research Farm, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (M.P) during the year 2014-15 in 15 years old *Dalbergia sissoo* plantation, planted at the spacing of 5 m x 5 m. Fifteen treatment combinations were laid out in split plot design comprised of 5 main treatments (Po-No pruning, P1-25% Pruning, P2-50% Pruning, P3-75% pruning and P4-open condition i.e. crop alone) and 3 agronomical management practices (F1-Recommended dose of fertilizer @ 120:60:40 NPK kg/ha + seedrate-80 kg/ha, F1+25% more nitrogen than recommended fertilizer dose, F1 + 25% more seed rate than recommended dose) replicated five times. Under each treatment, paddy crop (Variety-MR-219) was sown at a distance of 20 cm row to row. The morphological growth characters and biomass production of paddy and *D. sissoo* were recorded on influenced by different treatments.

RESULTS

The results revealed that different pruning intensities showed significant effect. As the pruning intensities in *D. sissoo* increased there was significant increase in number of effective tillers, (256), No. of grains/panicle (116), 1000 grain weight (21.3 g), grain yield (2.22 t/ha), straw yield (13.67 t/ha) and harvest index (37.7%), hence 75% pruning recorded maximum yield attributing characters and seed yield as compared to other treatments. Under open conditions maximum yield attributing characters and yield were recorded because more light was available which helped in photosynthesis and multiplication of cells. In agronomical management practices 25% more nitrogen dose than recommended recorded significantly higher number of these characters as compared to other management practices. In agrisilviculture system pruning at suitable age has vital importance to get maximum production of intercrops due to more light transmission to the crop otherwise, the yield will be reduced. The maximum tree height (10.56 m) and dbh-1.37 cm (24.05 cm) was recorded under No Pruning closely followed by 25% pruning as compared to other treatments. However, the maximum pruned biomass was noted in 75% pruning intensity (2010 kg/ha) as compared to other pruning intensities. The minimum pruning intensity i.e. 25% produced maximum tree height (11.92 m) and dbh (23.98 cm) which has contributed towards the accumulation of highest cylindrical volume (213.27 m^3/ha) and stand biomass production (167301 kg/ha) as compared to all other prunings. Based on the above findings it may be concluded that among different pruning intensities, 75% pruning produced significantly maximum grain yield (2.22 t/ha) and straw yield (3.67 t/ha) followed by 50% and 25% pruning No pruning recorded the lowest grain yield (1.24 t/ha) and straw yield (2.63 t/ha). Under agronomical management practices 25% more nitrogen than recommended dose of fertilizer and seed rate gave significantly higher grain (21.6) and straw yield (3.62 t/ha). 25% pruning led to record the highest cylindrical volume (217.27 m^3/ha) and stand biomass (148262 kg/ha).

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Effect of different crop modules on productivity and economics under integrated farming system

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At present, the country faces a net deficit of 35.6% of green fodder, 26% of dry fodder and 41% of concentrate (Hegde, 2006). India possesses huge livestock population 512.05 million (GOI, 2012).The productivity and profitability of marginal farmers are often lowparticular in western part of Uttar Pradesh. Farmersshould give priority to take more number of crops throughout the year on same piece of land at same time on account of riskavoidance and uncertainty due to climatic aberration/natural calamities. To improve the productivity from the livestock component there is need to provide a quality fodder for the livestock for which there is urgency to develop different crop modules under IFS for year round availability of fodder. Keeping in view above facts the research was conducted with a major objective to identify and standardized the suitability of fodder based crop modules for round the year green fodder production.

METHODOLOGY

The field experiment was conducted for two consecutive years during *kharif*, *rabi* and *summer* seasons of 2014 -16. The experiment was laid out in randomised block design with five replications. The treatments were consisted of five crop modules viz; maize-pea-sorghum; *dolichos*-wheat-teosinte, stylo hemata-carrot –cowpea, clitoria-oats-bajra and *Cenchrus* alone. The experiment was laid on clay loam soil with a pH of 7.45, low in organic carbon content (0.32%), available nitrogen (263 kg/ha), available P (27.2 kg/ha) and available K (122kg/ha). Observations related to yield and computation of economic data was done by following standard procedure.

Table 1. Effect of different crop modules on green fodder, dry matter and economics

Treatment	Kharif			Rabi			Summer		Economic returns		
	Green fodder yield (t/ha)	Dry matter yield (t/ha)	Grain yield (t/ha)	Green fodder yield (t/ha)	Dry matter yield (t/ha)	Seed/ green pod/ carrot yield/ (t/ha)	Green fodder yield (t/ha)	Dry matter yield (t/ha)	Gross return (/ha)	Net return (/ha)	Benefit : cost ratio
Cenchrus alone	48.76	14.78	4.02	21.23	5.77	-	16.47	3.21	111480	75160	2.06
Stylo- Carrot-Cowpea	14.70	4.41	-	22.82	7.32	28.60	27.13	5.50	319130	220430	2.33
Maize- Pea-Sorghum	-	8.36	7.14	6.74	2.04	3.58	53.66	11.63	358000	253450	2.42
Clitoria – Oat-Bajra	44.05	13.35	-	22.53	6.78	2.53	44.57	9.70	307315	210115	2.16
Dolichos- Wheat-Teosinte	47.33	14.20	-	-	5.52	4.17	30.37	6.37	292880	194230	1.96

RESULTS

Results of study reveals that maximum maize equivalent yield was recorded under stylo- carrot- cowpea (27.39 t/ha) crop module followed by clitoria- oat-bajra (25.66 t/ha) crop module and the minimum maize equivalent yield (9.28t/ha) was realized under *Cenchrus* grass was plantedalone as shown in Fig. 1. Green and dry fodder yields were estimated under different crop modules and results indicated that highest green and dry fodder yieldswere recorded under clitoria- oat-bajra crop module and lowest dry fodder production was registered under stylo-carrot-cowpea crop module. Data further revealed that maize-pea-sorghum crop module gavethe highest gross return (3, 58,000/ ha/year), net return (2, 53,450/ha/year) and benefit: cost ratio (2.42) as compared to other crop modules (Table 1).

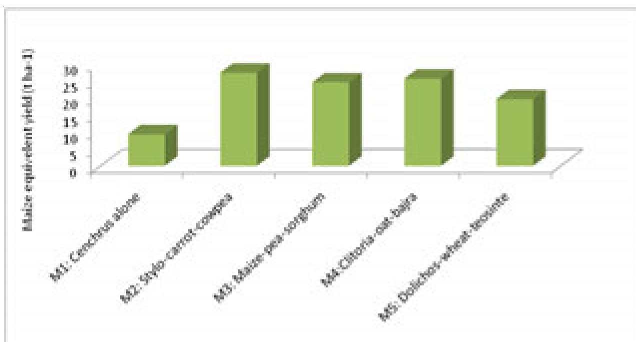

Fig. 1. Effect of crop diversification on productivity

CONCLUSION

Based on the results of present study, it was concluded that stylo-carrot-cowpea crop module gave the best results in terms of highest maizeequivalent yield (27.39t/ha/year). Whereas, maize-pea-sorghum crop module was the best in terms of net economic returns (2, 53,450/ha/year) and B: C ratio (2.42).

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Performance of integrated farming system components in arid region of Rajasthan

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Conventional approaches aim at enhancing crop production systems in the prevailing conditions is risky and not adequately remunerative.Therefore by adopting improved crop technologies together with the integration of crop, and livestock, the gains would be sustainable through the efficient feeding and use of livestock by products. Animals are fed with a combination of grazing stubble and stall feeding of purchased feeds and stored crop residues. The cropping system benefits from the use of animals for draught power, and soil fertility is maintained through the application of animal manure. The challenge to the research and extension system is to raise the level of farmer's management skills, since only through good management will the system sustain itself. By introducing strong research and extension programs focused on the integration of livestock and cropping systems, substantial gains can be made toward developing a sustainable, more productive agricultural sector in arid region. In area receiving > 300 mm crps and cropping systems, diversification, agroforestry and livestock rearing are major system of sustenance of arid zone farmers (Bhati and Joshi, 2007).Additional gains may also be achieved by introducing alternative crops and by educating farmers regarding the necessary practices and benefits of an integrated crop/livestock production system. Ratha et al (2000) reported that livestock based framing systems generated more than 3 times additional employment over arable farming. Keeping this in view, a study was conducted to assess an integrated farming system model at farmers' fields of different categories for increasing production and income of farmers.

METHODOLOGY

The experiment was conducted during *Kharif* season 2014-15 in the integrated farming systems developed at small, medium and large farmers of Village Utamber to assess the productivity of different components of the system. The arable cropping and agri hort system of ber and gonda fuits plant were compared with the existing farmer's practice of production. The treatments comprised of Farmer practice, improved practices, crop + Ber and Crop + Gonda at all three categories of farmers. The soil was coarse loamy sand, organic carbon ranges from 0.12 —0.14%, available phosphorus from 5.35-12.8 kg/ha and potassium 224-515 kg/ha with pH 8.5 -8.7. The fruits plants were planted in July 2013 in 0.5 ha at each location. Crops ie bajra, mung bean and cluster bean were sown during kharif 2015 with and without tree with improved recommended practices and compared with farmers practice.. Observation grain and stover yeild were recorded For assessing system productivity, along with improved crop production technologies, crop diversification, vegetable cultivation and livestock management practices were included to increase the production and income of the farmers.

RESULTS AND DISCUSSION

The study was conducted in the integrated farming systems developed at small, medium and large farmers of Village Utamber to assess the productivity of different components of the system. Technical interventions were compared with the existing farmer's practice of production. Improved production technology in arable crops significantly increased production of crops over the farmers practice. The improved varieties ie RHB-177 of pear millet, GM-4 of mung bean and RGC-1017 of Cluster bean were grown with improved crop production technologies. The increase in yield due to improved crop production technologies was 16.48, 19.46 and 18.42% for pearl millet, mung bean and cluster bean, respectively. The performance of crops in agri-horticulture was more or less comparable to each other for all the three crops under all the farmers' category. The productivity of crops among farmer's categories were varied. The higher yields of crops were obtained with large farmers followed by medium farmers. However, the per cent increase in yield of crops was higher with small farmers. The increase in yield was 8.25, 19.57 and 21.62 for pearl millet, 18.18, 16.67 and 23.53 for mung bean and 19.57, 18.18 and 18.42in cluster bean at large, medium and small farmers, respectively. The highest increase in crop production due to improved technology with small farmers might be due to higher seed replacement rate and crop diversification.in existing farming system as compared to other categories. Gill *et al* (2009) also reported that diversification of existing farming system by integration of enterprises resulted into higher productivity and 30-50% higher profit. The gross income from the farms of large and medium farmers was higher than the small category of farmers. The increase in return from the system due to improved practices was 11.85, 11.43 and 13.21 per cent higher than the existing farmers practices that recorded returns of Rs 54763, 54243 and 44563 per ha, respectively large , medium and small during kharif 2015. The contribution from vegetable production was higher for the farms of large and medium farmers compared to small farmers, but the percent improvement due to improved practices was more with small farmers. The contribution from livestock components was higher with small farmers as compared to large and medium farmers The income of farmer can be increased manifold by the way of diversification of farming system for sustainability and economic viability of marginal and small category of farmers (Manjunath and Itnal, 2004, Gill 2004) Use of improved livestock management practices showed maximum increase in in the gross returns of smaller farmer (15.2%) which was higher than the medium (13%) and large farmer (12.65%) categories.

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Analysis of farming system enterprises at south Kamrup district of Asom

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In Assam, more than 70% people depend solely on Agricultural activities and it's produces. Several researchers of our country recommended adopting integrated farming system (IFS) in different land situations as per the objective and aim of the concerned farmers. Integrated farming system is an approach in which different land based enterprises viz. crops, livestock, fishery, apiary, mushroom etc. are integrated with the bio physical and socio economic situation of the related farmers. Farming system approach is considered as a powerful tool for management of vast natural and human resources in the developing countries. This is a multidisciplinary approach and very effective for solving the problems of small and marginal farmers in India. Farming is a business and Agriculture is also an industry. Hence, decision making plays an important role with regards to the problems concerning production of commodities. Components of marginal and small farmers vary from place to place and within the district of the state also. Therefore this present investigation was carried out to know the technology adoptions of cereals, horticultural crops and livestock's together with the net returns of improved farmers in south Kamrup district of Assam.

METHODOLOGY

A field experiment was conducted during Kharif and Rabi season at Soumoria block of South Kamrup district of Assam in 2012–13 and 2013–14, respectively. All total 12 farmers were selected from three different village's *viz.* Hekra, Mondira and Pijupara. Total land area was found in between 7,500-8,150 sq m for each selected farmers. The texture of the soil type was sandy loam to silty loam with acidic range of pH 5.0 –5.8, available nitrogen is medium to high, available $P_2 O_5$ is low to medium and available K_2O is high in all the selected sites of the farmers, Av. annual rainfall is about 1780 mm maximum and minimum temperature of 36^{o}C in July – August and 12^{o}C in January, respectively. Three farmers grew summer rice and horticultural crops with his own knowledge and skill. Also they did not take any advice from the agricultural extension workers. They also reared scientifically fish and dairy cows. The land situation of the three villages was medium land (Vill- Hekra), medium low land (Vill - Mondira) and lowland (Vill-Pijupara). Recommended feed, fodders and liming (fish component) and nutrients were provided to all the selected nine farmers before the experimentation. Various types of suggestions were given to all the selected farmers of the 3 villages during that specific period.

RESULTS

Gross returns, Net returns were calculated for all the selected farmers of South Kamrup district of Assam. This two parameters were found very low(less than 50% of the Net return) in case of three farmers (3 villages x 1 farmer) where no scientific technologies were adopted. But it was found higher for all those (3 village x 3 farmers) selected farmers of Hekra. Mondira and Pijupara during 2012-13 & 2013-14. Average yield data for each component were calculated and gross returns, net return were again calculated with the current market price of 2015. The yearly Av. net return of two years earned by the '3' selected farmers from village Hekra was Rs. 1.36 lac/year, Rs. 1.31 lac/ year and Rs. 1.28 lac/year. In case of the farmers from the Village Mondira, net returns were Rs. 1.26 lac/year, Rs. 1.16 lac/year and Rs. 1.18 lac/year respectfully. Similarly the net returns recorded by the three farmers of Pijupara were Rs. 1.05 lac/year, Rs. 1.07 lac/year and Rs. 1.12 lac/year respectively.

CONCLUSION

Gross returns, net returns were very high in selected farmers of Hekra village and lowest gross returns, net returns were obtained by the villagers of Pijupara. In future dukery could be the most valuable enterprise for the flood affected areas of Pijupara in order to meet the damage caused by chronic flood. But other component of integrated farming system will remain same for all the farmers of Soumoria block of South Kamrup district.

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Livelihood improvement through integrated farming systems under irrigated dry conditions of Telangana

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Exploding population, urbanization and industrialization are leading to decline in per capita availability of vital agricultural resources and also fragmentation of farm holdings, making them operationally uneconomic. Majority of our farmers of India (80%) as well as Telangana (85%) are marginal to small landholders. The per capita arable land decreased from 0.34 ha in 1950-51 to 0.15 ha in 2000-01 and is expected to shrink to 0.08 ha in 2025. Such farm families depend on small piece of land for certain basic needs including food (cereal, pulses, oilseeds, milk, fruit, honey, fish, meat, egg etc.) feed, fodder, fibre, employment, etc. Farming system is a resource management strategy to achieve economic and sustained production to meet diverse requirements of farm households while preserving resource base and maintaining a high level environmental quality (Lal and Millu, 1990). A systematic integration of multi-enterprise systems in a scientific manner needs to be evaluated to evolve systems for efficient utilization of resources; in such a manner that product or by-product of one component becomes the input for other, becoming complementary and are organically well interlinked to each other without wastage.

METHODOLOGY

Studies on Integrated Farming Systems for marginal /small farmers under Irrigated dry situation is being conducted under AICRP-IFS since 2011-12 by integrating crops, horticulture and animal components in 1 ha area. The crop component in 0.7 ha, includes arable cropping systems viz., rice-maize, rice-sunflower, maize-castor, maize + pigeonpea-cowpea and pigeonpea + greengram-groundnut, fodder block and boundary plantation. The horticulture component (0.2 ha) included a fruit crop guava and vegetable intercrops like tomato, green chillies during rainy season and carrot, cluster bean in *rabi* season. The Livestock component (0.1 ha) was initiated with 2 dairy buffaloes (Murrah Breed), 6 goats (Osmanabadi) and a supplementary unit of 20 backyard poultry birds (Vanaraja). Complementary units Vermicomposting and composting were included for residue recycling in the system.

RESULTS

During first year (2011-12), holistic integration of animals with crops in 1 ha area resulted in net income of Rs.86, 200/- out of the total expenditure of Rs.1, 61,900/- compared to that of an average farmers' net income of Rs 52,000 in Southern Telangana Zone of Telangana state. During second year, despite poor performance of dairy and horticulture units, the IFS proved its stability by recording over all net returns of Rs 46,000/- with a cost of production of Rs 2,26,800/-. During 2013-14 also the performance of dairy and horticulture units was not up to the mark and incurred negative returns. However, the loss from dairy unit was compensated by goats there by recording a net return of Rs.1,17,750/- from livestock component and the IFS was found profitable with a net return of Rs. 1,51,855/- with a cost of production of Rs.2,74,800/-. During 2014-15, the IFS continued to be viable with a net return of Rs. 106175/- with a cost of production of Rs.3, 33, 236/-, but mortality of a milching buffalo resulted in meager contribution of livestock unit to the net income. During 2015-16, the net returns from 1 ha of IFS were Rs.1, 59, 020/- with a cost of production of Rs.3, 65,633/-. Out of this total net

Table 1. Profitability of IFS over years under ID situations of Telangana state

Component	Net Returns (Rs./ha)					
	2011-12	2012-13	2013-14	2014-15	2015-16	Mean
Cropping Unit (0.7 ha)-arable crops & fodder	50841	25679	112276	99729	97002	77105
Horticulture (0.2 ha)-orchard with under storey vegetables	539	-1423	-799	1226	4697	848
Livestock (0.08 ha) + composting (0.02 ha)	34819	21792	35588	5219	57320	30948
Total	86199	46048	147065	106174	159020	108901

Table 2. Livelihood analysis of crop + livestock + horticulture IFS (1 ha) unit during 2015-16

Farm enterprises	Value of all the farm commodities produced (Rs.) (A)	Value of Farm commodities required for the family (Rs.) (B)	Value of Farm commodities recycled within the system (Rs.) (C)	Marketable surplus (Rs.) (A-B-C)=D	Cost of production (Rs.) (E)	Family savings (Rs.) (If any) (D-E)
Crops & fodder	147656	20498	87105	40053	50693	0
Dairy	171934	20000	4696	147238	239584	0
Goatery	159902	3408	1662	154832	49028	105804
Horticulture	17140	7252	0	9888	12486	0
Supplementary- Back yard poultry	4378	4367	11	0	2450	0
Complementary - (FYM & VC)	23645	0	9850	13795	11392	2403
Total of all the farm produce	524655	55525	103324	365805	365633	108207
Family Labour Wages	109500					
Grand Total	217707					

income, 61.00% returns from crops including fodder, 2.95% returns from horticulture and 36.05% from livestock unit, were recorded. Component wise share of inputs and labour in total cost of cultivation indicated that 24.3 % of total COC was on inputs purchased from outside and 27.5% of COC could be met through input recycling, 30.0 % of expenses on labour could be met through family labour and only 18.1% of total COC was on hiring of labour. Survey based study conducted by Radha *et al*. (2000) in Andhra Pradesh with three agricultural and livestock based farming systems viz., dairy, poultry and sheep rearing clearly revealed that all the farming systems generated more than 3 times additional employment over arable farming. The net returns were higher in agriculture + dairy (Rs. 35293/-) followed by agriculture + poultry (Rs. 26830/-) and agriculture + sheep rearing (Rs. 14665/-). Livelihood analysis indicated that the current Crop + Livestock + Horticulture integrated farming system results in a total family saving of Rs 2,17,707/-. The system resulted in production of Rs.3,65,805/- worth of marketable surplus after meeting the requirement of family (worth of Rs.55,525/- with an assumed family size of 2+3) and material worth of Rs.1,03,324/- was recycled in the system. The system also provides an opportunity to save around Rs 1, 09,500/- worth of labour wages through employment generation of 878 man days. Nutritional, food and fodder security of the farm family could be met round the year from 1 ha of crop + livestock (dairy & goat) + Horticulture farming systems through production of cereals, pulses, oilseeds, fruits, vegetables, milk, meat and fodder for cattle.

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Rice-fish based integrated farming system: A potential for climate change resiliency, adaptation and mitigation strategies

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In recent years, the global climate change has been a concern for agricultural production and caused a major challenging threat in maintenance of national food security.Climate changes is already negatively impacting agricultural production and climate risks to cropping, livestock and fisheries are expected to increase in coming decades, and will be severely affected the rural livelihoods of small and marginal farmers. Further, the agricultural sector generates/emits about one-quarter of global greenhouse gas emissions which further fueling the global warming. To mitigate the environmental effects, development of Climate Smart agriculture (CSA), aiming Sustainability of farm production, adopting and building resilience agriculture to climate changes and reducing greenhouse gas emissions from agriculture (including crops, livestock and fisheries) is very much essential. In particular, rescuing/ improving of our traditional management agri-systems ecologically, development of diversified farming and crop-livestock integrated farming system with utilization of low external inputs and recycling of farm based waste will be a viable and robust path to increase the productivity, sustainability and resilience of peasant-based agricultural production under predicted climate scenarios.Keeping view of the above, ICAR-National Rice Research Institute, Cuttack, has been developed a rice-fish based integrated farming system model with involving ecological engineering concept of landscaping and introduction of various diversified enterprising componentsfor attaining sustainability of production and enhancing livelihood of farmer's (Nayak*et.al.,* 2012). In this study, we explore the four key agro ecological strategies (bio-diversification, soil conservation, water harvesting and farm waste recycling) which could be implemented in the design and management of rice-fish based integrated agro-ecosystems empowering the farmers to adopt the strategies of both i.e. increasing the climate resilience, climate change adoption and mitigation of global warming, and enhancing the economic benefits.

METHODOLOGY

The rice-fish based integrated farming system model was developed in 1990-91at ICAR-National Rice Research Institute (NRRI), Cuttack, India (85^{0}55'E, 20^{0}25'N; elevation 24 m) used for the present study. The system hasbeen developed for crop-livestock –horticultural and agro-forestry based integrated farming after suitable landscaping. The major components of model are rice, pulses, fish, duckery, poultry, goatry, seasonal vegetables and horticultural plants like banana, papaya, mango, guava, coconut and agro-forestry. During dry season, the main rice fields were used for cultivation of mung bean, water melon and/ or dry season vegetables etc. The various aspects of climate change adoption and mitigation aspects of the technology was assessed/ analyzed forconsecutive years along with the crop and water productivity and economic benefits of the system.

RESULTS

The designed systems has approximately rice fields area (65%), water refuge area (15%) and four side bund area (20%). 2.5- 3.0 m wide bunds all-round the side of the field. The present design will be helpful for making operational advantages for day to day managements of crop, livestock's in integrated farming system as well as helpful for soil and water conservation with longer period moisture retention in comparison to the mono-cropping system.The system (1 ha.) produced about 19.0 – 20.0 t of food and fodder(bio-mass), including 0.6 - 09 t of fish and prawn, 0.7 t of meat, 0.9 t of horticultural crops including vegetables, in addition to fuel wood and other crops residues. The adoption of system helpful in terms of soil health, carbon sequestration and water conservation, reduction of greenhouse gas emission, biodiversity and provide food security to farm families, and significantly enhanced the percentage rice yield, rice equivalent yields (REY), the ratios of output value to the cost of cultivation (OV-CC ratio), water productivity (WP), gross water productivity (GWP) and net water productivity (NWP) in comparison to the RMC. The system having agro-ecological featuresof high number ofplant and animal diversity, high structural diversity, exploitation of a full range of microclimates, dependence on local resources and crop varieties, etc.) have been proved to be enhancing stability and resiliency in climate changing scenario.The climate change adoption strategies includes the re-shaping of their farm land to make the land cultivable and to accommodate multiple subsystem (pond - rice field - vegetable garden, livestock- duckery, poultry, goatry, horticulture and agro forestry), with multiple components helping farmers for diversifying the source of income and employment, thus reducing the dependency on a single crop system along with soil and water conservation as whole.The Climate change mitigation strategies includelesser requirements of energy, fertilizer and pesticides for farm managements, thus, achieved the Green house gas (GHG) emissions avoidance.

CONCLUSION

The design of rice-fish based integrated farming system with suitable ecological engineering intervention leads to enhancement of farm and water productivity as well as farm income. Also, the rice based integrated farming system having an potential for climate change resiliency, adoption and mitigation strategies and thusenabling the farmer's management/ participation of climate risks, adoption and mitigation processes for building a climate resilient production systems for national food security.

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Evaluation of different IFS module under rainfed and scars rainfall area of Bundelkhand region in Madhya Pradesh

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Climatic variability is expected to disproportionately affect the small holder farmers and make their livelihood more precarious. Small holder farmers face numerous risks in agriculture production. Behavior of rainfall is erratic and inadequate and crops are mostly dependent on monsoon. Rainfed agroecosystem has a distinct place in Indian agriculture, occupying 67% of cultivated area, contributing 44% of the food grains and supporting 40% of the human and 65% of the livestock population (Venkateswarlu, 2005). The integration of various crops and animals enables synergistic interactions, which has a grater total contribution than the sum of their individual effects. Datia district is drought prone district where only Monocropping of Soybean/Blackgram/Sesamum during *Kharif* (about 80% cultivated area) is being followed due to low and erratic rainfall situation and with only 8-10 weeks of rainy period of 3-4 months. Small and fragmented land holding is one of the major hindrances to mechanical and commercial cultivation in Datia district. Low and imbalance level of fertilizer used also causes low crop yield. The integrated farming system assumed greater importance for the sound management of the farm resources to enhance the farm productivity, reduce the environment degradation, and improve quality of life for the resource poor farmers and to maintain sustainability. By adopting this integration system module makes the agriculture a profitable venture with advantages of efficient utilization of available resources, increase in water use efficiency, increase in crop productivity, increase in farm income, employment generation, alternate energy generation and saving of fuel wood, reduce environmental hazards, efficient bio waste management and soil health improvement.

METHODOLOGY

Krishi Vigyan Kendra Data (M.P) had conducted the demonstration on 5 Farmers field in sanora and broudi Villages of Datia district in Bundelkhand region of Madhya Pradesh. Selection of farmers was done on the basis of available resources. The IFS module was identified according to need and availability of resources on farmer's field. The demonstration on IFS was conducted during 2011-14 under NICRA project. All crop component and other enterprises were evaluated on the basis of Soybean equivalent yield (SEY) t/ha/year, gross return (Rs/ha/year) and net return (Rs/ha/year). For statistical analysis farmers were taken as replication. All the agronomic practices and technologies were adopted as per recommended. Following Modules were tested during present investigation *Identified improved IFS module for 1 ha:* Field crop (0.65 ha) + Veg. Crop (0.20 ha) + Dairy (0.10 ha) + Fisheries (0.025 ha) + Composting (5.75 cum) + Biogas (3 cum) *Traditional module of IFS***:** Crop production + Dairy*Farmers practice:*Monocropping of Soybean in *Kharif* season

RESULTS

Enterprises wise productivity and profitability results of Improved IFS module are shown in given Table 1. The data presented in table revealed that net return under Dairy (Rs 31998) and vegetable production (Rs. 42068) has been about 1.5 time more than only crop production (Rs. 29187). The other enterprises such as Fisheries (Rs. 4039), Biogas (Rs. 10698) and NADEP Composting (Rs. 3800) were also play a significant role to improve the farm economics or profits. The Improve IFS module also ensures the livelihood security in rainfed areas with scares rainfall under changing climatic scenario.This IFS model has improved in increase of crop and animal productively. It generated employment to family members, income and alternate energy generation and saving of fuel wood etc.Same results were also reported by Hada *et al*. (2012). The comparison of different farming system modules revealed that the net monetary return through Improved IFS module (Rs. 1228382.00/ha/year) which is significantly higher than traditional IFS module (Rs. 61158=00/ha/year) and farmers practice (Rs. 24451=00/ha/year). The increment in net returns is due to increment in soybean equivalent yield (SEY) in Improved IFS module through incorporation of different enterprises in planned manner. It was due to fact that system as whole provided opportunities to make use of by product or waste material of one component as input for other (Sanjeev kumar *et al.,* 2011). The highest SEY 81.32 q/ha/year was recorded in Improved IFS module which was significantly higher than traditional IFS module (3.01 t/ha/year) and farmers practice (1.54 t/ha/year).

Table 1. Production and Economics of different enterprises under Improved Farming System module

Enterprises	Area Allocation (ha)	Crop / Enterprises	Yield (kg)	Cost of cultivation (Rs)	Net Return (Rs)
Field crop	0.65	Soybean	1004	8695	16405
		mustard	729	7735	15595
Vegetable crop	0.20	Tomato	3108	6636	24443
		Chilli	2844	5126	17625
Dairy	0.10	Milk (liter)	2283	36492	31998
Fisheries	0.025	Meat	102	1777	7818
Biogas	3 cum	Gas (q)	730	7852	10698
		Slurry (q)	182		
NADEP	5.75 cum	Composting (q)	120	1200	3800
Total (Improve IFS module) Field crop (0.65 ha) + Veg. Crop (0.20 ha) + Dairy (0.10 ha) + Fisheries (0.025 ha) + Composting (5.75 cum) + Biogas (3 cum)				75513	128382
Farmers practice – 1 : Crop (Soybean + Mustard) + Dairy			52922	61158	
Farmers practice – II :Mono cropping of Soybean			13303	24451	

Table 2. Soybean Equivalent Yield (kg/ha), gross return (Rs/ha) and Net Return (Rs/ha) under different farming system module

Treatment	SEY (t/ha/year)	Gross Return (Rs/ha/year)	Net Return (Rs/ha/year)
IFS Module	8.13	203287	128382
Traditional IFS module	3.01	75131	61158
Farmers practice (Monocropping)	1.54	38424	24451
SEm +-	0.12	2885.44	3122.75
CD (P=0.05)	0.40	7997.89	8655.68

CONCLUSION

It was concluded from this study that Improved IFS module should be suitable to ensure livelihood security in rainfed scares rainfall areas of Bundelkhand region with fulfill the food fodder and fuel requirement of small and marginal farmers.

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Farming system - a climate resilient option in eastern India plateau

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Mitigation of climate change needs adaptation of potentially best indigenous farm practices in existing cropping systems and livestock systems. Rainfed agriculture in Eastern India plateau is mono-cropped. Existing cropping system is rice/ maize - fallow; rice/ maize - chickpea/ lentil and rice/ maize/ finger millet - vegetables. Crop productivity is low due to dependency on rain, intermittent droughts, owing to monsoon variations and increasing temperature (day and night). Crop damages in conventional cropping systems are common due to weather extremes. A farm pond in homestead land can change the cropping system and enhance cropping intensity by making life saving irrigation possible in the dry spells and can also increase total farm income as fishery and/or duckery can also be practiced in the farm pond (Singh, 2011). In addition, fruit crops and vegetables can be raised on pond embankments. Thus, there is need of integration of crops with other farm enterprises-horticulture, livestock, secondary agriculture, etc. in Integrated Farming System (IFS) mode for climate resilience in agriculture.

METHODOLOGY

An Integrated Farming System (IFS) model of 1 ha area with crops (8000 m^2), dairy (two Holstein Frisian <50% cows in 590 m^2), vermi-compost (265 m^2), mushroom (145 m^2), fishery (1000 m^2) and apiary (5 boxes) is being practiced at Birsa Agricultural University, Ranchi since 2013-14 to increase productivity of farm and to get round the year income. Different cropping systems followed in the model were Rice-Wheat (2500 m^2), Maize + Blackgram (1:2) - Lentil (2000 m^2), Maize + Soybean (1:2) - Mustard (1000 m^2), Groundnut-Mustard (1000 m^2) and Fodder maize + Cowpea - Berseem + Oat (1500 m^2).Output from different component was converted to rice equivalent yield to judge the productivity of enterprises.

RESULTS

Among the cropping system, fodder sequence gave the highest rice equivalent yield (2.93t) and net return (Rs. 20932) while, from secondary agriculture dairy component gave the highest REY (11.11 t) and gross return (Rs. 112726) but lower net return (Rs. 13898) than vermicompost due to higher cost of cultivation (Table 1).The products like crop residues, weeds, cowdung, vermicompost, shed wastage, harvested water were recycled as the input of other components within the system The different components of the farming system provide year round production through which farmers can get regular cash in hand which can be utilized to meet out the daily nutritional requirement to the farm family. However, March and October months were more remunerative in com-

Table 1. Yield and economics of different components of IFS for 1 ha model (2014-15)

S. No.	Components	Area (m^2)	Rice equivalent yield (t)	Gross return (Rs.)	Net return (Rs.)
1	Cropping system				
	Rice-wheat	2500	2.73	33615	17006
	Maize+black gram (1:1)-lentil	2000	1.85	20268	8883
	Maize+soybean (1:1)-mustard	1000	1.05	10826	5368
	Groundnut-mustard	1000	0.78	7970	2657
	Fodder maize + Cowpea - Berseem + Oat	1500	2.93	29325	20932
	Total	8000	9.34	102003	54846
2	Dairy	590	11.11	112726	13898
3	Vermicompost	265	1.94	19392	15344
4	Mushroom	145	0.93	9360	5684
5	Fishery	1000	0.30	3200	916
	Total	10000	23.62	246682	90688

Table 2. Month wise income generation in 1 ha IFS model (2014-15)

Months	Gross return (Rs.)	Component
April	9943	Milk, Mushroom, Vermicompost
May	9615	Milk, Vermicompost
June	12911	Milk, Fish, Vermicompost
July	11040	Milk, Vermicompost, Fodder
Aug	13290	Milk, Mushroom, Vermicompost, Fodder
Sep	17720	Milk, Mushroom, Vermicompost, Fodder, Black gram
Oct	33732	Milk, Mushroom, Vermicompost, Fodder, Maize, Soybean, Groundnut
Nov	10634	Milk, Mushroom, Vermicompost
Dec	28454	Milk, Mushroom, Vermicompost, Rice, Fodder
Jan	15431	Milk, Mushroom, Vermicompost, Fodder
Feb	18369	Milk, Mushroom, Vermicompost, Mustard, Fodder
Mar	47048	Milk, Mushroom, Vermicompost, Wheat, Lentil, Mustard, Fodder

Total* 228187 * In addition, income from other sources (Rs.18495) to be added from FYM, cow dung, *Tephrosia* leaves, decayed mushroom bags and fruits & vegetables from kitchen garden.

parison of other months due to larger sell of the produce especially crop components (Table 2). Thus, the diversification of agricultural enterprises on a unit land area not only provides round the year income instead of single income under rice-fallow system but it also provides security to the farmers under changing climatic scenario.

CONCLUSION

Integrated farming system provides an option for enhancement in productivity from a unit area of land along with regular income throughout the year and also give security to the farmers under aberrant weather condition.

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Integrated farming system model under dryland vertisol of southern zone of Tamil Nadu

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Crop cultivation under drylands are always risky, uncertain due to erratic and uneven distribution of rainfall and crop failure has become common phenomenon in drylands. It is a concept of ecological soundness leading to replenishment of organic matter by way of proper recycling of waste through integration of different enterprises (Jayanthi etal 2003). In this juncture along with crops, inclusion of goat rearing and milch animal is a viable option in drylands to recycle organic residues, provide employment opportunities and to generate farm income (AICRPDA 2008). In view of the above conditions an attempt has been made for a holistic integration of different farming enterprises such as of crop, goat and livestock with the objective of increasing income and effective recycling of farm wastes and sustain the productivity and profitability of the farm under rainfed vertisol conditions.

MATERIALS AND METHODS

Dryland farmers of the southern zone normally grow millets, cotton and pulses field. A field experiment on integrated farming was conducted during 2010-15 at Agricultural Research Station, Kovilpatti involving crops, goat (10+1), livestock (1). An area of 1.6 ha was taken for the study purpose.

Table 1. Mean System Productivity of Different Enterprises (Kg/Ha)

Enterprises	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	Mean
CCS*	1,391	1,368	131	230	2511	2713	1,391
IFS**	7,284	18,915	12,000	10,060	16978	10609	12,641

Table 2. Mean Total System Income (Rs./ha)

Enterprises	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	Mean
CCS	11,125	8,210	1,575	2,760	32643	35,281	15,266
IFS	58,277	1,13,496	1,43,970	1,20,720	1,86,758	1,33,876	1,26,183

Table 3. Mean Net Income Of Different Enterprises (Rs./ha)

Enterprises	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	Mean
CCS	11,125	860	-10,425	-8,340	15,143	10,906	3,212
IFS	58,277	71,346	62,445	47,720	96,858	47,997	64,107

Table 4. Employment generation (Man days/ year)

Enterprises	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	Mean
CCS	195	187	70	190	206	212	177
IFS	420	386	435	390	452	437	420

*CCS - Conventional Cropping System **IFS - Integrated Farming System

Under integrated farming system 1.20 ha was assigned for crop activity, 0.30 ha for fodder and 0.10 ha for cattle shed, whereas in conventional cropping system 0.6 ha was assigned for sorghum, 0.6 ha for cotton + blackgram and 0.4 ha for greengram. The rainfall received were 333, 587,503,228 and 253 mm during 2009-10, 2010-11, 2011-12, 2012-13 and 2013-14 respectively. The rainfall received during 2009-10, 2012-13 and 2013-14 were found deficit.

RESULTS AND DISCUSSION

Integrated farming system (IFS) was compared with conventional cropping system (CCS) in terms of system productivity, system income, net income and employment generation for five years and furnished in Table 1, 2, 3 and 4. IFS surpassed the conventional cropping system with respect to system income and productivity. In IFS, due to integration of different enterprise such of crop, livestock and goat rearing resources were effectively recycled. The average mean system productivity and mean system income in IFS were 12,641 kg/ha and 1,26,183 Rs./ha whereas in conventional system the values were 1391 kg/ha and 15,266/ha. The mean employment generations were 177 and 420 man days/year due to cropping alone and integration of crops, livestock and goat rearing respectively.

CONCLUSION

Integrated farming system recorded mean average system productivity of 12,641 kg/ha and total system income of Rs. 1,26,183 besides 420 man days employment opportunities were generated in the rainfed vertisols of Southern Zone by integration of animal components (goat and livestock) along with conventional cropping helped to enhance the farm productivity and tide over the risks of crop failure even during drought years.

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Integrated farming system approach for income enhancement of marginal and small farmers of Himachal Pradesh

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The average holding of a farm in India has been declining and over 80 out of 105 million operational holdings are now below the size of 1.0 ha. Conventional farming is risky and farmers are reluctant to invest heavily in crop production. With increasing pressure from the burgeoning human population, only vertical expansion is possible by integrating appropriate farming components requiring lesser space and time and ensuring periodic income to the farmer. The integrated farming system therefore, assumes greater importance for the sound management of farm resources to enhance the farm productivity, reduce the environmental degradation, improve quality of life for resource poor farmers and to maintain sustainability (Jayanthi *et al*., 2010). Integrated farming system (IFS) is considered as one of the best option towards intensification of small holder farm income to ensure sustainable livelihood. Integration of resources is made through a combination of land, water and animal resources of a farm through careful planning including recycling of bio-resources. Integrated Farming System (IFS) plays an imperial role for maximizing their profit and production to meet the nutritional requirement with food security with less investment. Further in IFS it is more advantageous that the farmers can able to produce more by using optimal resource utilization and recycling of waste materials and family labour employment (Sasikala *et al*., 2015). Therefore farming system approach have the potential to integrate different combinations of enterprises and to study their interaction effect with resources available to the farmers and the environment without dislocating the ecological and socio-economic balance in one hand and attempts to meet the national goals on the other.

MATHODOLOGY

An integrated farming system model has been developed from 2010-15 on one hectare land area under irrigated conditions at Padhiarkhar farm of Department of Agronomy, CSKHPKV, Palampur. H.P. The soil of experimental site is silty loam in texture with low organic carbon content (0.82%), low in available nitrogen (117.15 kg/ha), medium in available phosphorus (38.1 kg/ha) and low in available potassium (255.3 kg/ha). The one hectare land area is distributed as crops-6500 sq m, horticulture cum vegetable crops-1750 sq m, Fodder crops- 1000sq m, Vermicompost unit+ Poultry shed -225 sq m. supporting activities – 525 sq m. Simple percentage analysis were used to interpret the data. The study was conducted from Kharif 2010 to Rabi 2015.

RESULTS

Net returns of Rs 33,500/- were obtained from rice-wheat cropping system. Moreover, the returns are obtained two times in a year after the sale of rice and wheat grains in the market. However, in integrated farming system approach, net returns of Rs 75,238/ ha were obtained. The dairy unit provides regular income on daily basis and the profitability further increases from the sale of young calves. Vegetable and fruit component provides balanced nutrition to the family members. The crops component included the diversified crops *viz.,* maize, oil seeds, pulses, vegetables and fodder crops etc so that all the domestic needs can be met from the own farm. The per cent contribution of net returns of different components of integrated farming system model in terms of cropping systems (maize, rice, wheat soybean), Livestock (dairy animals), others (fodder block/forage crops), Mushroom, horticulture cum vegetable cum agroforestry(Gobhi Sarson, okra, frenchbean, broccoli, cauliflower, maize, soybean), were to the tune of 48, 33.7, 11.3, 5.5 and 1.3 per cent respectively. In the present study in rice-wheat system Rs. 57/ha/day net returns can be obtained where as from integrated farming system the net returns of Rs 206/ha/day have been obtained i.e. Rs 149/ha/day extra over rice-wheat cropping system.

CONCLUSION

Thus integrated farming system approach seems to be the only option to make the agriculture sector more profitable and sustainable. In the present study, 124% more gain from crop+ Horticulture cum vegetable + Dairy + Vermicompost + Mushroom in Integrated farming system model was obtained compared to traditional rice-wheat system.

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Development of water and nutrient self-reliant farming system for small holder farm in high rainfall zone

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In spite of large-scale expansion of irrigation systems, 55% of the gross cropped area in India is still rainfed and it is likely tocontinue in the near future (DWM, 2013). Effects of climate change may further intensify the inherent problems of rainfed agriculture. A Self Reliant Farming System (SRFS) is envisaged as a system where the use of external sources for meeting the requirement of water, nutrient, feed and energy is minimized (Rautaray *et al.*, 2016). For achieving the objective of sustainable agriculture especially in ranfed areas, there is a need to develop an SRFS which will conserve soil, water, and nutrients; and minimize the use of fossil fuels, chemical fertilizers, and synthetic pesticides. So, water security at farm level through water harvesting is the option for such areas. Secondly, cash constrained farmers face increasing relative prices of mineral fertilizers (FAO, 2012). Adverse effects of mineral fertilizers on soil health are a constraint to sustainability, in addition to their availability in time. So, the small farmers have to rely increasingly on recycling of residues for conserving nutrients within the system (Alvarez et al., 2014). With this background, a field experiment was initiated in January 2015 at the Research Farm of Indian Institute of Water Management, Bhubaneswar to develop an SRFS.

METHODOLOGY

A farm pond (66m x59 mx 3m depth) was renovated for water harvesting and attaining self-reliance with respect to water. A surplus structure is constructed inside the farm pond (at the down side) to allow excess run-off in the event of high rainfall. An inlet has been constructed using locally available lateritic stone for collecting run-off from the upper reach of the farming system site. Run-off water before entering into the farm pond was allowed to pass through a low land rice field (50 cm below the pond inlet) with the objective of reducing sedimentation load in the farm pond. On the embankment (top width 4.5 m and bottom with 7.5 m)of the farm pond, two rows of banana at the edges and one row of papaya at the centre of dyke was planted in diagonal pattern with plant spacing of 2.5 m for efficient utilization of space and solar radiation. A drip irrigation system was installed for irrigating banana and papaya plants (two emitters of 4 liters per hour discharge capacity for each plant) to achieve economy in water use for ensuring water reliance. Composite pisciculture (30000 fry ha^{-1}, 30% *catla*, 30% *rohu* and 40% *mrigal*) was adopted in the pond to enhance profitability at no additional consumptive use of water.For achievingself-reliance with respect to plant nutrients, green manuring by sesbania, inclusion of legume in rotation, application of rhizobium to legume seeds and use of vermicompst (generated from the same farming system) were attempted. Nutritional requirement of rice was met from sesbania green manuring (60 kg N ha^{-1}) and the remaining 20 kg N from 3 ton of vermicompost. For comparison, adjacent plot was grown with the same fertilizer dose but using urea, di-ammonium phosphate and muriate of potash as source. After harvest of wet season rice, blackgram, cowpea, groundnut, maize, cabbage, and utera blackgram were grown in subplots using vermicompostapplied at 3175, 3968, 4127, 5460 and 9127 kgha^{-1}, respectively.

RESULTS

The first year result showed that Grain and straw yields of rice under the SRFS (organic nutrition) were 3880 and 5520 kg/ha, respectively, which were 8 and 2 % lower compared the conventional practice (inorganic nutrition). Total energy input and output under the SRFS were 6.2 GJ ha^{-1} 126 GJ ha^{-1}, respectively, whereas these were 10.2 GJha^{-1}and 133 GJha^{-1}under the conventional practice. However, energy efficiency

Table 1. Nutrient use, Yield and Energy input and output in rice cultivation under Self-reliant farming systemand Conventional practiceduring wet season 2015

Items	Self-reliant farming system (Sesbania green manure and compost)	Conventional practice
Grain Yield (kg/ha)	3880	4210
Straw yield (kg/ha)	5520	5650
Energy input (GJ/ha)	6.2	10.2
Energy output (GJ/ha)	126.0	132.5
Specific energy (t output/GJ)	1.53	0.97
Specific energy (t grain/GJ)	0.63	0.41
Net Energy (GJ)	12.0	12.2
Energy output : input ratio	20.5	13.0
Gross Return (INR)	60616	65432
Net Return (INR)	16922	20817

in terms of energy output:input ratio(20.5) and the specific energy (0.63 for grain and 1.53 for biomass yield) was higher inSRFS. The gross and net returns of rice were higher by 7 and 19 %, respectively under conventional practice as compared to SRFS. The performance of 6 dry seasons crops were evaluated (based on yield decrement) under SRFS as compared to the conventional practice. Groundnut was most suitable after rice with lowest yield decrement (16%). Among the crops harvested for grains, water productivity highest for black gram and groundnut crop (0.54 kg m^{-3}) followed by maize (0.40 kgm^{-3}). Haulm of legume crops are especially useful as animal feed enriched with protein. After 225 days of fry to fingerling rearing, the average mean body weight is 640.0g, 430.0g, and 445.5g for *Catla, Rohu,* and*Mrigal*, respectively.

CONCLUSION

It was feasible to develop water and nutrient reliant farming system in the high rainfall area using harvested pond water, and in-situ bio-resources and wastes. Rice-Groundnut may be considered as suitable cropping system under SRFS.Less yield and net returns under SRFS in the first year may be reduced over years due to possible accumulation of residual nutrients and soil water holding capacity.

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Integrated farming system with alternate land uses for achieving economic resilience in arid zone farming

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Growing annual crops in arid zone is a risky business. This is due to aberrant weather situations mainly low & erratic rainfall (100-450 mm, CV 36-65%). The other factors being high temperature, desiccating winds, poor soil fertility and limited scope for irrigation. To spread the risk, farmers since ages practice multiple enterprises. Land is put to alternate uses along with rearing of livestock. This issustainable at low levels of production. To make these systems viable at present level of expectations, combining different land use strategies in tree-crop- grass- livestock continuum under the ambit of farming system mode appeared pragmatic. Based on long term studies on alternate land uses, an integrated farming system experiment was laid out at CAZRI, Jodhpur (300-400 mm rainfall zone) over 7 hectares of land. The main objectives of IFS was to meet the fodder requirement of livestock, providing yearlong employment, higher income and to spread the risk.

METHODOLOGY

This Integrated Farming system experiment commenced in 2001 over 7 ha land and had undergone 14 years comparing 8 land use systems i.e. Arable (crops alone grown with natu-

Table1.Economics of alternate land use systems of integrated farming system.

System	Components	Cost of Cultivation (₹10³/ha)	Net Returns (₹10³/ ha)	B:C ratio 2012-13	2013-14	2014-15
Arable Farming	Crops alone	14.6	11.9	1.46	1.86	2.05
Agro-forestry	*P. cineraria* + Crops	19.4	24.5	2.02	2.34	2.41
Agro-forestry	*H. binata* + Crops	19.5	19.0	1.52	1.82	2.31
Agri-Horti	*Z. mauritiana*+ Crops	47.4	66.1	2.42	2.39	2.36
Horti- pasture	*Z. mauritiana* + Grass*	29.2	29.8	1.56	2.54	2.12
Silvi- pasture	*C. mopane* + Grass	16.4	39.6	2.94	3.75	3.48
Agri-pasture	Grass alone	16.3	32.2	2.9	3.29	2.65

**Cenchrusciliaris*

Table 2. Whole farm economics of integrated farming system *vis a vis* prevalent arable farming (7 ha)

Economics and employment indicators	Integrated Farming System			Arable Farming system		
	2012-13	2013-14	2014-15	2012-13	2013-14	2014-15
Gross Returns (× 10³.)	459.8	573.7	516.8	120.9	231.3	204.3
Total cost (× 10³)	260.7	292.5	268.6	83.1	124.4	99.6
Net Returns (× 10³)	199.1	281.2	248.2	37.8	106.8	104.7
B:C Ratio	1.76	1.96	1.92	1.46	1.86	2.05
Employment Generation (Man days)	845	931	823	442	460	438
Wages (× 10³)	151.6	167.6	148.1	79.5	82.8	78.8
Total Earning (Net Returns + Family Wages) (× 10³)	350.7	448.8	396.3	117.4	189.6	183.5

ral tree density), *Prosopis cineraria* + crops, *Zizyphusmauritiana*+ crops, *Hardwickiabinata*+ crops, *Colophospermum mopane* + grass (*Cenchrusciliaris*), Agri-pasture (rotation of *Cenchrusciliaris*and crops for 3-5 years), *Zizyphusmauritiana* + grass(*Cenchrusciliaris*) and *Acacia tortilis* alone . The crops taken were pearl millet (*Pennisetumglaucum*), cluster bean (*Cyamopsis tetragonoloba*), greengram (*Vignaradiata*), and dew gram (*Vignaacontifolia*) in 2:1:1:1 ratio following cereal -legume-legume rotation grown during rainy season. Six adult cattle units (4 cows, 8 bucks & 4 rams) were managed under mixed feeding system (i.e. stall feeding + grazing). Daily record of all the inputs and outputs was maintained. While calculating the economics, those products that were consumed itself in the system were not considered (e.g. fodder, manure etc.)

RESULTS

Amongst different land use systems, the net returns from agri-horti system were 6 times higher over crops grown alone.However, B:C ratio was higher in grass based systems. Amongst the agroforestry system, net returns from *P. cineraria*+ crops (24, 5000) were double of arable farming and 28.9% higher over *H. binnata* based agroforestry system (Table1). This might be due to synergistic effect of *P. cineraria* on annual crops and additional availability of top feed and fuel wood from tree component. As evident from B: C ratio, tree based systems showed more stability in income compared to crops alone.Whole farm analysis of IFS model revealed that this not only improved the gross returns by many times but also imparted stability over the years with aberrant weather conditions. The year 2012 was abnormal with delayed monsoon (1st rains on 4th August), 2013 was with normal monsoon while there was terminal drought during 2014. In spite of such diverse weather situations, it had generated net returns from 1.99 lacs to 2.81 lacks. It had generatedyearlong employment for the family of six members with three adult workers (823-931 man-days, Table 2). Thus, the total income for the household ranged between 3.5 to 4.48 lakh compared to 117.4 to 189.6 lakh under arable system. Hence it may be concluded that under rainfed situations of arid region (300-500 mm annual rainfall) with normal operation holding from 4-8 ha, food, feed and income security can be achieved through diversifying the land with crops- trees-grasses and animals in an integrated farming system approach.

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Integrated farming system approach to achieve zero hunger challenge

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During seventies and mid-eighties, the agricultural growth rate increased rapidly and thereafter started steady declining. Punjab rural economy is completely dependent on two most important resources i.e. land and water that have sharply deteriorated over time (Walia *et al.*, 2016). The use of inputs has also increased to a much high level resulting in over exploitation of natural resources (Dhawan and Singh, 2015). Rice-wheat is the predominant cropping system of Punjab due to assured irrigation facilities and better adaptability. Now, Punjab agriculture has reached at a point of stagnation (Dhawan *et al*., 2015). Therefore, the present study was conducted to find out the possibility of diversification in traditional rice- wheat cropping system in view of sustainability and to enhance profitability of marginal and small farmers in Punjab agriculture.

METHODOLOGY

The study was conducted during 2012-13 at the research farm of Department of Agronomy, Punjab Agricultural University, Ludhiana under 'All India Coordinated Research Project on Integrated Farming Systems (ICAR)'. The Integrated Farming System model experiment was initiated during kharif 2010. The study was conducted on a 1.0 ha model (10000 sq.m area) farm and it is distributed for use as follows 6400: sq.m for field crops i.e. Cereals/pulses/oilseeds/green fodder etc., 1900 sq.m for horticultural crops and vegetable intercropping, 300 sq.m for agro-forestry, 200 sq.m for dairy enterprise, 1000 sq.m for aquaculture (Fresh water fish production), 200 sq.m for kitchen gardening. In addition to this boundary plantations were also done in which craneberry (Karonda) and galgal were grown. The mushroom cultivation was also done as an additional enterprise. Economics of different farming systems including dairy were analyzed for which suitable statistical analysis such as percentages, benefit-cost ratio (B: C ratio) were used to carry out the results and for proper inference of the study.

RESULTS

The study revealed that gross returns of Rs. 282692/ ha can be obtained from integrated farming system approach with input costs of Rs. 127485/ha and after deducting the costs of production, Rs. 155207 / ha of net returns can be obtained from 1.0 ha model of integrated farming system (Table 1). Along with this, dairy unit provides income on daily basis. The dairy component, aquaculture, and agroforestry provided the net returns of Rs. 48630, Rs. 5840 and Rs. 2960, respectively from 1700 sq.m area on collective basis. Vegetable and fruit component provides balanced nutrition to the family members. In integrated farming system approach, a farmer can obtain net returns of Rs. 155207/ha. Moreover dairy unit provides income on daily basis. Vegetable and fruit component provides balanced nutrition to the family member. In the rice-wheat system Rs. 257/ha/day net returns can be obtained whereas from integrated farming system the net returns were

Table 1. Relative efficacy of different farm enterprises proposed to be included in to the integrated farming system model at PAU, Ludhiana

Farm Enterprises	Size of the unit (area/number)	Gross returns (Rs./year)	Cost of production (Rs./year)	Net returns (Rs./year)	B:C Ratio
Field crops (cereals/pulses/oilseeds/ green fodder Rs. etc.)	6400 m^2	124385	55365	69020	2.25
Horticulture guavavegetables	1900 m^2	150038877	11620	28757	3.47
Agro-forestry	300 m^2	3960	1000	2960	3.96
Dairy	400 m^2	105630	57000	48630	1.85
Aquaculture (fresh water fish production)	1000 m^2	8340	2500	5840	3.34
IFS model (10,000 m^2)	10000 sqm	282692	127485	155207	2.21

Rs. 425/ha/day i.e. Rs. 168/ha/day extra over rice-wheat cropping system.

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Effect of crop modules on yield and nutrients uptake pattern in integrated farming system

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According to an estimate, the shortage in green fodder, dry fodder and concentrate is 35.6%, 26% and 41%, respectively (GOI,2012). The production gap in animals should also close through integration of fodder crops in existing crop-livestock based integrated farming system. Since farmers are reluctant to grow the fodder crops in mainland due to low market prices. Keeping in view improving the productivity of the livestock there is urgency to develop different crop modules under IFS for year round availability of fodder. With the above facts in mind a research was conducted with a major objective to identify the crop module with better quantitative with qualitative valueto meet out the demand of round the year green fodder.

METHODOLOGY

The field experiment was conducted for two consecutive

Table 1. Effect of different crop modules on dry fodder production under different crop modules in IFS.

Treatment	Dry matter yield (t/ha)			System dry matter yield (t/ha/year)
	Kharif	*Rabi*	Summer	
Cenchrus alone	14.78	5.77	3.21	23.76
Stylo- Carrot-Cowpea	4.41	7.32	5.50	17.23
Maize- Pea-Sorghum	8.36	2.04	11.63	22.03
Clitoria – Oat-Bajra	13.35	6.78	9.70	29.83
Dolichos- Wheat-Teosinte	14.20	5.52	6.37	26.09

Table 2. Effect of different crop modules on nitrogen content and protein yield under different crop modules in IFS

Treatment	Crude protein content (%)			Crude Protein yield (kg/ha)			SCPY
	Kharif	*Rabi*	Summer	*Kharif*	*Rabi*	Summer	(kg/ha/year)
Cenchrus alone	7.18	7.25	7.06	1062	418	227	1707
Stylo- Carrot-Cowpea	15.75	8.87	15.06	694	649	828	2172
Maize- Pea-Sorghum	6.56	13.81	6.50	548	282	756	1586
Clitoria – Oat-Bajra	11.12	6.37	6.31	1484	432	612	2528
Dolichos- Wheat-Teosinte	10.12	5.56	7.12	1437	307	453	2197

Where, SCPY - system crude protein yield years during *kharif*, rabi and summer seasons of 2014 -15. The experiment was laid out in randomized block design with five replications. The treatments were consisted of five crop modules *viz*; Maize-Pea-Sorghum; Dolichos-Wheat-Teosinte, Stylo -Carrot –Cowpea, Clitoria-Oats-Bajra and *Cenchru* alone. The experiment was laid on clay loam soil with near to neutral pH (7.45), low in organic carbon content (0.32%), available nitrogen (263 kg/ha), available P (27.2 kg/ha) and available K (122 kg/ha).Observations related to yield, nutritive parameters and computation of crude protein was done by standard procedure.

RESULTS

Data in Table 1 shows that dry fodder production maximum total dry fodder production was recorded under Clitoria- Oat-Bajra cropping systems (29.83t/ha/year) and followed by Dolichos- Wheat-Teosinte crop module in term of total dry fodder production(26.09t/ha/year).Crude protein content varied among different crops in different crop modules. Highest crude protein among three seasons was exhibited in stylo followed by cowpea (Table 2). However clitoria crop recorded highest crude protein yield (1484kg/ha) and highest system crude protein yield was recorded under Clitoria- Oat-Bajra (2528 kg/ha/yr).

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Development of location specific integrated farming system models for small and marginal farmers' of Bihar

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Due to declining per capita availability of land in India, there is hardly any scope for horizontal expansion of land for food production. Only vertical expansion is possible by integrating appropriate farming components that require lesser space and time to ensure periodic income to the farmer. Further, modest increments in land productivity are no longer sufficient for the resource-poor farmers. Hence, intelligent management of available resources, including optimum allocation of resources, is important to alleviate the risk related to land sustainability. Moreover, proper understanding of interactions and linkages between the components would improve food security, employment generation as well as nutritional security. This approach can be transformed into a farming system that integrate crops with enterprises such as – agro forestry; horticulture; cow, sheep and goat rearing; fishery; poultry and pigeon rearing; mushroom production; sericulture; and biogas production – to increase the income and improve the standard of living of small and marginal farmers. The challenge of such an integrated farming system (IFS) is to upgrade technological and social disciplines on a continuous basis and integrate these disciplines to suit the region and the farm families in a manner that will ensure increased production with stability, ecological sustainability and equitability (Varughese and Mathew, 2009).

METHODOLOGY

Field experiments were conducted at ICAR Research Complex for Eastern Region, Patna and at farmers' field during 2011 to 2015 for the purpose of efficient farm based resource recycling, increasing land and water productivity, sustaining soil health and maintaining soil fertility, securing nutritional security and enhancing livelihood of small and marginal farmers. To achieve these objectives one acre IFS model (Crop + Goat + Poultry + mushroom) and two acre IFS model (Crop + dairy) + fish) were developed. In the developed models allocation of area under crops, livestock, fishery, horticulture and other enterprises have been made in such a way that it could fulfil the demand and needs for farm families (nutrition and income) and system (nutrient/resource recycling) at the same time. Under crop components, rice-wheat, rice maize, rice- gram and rice- mustard- moong (cereal based cropping system) and cowpea-okra- tomato, okra- cabbage-cucurbits- cabbage and okra - cauliflower - onion (vegetable based cropping systems) were followed. Pattern of nutrient recycling within the system was also studied. All around the field bunds, pigeon pea plantation were done to enrich the field bunds and to supplement additional protein to the farm families.

RESULTS

Under one acre model, Cowpea - cauliflower- onion cropping system along with poultry + mushroom + goatry fetched the highest net income of Rs. 76,628/annum (Rs. 210/day, B:C:: 1.5) with an initial investment cost of Rs.1,02,220**/-,** while under two acre IFS model, a net return ofRs. 1,26,160/ annum (Rs. 346/day, B:C:: 1:7) was achieved with an initial investment of Rs.2,05,500.An additional employment of 67

Table 1. Recycling of farm waste and gain/saving of nutrients in one acre IFS model (2012- 15)

SI. No	Farm waste	Quantity produced (q)	Production/ use pattern (q)	Nutrient gain (kg)	Total nutrient gain upon recycling	Saving due to resource recycling (Rs.)	Fert. Saving (kg)
1.	GoatManure (20+1)	24.9	18.5 (GM- 7.2) 6.4 (VC- 1.7)	N- 10.1 P- 5.8 K-11.6	N-47.9 P-38.8 K-38.2	2684/-	104 kg urea 242.5 kg SSP63.6 kg MOP
2.	Veg. waste	68.4	18.4 (VC- 7.8) 50.0q- As fodder	N- 14.1 P- 12.5 K- 14.8			
3.	Poultry manure (700)	20.8	Used in crops(35.2)	N-23.7 P- 20.5 K- 11.8			
4.	RWMML Straw	48.8	4.4 (mushroom) 1.6- Hut 42.8 q- sold				

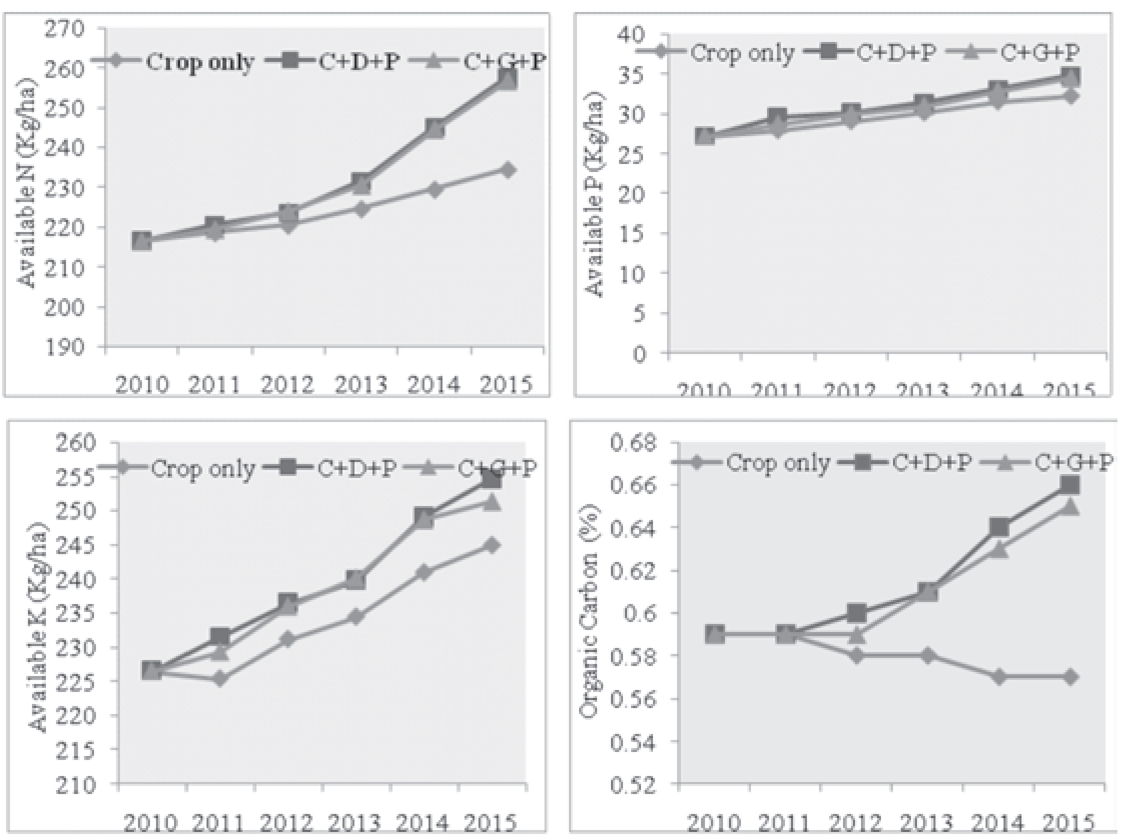

Fig.1. NPK & Organic carbon trend under different integrations
Note: C= Crop, D= Dairy, P= Poultry, G= Goat

Table2. Recycling of farm waste and gain/saving of nutrients in two acre IFS model (2012-15)

SI. No	Farm waste	Quantity produced (t)	Production/ use pattern (t)	Nutrient gain (kg)	Total Nutrient Gain from recycling	Saving (Rs.)	Fert. Saving (kg)
1.	Cow dung(2 +2)	14.5	8.2 (FYM- 3.6) 2.5 (VC: 1.3) 4.0- Pond treat.	N-24.5 P- 12.2 K-15.3	N=65.6 P=48.5 K=47.7	Rs.3426/-	143 kg urea 303kg SSP 80.0 kg MOP
2.	Veg. waste	12.2	6.2 (VC-1.6) 6.5 As fodder	N- 34.6 P- 31.1 K- 27.7			
3.	Duck droppings(35)	1.17	As fish feed	N- 6.5 P- 5.2 K- 4.7			

and197 man-days were also generated through one acre and two acre model, respectively. Enterprises within IFS, function together, complementing each other as sustainable agriculture requires system approach (Singh *et al*, 2009) and system implies a set of agricultural activities organised while preserving land productivity and environmental quality and maintaining a desired level of biological diversity and ecological stability. Studies on nutrient recycling under one and two acre IFS model revealed that about 47.9kg of nitrogen, 38.8kg of phosphorus, 38.2kg of potassium and 65.6kg of nitrogen, 8.5kg of phosphorus and 47.7kg of potassium were added in the soil upon resource recycling within the system, respectively (Table 1 and 2). An appreciable increasing trend was also recorded in case of NPK & O.C. status of soil over rice- wheat cropping system where organic carbon (O.C.) was found in decreasing trend (Fig. 1).

CONCLUSION

IFS model comprising of crop components, dairy, poultry and fishery is the most suitable and efficient farming system model giving the highest system productivity for irrigated agro-ecosystem of North eastern plain zone which has considerable potential to provide food security, nutritional benefits, employment generation and providing additional income to resource poor small farmers. In general, IFS enable the agricultural production system sustainable, profitable (3-4 fold) and productive on long term.

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Enhanced profitability and nutrient management using farmpond water based integrated farming system module for small holders in rainfed area

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Cost of cultivation borne by small farmers is unaffordable especially when the resources are poor and scarce. In order to save them from the clutches of moneylenders, a profitable system is to be developed which reduce dependency on external inputs. The onus further lies on small farmers of rainfed regions due to climatic, management and marketing risks involved in rainfed agriculture. Despite good rainfall, the income from agriculture does not suffice the livelihood requirement because of hiked input prices and unregulated markets. Therefore, through this long term study, an attempt was made to understand the support extended by livestock as a prop up component to small farmers though under poor management butfarm pond based integrated farming system module in *Alfisols*.

METHODOLOGY

A long term (2004-2011) study was carried out in an Alfisolwatershed covering an area of 1.65 ha at Hayathnagar Research Farm, ICAR-Central Research Institute for Dryland Agriculture, Hyderabad (17º20'N latitude and 78º35'E longitude). The crop and vegetable components were grown on three pediments consisting of upper soil depth of 8.0±4.3 cm (D_1) with low water requirements of grasses (19 % of area), middle basin of depth 15±4.4 cm (D_2) with arable crops and cropping systems as sorghum + pigeon pea (2:1) and castor + cluster bean (1:1) (48 % of area) and lower basin of depth 30±12 cm (D_3) with agro-forestry systems (25 % of area) and vegetables (8% of area), respectively. A farm pond of 650 m^3 capacity was dug at the lowest point of the watershed for rainwater harvesting and recycling as supplemental irrigation to vegetables. Glyricidia was grown along the graded bunds, teak, henna and subabul plants were planted in the alternative rows and papaya and drum stick were planted around the periphery of the farm pond. Rainfall characteristics, seed and fodder yields of arable crops, agro-forestry systems, grasses, bushes and other perennial crops along with their economics, rainfall use efficiency were collected for all the years (2004-11). The rainfall was categorized as deficit (<20% of normal as in 2004, 2009 and 2011), normal (750 mm long term rainfall as in 2006 and 2007) and excess (>20% of normal as in 2005, 2008 and 2010) and evaluation of farming system in different categories of rainfall years were carried out based on net income (Rs.) and nutrient recycling. This included combination of cropping systems with one cattle or two sheep without any external inputs.The nutrients in the form of N, P_2O_5 and K_2O produced from both dung (0.7, 0.51 and 0.29%, respectively) and urine (1.47, 0.05 and 1.96%, respectively) were considered to calculate the total nutrients recycled. Fertilizer equivalents in terms of urea, SSP and muriate of potash were calculated based on their N, P and K contents by using a coefficient of 0.46, 0.16 and 0.6, respectively.

RESULTS

Net income from FS per hectare was highest in excess rainfall years (Rs. 13419/-) as compared to normal and deficit rainfall years. The net income (Rs.) from crop combination with one dairy animal (10588- 15153) or two sheep (11321-14748) were the highest among all the combination over different rainfall years. These benefits over different years were unaffected by the rainfall of corresponding year due to the fact that biomass obtained from the cropping system was sufficient to cater to the need of these animals. Among the cropping systems, Sorghum+pigeon pea (3:1) was the most performing combination with a net income of Rs. 10941-17918/ha (Maruthi *et al.*, 2015).Sheep are the poor man's cow in arid and semi-arid regions. The suggested module would be able to save the urea fertilizer to the tune of 54.9 kg during deficient rainfall years and 68.8-70.0 kg during normal/excess rainfall years (Fig. 1). Similarly, SSP fertilizer can be saved to the tune of 84 kg during normal and 105.1-107.1 kg during normal/excess rainfall years. Even muriate of potash fertilizer can be saved upto 34.1 kg during deficit and 42.7-43.5 kg during normal/excess rainfall years. Thus, the meta analysis can suggest that using this type of farming module could save huge money spent every year on soil nutrients as fertilizer even using unproductive cattle.

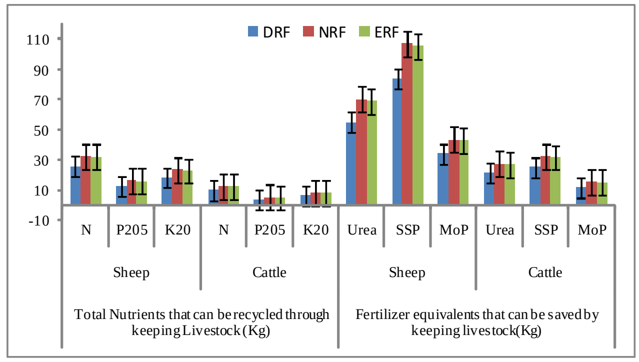

Fig. 1. Nutrient recycling though sheep rearing in rainfed watershed based farming system during various years (DRF: deficit rainfall; NRF: Normal rainfall; ERF: Excess rainfall) N, P_2O_5, K_2O: available nutrients forms; SSP: Single Super Phosphate, MoP: Muriate of Potash

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Farmer participatory crop – livestock silvipastoral farming system

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Study on crop - livestock silvipastoral farming system was conducted in the farmer field through participatory mode. The objective was to document the existing farming system and to evaluate the improved silvipastoral farming system in terms of productivity, profitability and employment generation .

METHODOLOGY

Research was conducted in the farmer field in dry land areas of Western Zone of Tamil Nadu. The soil of the experimental field is red calcareous belonging to tulkanur series.

Components in the silvipastoral system

Based on the results of the field survey, the components of the present farming system investigation were selected in such a way to suit with the existing silvipastoral system and to evaluate their potentiality to improve the productivity and soil fertility. Field experiments were conducted in three farmers fields at Kangeyam and Dharapuram to assess the carrying capacity of silvipastoral systems for a period of two years. Non-replicated experiment included five silvipastoral systems *viz., Acacia leucophloea* + *Cenchrus ciliaris, Acacia leucophloea* + *Cenchrus ciliaris* + *Stylosanthes hamata, Acacia leucophloea* + *Cenchrus setigerus* + *Stylosanthes hamata, Acacia leucophloea* + fodder sorghum + *Pillipesara* and *Acacia leucophloea* + *Cenchrus setigerus* + *Stylosanthes hamata* & fodder sorghum + *Pillipesara.* One unit of Mecheri sheep of five ewes (female) and one ram (male) and two buffaloes were maintained in each location. The manure obtained from livestock along with crop residues was used for making vermicompost. The quantity of available manure was calculated based on dry weight.

The productivity of the components, economic returns, employment generation, energy budgeting and resource recycling of the different silvipastoral systems were evaluated to identify the best silvipastoral farming system. The productivity of the components integrated was converted as *Cenchrus* equivalent yield on the basis of prevailing unit cost of the produce of each component. The productivity of livestock assessed by the lactation milk yield, Sheep by sale of kids. Labour requirement were recorded and given in man days per year. The economics of each enterprise was calculated based on the economic produce of enterprises.

RESULTS

Survey was carried out to characterize the prevailing farming systems of the dry land areas of Western Zone of Tamil Nadu. Information collected from primary and secondary sources indicated that, farming was the primary occupation of all farmers. The average size of each land holding was small. About 44% of the farmers were small (2.5 to 5.0 ha), 30% of the farmers were big (more than 5.0 ha) and 26% of the farmers were marginal (less than 2.5 ha). Of these, 73% of the farmers owned pasture land and about 77% of the farmers were having sheep than other livestock like cattle, goat, buffalo and poultry.

The main farming system of the zone was silvipastoral system locally called “*Korangadu*”. *Korangadu* has predominantly three major species of flora which were spatially arranged in three tiers. The lower tier was grown with grass *Cenchrus*; tree species include *Acacia leucophloea* locally called as *Velvel* and land was fenced with thorny shrub locally called as *Mullu Kiluvai* (*Commiphora berryii*) as live fence. Size of individual paddocks of *Korangadu* land ranges from 1.5 ha to 10 ha depending on the wealth status or ownership pattern of farmers. *Korangadu* grazing land provided livelihood for landless livestock keepers by feeding their animals. Existing silvipastoral system was not able to provide nutritious and off season fodder to livestock and also the paddock was not rotated for grazing in regular basis, leading to soil fertility deterioration. Similar findings were made earlier by Riziki *et al*. (2008).

In an area of one hectare, highest system productivity of 73500 kg and 61820 kg was registered in *Cenchrus setigerus* + *Stylosanthes hamata* & fodder sorghum + *pillipesara* along with sheep (5+1) and buffalo (2 No.’s) during first and second year, respectively. The contribution of the forage crop components to the system productivity was 22 per cent and livestock components *viz.,* sheep was 11 per cent and buffalo was 67 per cent. Among the silvipastoral farming systems, highest productivity of forage crops was recorded in *Cenchrus setigerus* + *Stylosanthes hamata* & fodder sorghum +

Pillipesara due to the inclusion of legume crop along with grass and cereal in the system might have contributed for increased fodder yield. This was in line with the findings of Esther Shekinah (2005).

Higher net return of Rs. 32485 ha^{-1} year^{-1} and benefit cost ratio of 2.58 was recorded in *Cenchrus setigerus* + *Stylosanthes hamata* & fodder sorghum + *Pillipesara* with sheep and buffalo. Fodder sorghum + *Pillipesara* with sheep and buffalo recorded consistently lower net return and benefit cost ratio. Higher gross return was obtained due to an increased live weight of sheep and by the sale of buffalo milk.

Higher employment opportunity was recorded in *Cenchrus setigerus* + *Stylosanthes hamata* & fodder sorghum + *Pillipesara* with sheep and buffalo. The employment generated by *Cenchrus ciliaris* alone with sheep and buffalo was the least. Such higher employment generation was reported in dry land integrated farming system earlier by Radhamani (2001).

Integration of sheep and buffalo, *Acacia leucophloea* tree + fodder crops as component in the silvipastoral farming system would enhance the productivity, income of the farm, employment of family labour apart from the efficient resource and residue recycling between the components.

CONCLUSION

Based on the findings, it is concluded that to enhance and sustain the productivity, economic returns, constant and year round employment for family labour, enhanced soil fertility with nutrient recycling, integration of *Cenchrus setigerus* + *Stylosanthes hamata* & fodder sorghum + *Pillipesara* with sheep (5+1) and buffalo (2 No.'s) could be the best silvipastoral farming system for dry land of Western Zone of Tamil Nadu.

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Lac integrated farming system-A new approach in lac cultivation

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Demographic pressure has left us with no further scope for horizontal expansion of land for cultivation owing to fragmentation and subdivision of land. The only option left is vertical expansion by encouraging scientific agro forestry to combat the challenge of sustained food security and meet the energy requirements for domestic purpose on available land resources. In fact, integrated farming system will play very effective role in the utilization of the natural resources in most rational manner or sustained crop diversification of farm enterprises which have less demand on space and time with very limited resources especially in rain fed area. Lac has good potential to be included in Agro-forestry as it is relatively low cash and labour input crop with high returns; compatible with existing rural livelihood activities in terms of its labour requirement and encourages conservation of host trees and leads to a re-greening of land. Besides, it has high potential for generating employment for both men and women particularly in the off agricultural season in lac growing regions of the country.

METHODOLOGY

Selection and geometrical arrangements of components: Model- Lac Integrated Farming System (LIFS) Model developed at Research Farm, Indian Institute of Natural Resins and Gums (IINRG), Ranchi. It is multi-tier hortilac system in an area of 50x 50 square meter comprising of lac host plants i.e. *Flemingiasemialata* (semialata)and *Ziziphus mauritiana (ber)*, *fruit* trees aonla (*Emblica officinalis* syn. *Phyllanthus*

Table 1. Yearwise net income from different components in LIFS. Economics of LIFS model (area 50mx 50m)

Year	Net Income from lac (Rs.)		Net Income from fruits (Rs.)	Net income from vegetables (Rs.)	Total Net income (Rs.)
	semialata	*ber*			
1st	-12,036	-3,741	-17,807	2,500	-31,084
2nd	24,975	-451	-7,302	2,500	19,722
3rd	52,515	-751	-6,780	2,500	47,484
4th	52,515	-863	-6,200	2,500	47,952
5th	52,515	30,480	10,811	2,500	96,306
6th	52,515	30,480	11,060	2,500	96,555
7th	52,515	30,480	13,420	2,500	98,915
8th	52,515	30,480	51,779	2,500	1,37,274
9th	52,515	30,480	83,279	2,500	1,68,774

emblica), guava (*Psidium guajava*) and lime (*Citrus aurantifolia* Swing) and vegetable (bittergourd). There are nine paired rows of *semialata* alternating with fruit trees. Lay out. *Semialata:* plant to plant distance in a row - 1m, row to row 0.75 m and between two paired rows – 5 m. (81 plants in each of the nine paired rowstotaling 729 plants). *Guava:* plant to plant in a row - 5m, row to row in - 5m, (9 plants in each of the three rowstotaling 27 plants). *Lime:* plant to plant in a row - 5m, row to row in - 5m, (9 plants in each of the two rowstotaling 18 plants). *Ber* and *Aonla* (mixed row) - plant to plant in a row - 5m, row to row in - 10m, (4 plants of *ber* and 5 plants of *aonla* in each of the five rowstotaling 20 plants of *ber* and 25 plants of *aonla*).

RESULTS

Lac yield:Average broodlac yield in *semialata*is 250g/plant for winter and 150g/plant for summer crop, and 6-10kg/plant in *ber*. Fruit yield:Grafted plants of guava came into bearing at the age of 3 years and peak harvesting periods are August-September for rainy season crop and Jan-Feb. for winter season crop. A ten year old guava tree gave an average yieldof75 kg of fruit per tree.Lime fruits are harvested generally between December to February. Average yield of lime is 500 fruits /tree/year.Aonla plants came in to bearing quite late. Generally, vegetatively propagated tree starts bearing commercial crop after 3-4 years of planting, while seedling tree may take 8-10 years to come into bearing. Generally, aonla fruits are ready for harvest in November-December. On an average, a mature tree yielded 150 to 200 kg fruits per annum.Economics:In the first year of establishment of LIFS, none of the components except bitter gourd started yielding. Therefore net expenditure exceeded net income by Rs 31,084. While lac crop on semialata was raised in the following July after one year of planting, net income of Rs 19,722 was earned in second year from lac component. Lac crop on ber was raised after five years, so income from lac on ber started only after fifth year. Whereas fruit trees guava, lime and aonla came into bearing after 3rd, 5th and 8th years respectively. Over all net income increased fromRs 19,722 in second year to Rs 1,68,774 in eighth year from an area of 50 X 50 m, suggesting LIFS to be a highly profitable, diverse out-put more sustainable system than monocropping system (Table 1). These IFS systems were also found more sustainable and employment generative.

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Productivity and economics of rice–wheat cropping system as influenced by different establishment methods and sowing schedules under in Indo-Gangetic Plains (IGP)

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A field experiment was conducted at Jammu during the year 2008-2009 and 2009-2010 to evaluate the effect of two establishment methods (conventional sowing and zero tillage) in wheat (*Triticum aestivum*) and four establishment methods (conventional transplanting of 25 days seedling, dry seeding @ 40 kg/ha, wet seeding after puddling @ 40 kg/ha and SRI methods) and 4 sowing schedules (15th May, 25th May, 5th June and 15th June,) in rice (*Oryza sativa*) under rice - wheat cropping system. Rice establishment methods and sowing schedules had significant impact on total productivity and production efficiency in rice- wheat cropping system. Both the direct seeded methods of rice, being at par, recorded significantly higher total productivity and production efficiency as compared to conventional transplanting or SRI method. Similarly, 15th June rice sowing schedule resulted in marked increase in total productivity and production efficiency of rice- wheat cropping system as compared with other sowing schedules. Among the establishment methods of both wheat and rice the highest net return was obtained in zero tilled wheat-wet seeding rice (Rs. 62371 and Rs. 73877 per ha respectively, during 2009 and 2010) which was followed by zero tilled wheat-direct seeding rice (Rs.61557 and Rs. 73725 per ha), respectively, during both the years. Higher benefit cost ratio were recorded when wheat was established through zero tillage and rice through wet seeded sown on 15th of June in rice- wheat cropping system. Rice-Wheat cropping System (RWCS) has a long history in Indian sub-continent, particularly in Indo-Gangetic Plains (IGP) with an area of about 12.5 million hectare. However, stagnation in the productivity of RWCS has been a serious concern remains in the recent past from the view point of food security in India. Over the last decade there has been a concern about the equity in environmental degradation and sustainability of resources in Rice-Wheat Cropping System. Zero tillage planting of wheat after rice has been the main success in the quest of resource conservation technologies that can save water, reduce production costs and improve productivity in the cereal bowl of South-East Asia. The alternative to puddling and transplanting could be direct seeding which besides labour engagement allows timely planting of the succeeding wheat crop because of earlier maturity than transplanted crop thus saving water, labour and fossil fuel consumption .The rice-wheat system productivity has been reported to get reduced by 40 per cent when planting is delayed by 45-55 days. Timely planting of rice crop is also found to increase the rain water use efficiency as compared to the delayed planting. Moreover, the problems of repeated tillage operations *viz.* high energy requirement for wheat sowing after rice, less turn around period, low nutrient response and high cost of production are the main constraints for this production system. To overcome such problems adaptation of reduced tillage techniques can result in timely sowing of wheat and may help in saving energy units at the farm level. As regards the time of planting/sowing and methods of establishment for RWCS, specific package of practices need to be developed to realize the full genetic potential of high yielding varieties/hybrids in the future. The role of hybrid rice in self sufficiency of food grains has also been established by several workers. Therefore, the present investigation was undertaken to evaluate the impact of different establishment methods and sowing schedules on productivity and economics of rice (*Oryza sativa*) - wheat (*Triticum aestivum*) cropping system.

Symposium 5
Abiotic and Biotic (Weeds) Stress Management

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Evaluation of rice genotypes for osmotic stress induced root traits

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Cereals are the most important component of human diet. The rate of gain in yield is declining. Drought is the most important abiotic stress that hinders the increase in productivity of cereals. Root system architecture (RSA) of plant determines the ability of plant to extract moisture and mineral nutrients from the soil. Root number, length, angle, diameter, volume, secondary roots and root hairs collectively acts as the basic infrastructure of RSA through which plants can absorb moisture and mine for nutrients. Considerable variability for constitutive variation in root traits has been reported among and within the crops. Although mild to moderate drought stress is known to induce root elongation to mine water from the deeper soil layer, the genetic variability and physiological and molecular basis of drought induced root growth is not understood well. This study was conducted to identify rice genotypes with contrasting root growth osmotic stress.

METHODOLOGY

Screening was performed in the glasshouse of National Phytotron Facility, ICAR-IARI, New Delhi. Plastic tray of 10-liter were used for the hydroponics system. Thermocol sheets of 15mm thickness was fitted on a plastic mesh of 2mm pore size from one side to hold the seeds/seedlings. 10 mm holes were drilled on the Thermocol sheet 2.5cm x 1cm apart. In all there were 90 holes on the sheet. Seed were first treated with 4% w/v NaClO for 5 minutes, then they were washed 3 times and set on filter paper for germination. Seeds were first kept in Petri plate lined with germination paper, for 48 hours. The germinated seeds were transferred on to the hydroponics system. Osmotic stress of -0.15 MPa was induced with PEG 6000. For first seven days plants were grown in the water followed by half strength Hoagland's solution for non-stress condition, and half strength Hoagland's solution plus PEG 6000 for osmotic stress treatment for next seven days. pH of the solution was adjusted to below 5. The solution was constantly aerated with the air pump. Data were recorded after 14 days after germination. Roots were washed with water and then scanned with a scanner (EPSON11000 XL) and analyzed with the 2D root analysis software (WinRHIZO). 255 rice genotypes were screened with six genotypes as checks. ANOVA was performed with the augmented complete block design.

RESULTS

The analysis of variance shows highly significant differences among genotypes under stress condition (Fig. 2). The adjusted mean root length ranged from 33.61 cm to 189.77 cm, while average mean root length was 81.88 cm. Osmotic stress has caused a decrease of root length in some genotypes and enhancement in some others as compared to control condition. Osmotic stress induced changes in root length among checks varied from 12.5% reduction to 14% increase (Ayalew*et al*., 2015). However, about 100 genotypes showed significant changes in the root length as compared with six Check genotypes. The analysis of variance shows significant differences among genotypes under non stress condition. The adjusted mean root length ranged from 17.31 cm to 162.32 cm, while average mean root length was 79.87 cm (Fig. 1).

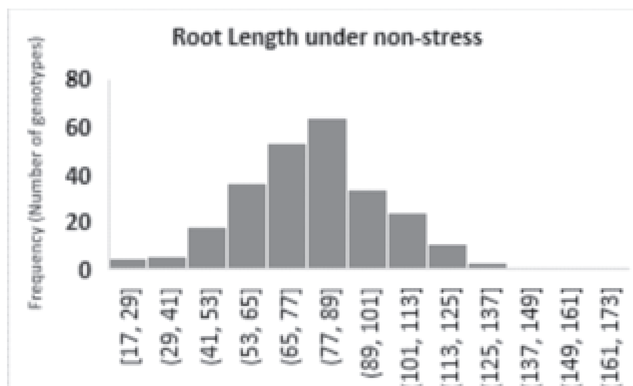

Fig. 1.

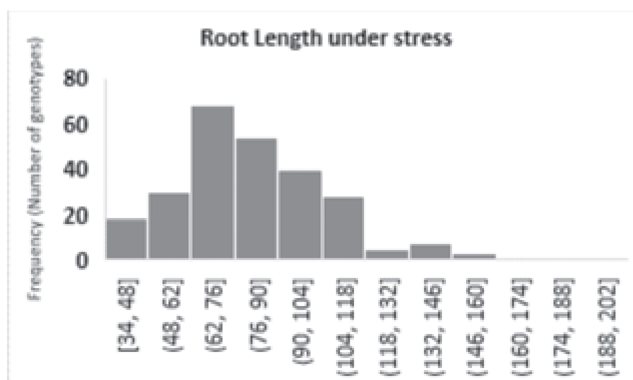

Fig. 2.

The six checks belonging to drought tolerant (APO, N-22, Sahabhagidhan) and drought susceptible (IR-64, Swarna and Pusa Sugandh 5) group were used. So some of the genotypes have performed better than the checks in terms of mean root length in non-stress condition. Results from this study showed that the rice genotypes screened vary significantly for constitutive root length under non-stress conditions and inductive root growth under osmotic stress. A set of genotypes which showed inductive root growth under osmotic stress condition were identified, which will be useful for understanding the physiological and molecular genetic basis of drought-induced root growth in rice.

CONCLUSION

The study showed the availability of considerable genetic variability, and these genotypes with inductive root growth can be used as donors in breeding programs. The hydroponic system was found to be a handy tool for root phenotyping for large number of genotypes.

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Integrated weed management in *Bt.* cotton (*Gossypium hirsutum)*

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Cotton is one of the major commercial crop and also called 'White Gold'. It plays an important role in textile industries and is a means of livelihood for millions of farmers and those concerned with its trade, processing, manufacturing and other allied industries. India is the second largest producer of cotton in the world after China accounting for about 18 per cent of the world cotton production. In India, Maharashtra stands first in area, production and productivity of cotton followed by Gujarat and Rajasthan. Venugopalan *et al.* (2009) reported a reduction in yield due to weeds in cotton crop to the extent of 50 to 85 per cent. Day by day the area under *Bt* cotton in Maharashtra is increasing. On other hand, due to scarcity of labours, increased labour wages rate, farmers are severely facing problem of timely weed management in cotton crop and increased cost of production. Considering these facts, the present investigation entitled "Integrated Weed Management in *Bt* Cotton'' was planned and conducted.

METHODOLOGY

The experiment was laid out in Randomized Block Design with three replications and 10 treatments viz., T_1- One Hoeing at 15 DAS + Two Hands weeding at 30 and 45 DAS, T_2- Three Inter-cultivation through mechanical weeder at 20, 40,and 60 DAS,T_3- Pendimethalin PE @ 1.0 kg/ha *fb* One HW at 45 DAS, T_4- Oxyfluorfen PE @ 0.1 kg/ha *fb* One HW at 45 DAS, T_5- Pendimethalin PE @ 1.0 kg/ha *fb* Pyrathiobac Sodium PoE 75 g/ha at 45 DAS + one inter-cultivation through mechanical weeder at 60 DAS, T_6- Pendimethalin PE @ 1.0 kg/ha *fb* Quizalofop ethyl PoE @ 50 g/ha at 45 DAS + one inter-cultivation through mechanical weeder at 60 DAS, T_7- Oxyfluorfen PE @ 0.1 kg/ha *fb* Pyrathiobac Sodium PoE @ 75 g/ha at 45 DAS + One inter-cultivation through mechanical weeder at 60 DAS, T_8- Oxyfluorfen PE @ 0.1 kg/ha *fb* Quizalofop ethyl PoE @ 50 g/ha at 45 DAS + One inter-cultivation through mechanical weeder at 60 DAS, T_9- Weedy check and T_{10}- Weed free check. The recommended fertilizer dose (125:65:65 N, P_2O_5 and K_2O kg/ha) was applied through Urea (46 per cent N) and Single super phosphate (16 per cent P_2O_5) and muriate of potash (60 per cent K). The pre-emergence herbicides viz., Pendimethalin and Oxyflurofen were sprayed very next two days after sowing and post–emergence herbicide viz., Pyrithiobac sodium and Quizalofop ethyl were applied 45 days after sowing as per treatments by using hand operated knapsack sprayer, fitted with flat fan nozzle.

RESULTS

The predominant weed flora observed in the experimental plot were *Cynodon dactylon* L., *Commelina benghalensis* L., *Eichnochloa colonum L.*, *Euphorbia hirta* L., *Phyllanthus niruri* L., *Convolvulus arvensis L., Parthenium hysterophorus L., Digetari aarvensis* L., *Physalis minima* L. and *Cyperus rotundus* L. The results revealed that, treatment weed free check recorded minimum and significantly lowest total weed

Table 1. Weed count, weed dry weight and yield as influenced by different weed control treatments

Treatment	Weed count /0.5m² At harvest	Weed dry weight (g/m²) At harvest	WCE (%) At harvest	Yield (t/ha)		
				Lint	Seed cotton	Stalk
One hoeing at 15 DAS + Two hand weeding at 30 and 45 DAS	8.0 (63.50)	8.24 (67.42)	69.63	0.92	2.56	3.84
Three inter culturing through mechanical weeder at 20, 40 and 60 DAS	8.59 (73.30)	8.72 (75.71)	64.94	0.53	1.54	2.30
Pendimethalin PE @ 1.0 kg/ ha *fb* One HW at 45 DAS	8.63 (73.97)	8.35 (69.25)	64.62	0.65	1.86	2.79
Oxyflurofen PE @ 0.1 kg/ha *fb* One HW at 45 DAS	8.79 (76.80)	8.67 (70.27)	63.27	0.63	1.78	2.67
Pendimethalin PE @ 1.0 kg/ha *fb* Pyrathiobac Sodium PoE @ 75 g/ha at 45 DAS + one interculturing through mechanical weeder at 60 DAS	7.37 (53.81)	7.25 (52.18)	74.26	0.95	2.58	3.87
Pendimethalin PE @ 1.0 kg/ha fb Quizalofop ethyl PoE @ 50 g/ha at 45 DAS + one interculturing through mechanical weeder at 60 DAS.	8.15 (65.92)	8.46 (71.17)	68.47	0.57	1.63	2.45
Oxyflurofen PE @ 0.1 kg/ha *fb*Pyrathiobac Sodium PoE @ 75 g/ ha at 45 DAS + one interculturin through mechanical weeder at 60 DAS	7.81 (60.49)	8.03 (64.12)	71.07	0.93	2.57	3.84
Oxyflurofen PE @ 0.1 kg/ha *fb* Quizalofop ethyl PoE @ 50 g/ha at 45 DAS + one interculturing through mechanical weeder at 60 DAS	8.45 (70.90)	8.61 (73.66)	66.09	0.55	1.55	2.32
Weedy check	14.47 (209.10)	11.70 (137.05)	0.00	0.35	1.01	1.51
Weed free check	00	0.00	100.00	0.98	2.72	4.08
CD (p=0.05)	0.70	0.98	1.62	0.06	0.17	0.54

Note: Figures in parenthesis are original values whereas figures outside the parenthesis are square root (Öx+0.5) transformed values.

count and weed dry weight at harvest as compared to rest of the treatments, but it was at par with treatments PE application of pendimethalin@ 1.0 kg/ha *fb* Pyrathiobac Sodium PoE 75 g/h at 45 DAS + one interculturing through mechanical weeder 60 DAS (T_5), Oxyfluorfen PE @ 0.1 kg/ha *fb* Pyrathiobac Sodium PoE @ 75 g/ha at 45 DAS + One interculturing through mechanical weeder at 60 DAS (T_7) and One Hoeing at 15 DAS + Two Hand weeding at 30 and 45 DAS (T_1). Among the weed control treatments, the higher values of weed control efficiency was observed with treatments, weed free check, PE application of pendimethalin@ 1.0 kg/ha *fb* Pyrathiobac Sodium PoE 75 g/h at 45 DAS + one interculturing through mechanical weeder 60 DAS (T_5), Oxyfluorfen PE @ 0.1 kg/ha *fb* Pyrathiobac Sodium PoE @ 75 g/ha at 45 DAS + One interculturing through mechanical weeder at 60 DAS (T_7) and One Hoeing at 15 DAS + Two Hand weeding at 30 and 45 DAS (T_1), Hiramath *et al*. (2013) also reported the similar findings. The important growth attributes *viz.,*plant height, number of sympodial branches, total dry matter accumulation/plant and important yield contributing characters *viz.,* weight of seed cotton/plant, weight of lint/plant and seed cotton, lint and stalk yield (t/ha) were significantly higher in the treatment weed free check and it was at par with treatments PE application of pendimethalin@ 1.0 kg/ha *fb* Pyrathiobac Sodium PoE 75 g/ha at 45 DAS + one interculturing through mechanical weeder 60 DAS (T_5), Oxyfluorfen PE @ 0.1 kg/ha *fb* Pyrathiobac Sodium PoE @ 75 g/ha at 45 DAS +One interculturing through mechanical weeder at 60 DAS (T_7) and One Hoeing at 15 DAS + Two Hand weeding at 30 and 45 DAS (T_1).

CONCLUSION

Thus, it can be concluded that for effective weed control and higher monetary benefits, integrated weed management with PE application of oxyfluorfen@ 0.1 kg/ha *fb* Pyrathiobac Sodium PoE @ 75 g/ha at 45 DAS + One interculturing through mechanical weeder at 60 DAS could be better option where labour availability is a severe problem.

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Weed management in soybean-wheat cropping system under conservation agriculture

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Conservation agriculture is an advanced agronomic tool of growing crops with least disturbance to the soil,thus avoiding frequent tillage which isprimarily done for seed bed preparation and weed control. Conservation agriculture systems is being promoted due to its potential to conserve, improve and make efficient use of resources like soil, water and nutrients besides energy savings and environmental benefits (Karunakaran *et al*., 2015). Farmers can save up to 40% of time, labour and fuel in conservation agriculture besides reducing soil erosion, increasing soil moisture conservation, lowering surface run-off of herbicides and fertilizers, and improving profits as compared to conventional agriculture. In traditional agriculture weeds are controlled by manual weeding; but manual labour employed for weeding is gradually becoming scarce and expensive due to rapid urbanization and industrialization besides being tedious and time consuming. The proportion of economically active population engaged in agriculture decreased from 64% in 1990 to 57% in 2005. Herbicides use is expected to be increased for control of weeds in conservation agriculture, but there is hardly any herbicide that can control different kinds of weeds. Weeds present before sowing of crop needs to be killed or controlled by using non-selective herbicides like glyphosate or paraquat. Due to presence of crop residue, pre-emergence herbicides alone may not work effectively in conservation agriculture, as they may intercept a considerable amount of soil-active herbicides. Soybean-wheat cropping system is one of the most prominent systemssuitable for conservation agriculture being practiced in large area by the farmers in Madhya Pradesh. The information on weed management aspects for soybean-wheat cropping system under conservation agriculture is lacking and hencethe experiment was conducted to develop a strategy for effective weed management through judicious use of effective herbicides either alone or in combinations to increase the productivity and sustainability of soybean-wheat production which in turn will also ensure that herbicide use remains profitable and environmentally sound over a long period of time under conservation agriculture.

METHODOLOGY

Field experiments were conducted with soybean-wheat cropping system under conservation agriculture (no till) systems in Vertisols of Central India during 2014and 2015at the Research Farm of ICAR-Indian Institute of Soil Science, Bhopal, Madhya Pradesh. The soil of the experimental field was clayey in texture with low in available nitrogen (266 kg/ha) and high in available phosphorus (27.34 kg/ha) and potassium (524 kg/ha). The experiment was laid out in randomized block design with seven treatments replicated thrice under no till conditions. A uniform application of Glyphosate @ 1000 g a.i./ ha has been applied in all the treatments for the control of emerged weeds within 48 hours after sowing of cropsin all the treatments except in control and hand weeding treatments during both the seasons. Soybean variety JS-335 was sown in the experimental field at a row spacing of 30 cmduring the last week of June, 2014 and 2015 with the help of zero seed cum fertilizer drill. Recommended rate of fertilizer (30kg N+60kg P_2O_5 +40 kg K_2O/ha) has been applied uniformly. Wheat variety C-306 was sown in the experimental field at a row spacing of 22.5 cm during the second week of October, 2014-15 and 2015-16 with the help of zero seed cum fertilizer drill. Recommended rate of fertilizer (100 kg N+60 kg P_2O_5 +40 kg K_2O/ha) has been applied uniformly.

RESULTS

The major weed flora in soybean comprised of *Echinochloa crusgalli, Panicum javanicum* and *Brachiaria recemosa* among grassy weeds whereas *Digera arvensis, Alternanthera sessilis, Celosia argentea, Cesulia axilaris, Cynotis ciliaris and Euphorbia geniculata* among the dominant broad leaved weeds.While in wheat comprised of*Digitaria sanguinalis*, *Launaea procumbens*, *Tridax procumbens*, *Phyllanthus niruri*, *Dichanthium annulatum*, *Convolvulus arvensis* and *Alternenthera sessilis* in the experimental field.Among different treatments significant response of herbicides in terms of suppression in weed population and weed biomass has been recorded as compared to control.

Maximum weed density 268m^{-2} and weed dry weight (2.0t/ha) was recorded under control while lowest number of weeds 98.22m^{-2} was recorded under post emergence application of imazethapyr @ 100 g a.i./ha at 20 DAS, while the lowest weed biomass (0.05t/ha) and maximum weed control efficiency (97.34%), was recorded under hand weeding treatment.Among herbicidal weed management treatments lowest weed biomass (0.23t/ha) and highest weed control efficiency (88.10%), was recorded under.pre emergence application of pendimethalin @ 1000 g a.i./ha followed bypost emergence application of imazethpyr @ 100 g a.i./ha at 30 days after sowing (Table 1).In case of wheat,maximum weed density (177.33/m^2) was recorded under control while lowest weed density (21.73/m^2), weed biomass (0.20t/ha) and maximum weed control efficiency (88.88%), was recorded under hand weeding treatment. Among herbicidal weed management treatments lowest weed density (24.03/m^2),weed biomass (0.23t/ha) and highest weed control efficiency (87.22%) was recorded withpost emergence application of mesosulfuron 4 g a.i./ ha+ idosulfuron 400 g a.i./ha at 20 days after sowing treatment (Table 2). Significant response of various herbicidal treatments on yield attributeswas recorded as compared to control. Maximum biological yield (4.13t/ha) and seed yield (1.41t/ha) was recorded under hand weeding treatment which was at par with pre emergence application of pendimethalin @ 1000 g a.i./ha followed bypost emergence application of imazethapyr @ 100 g a.i./ ha at 30 days after sowing (3.90t/haand 1.31t/ha) and lowest weed index (6.95%) Table 1. Similarly maximum biological yield (9.54t/ha), grain yield (3.76t/ha) was recorded under hand weeding, which was at par with post emergence application of mesosulfuron + idosulfuron 400 g/ha at 20 days after sowing with 9.34t/ha biological yield, 3.68 t/hagra in yield and lowest weed index (2.15%) table 2.

CONCLUSION

Weeds can be effectively managed under conservation agriculture systems through application of herbicides in proper

Table 1. Effect of different weed management treatments on yieldand weed parameters of soybean (Pooled data)

Treatment	Weed density/m^2	Weed Biomass (t/ha)	WCE (Weed biomass) (%)	Biological yield (t/ha)	Seed yield (t/ha)	Weed index (%)
Absolute control	268.00	2.0	0.00	1.23	0.42	69.93
Two hand weeding at 20 & 40 DAS	118.22	0.05	97.34	4.13	1.41	0.00
Pre em. Pendimethalin @ 1000 g a.i./ha.	123.11	0.26	86.96	3.02	1.03	26.74
PoE Propaquizafop @ 100 g a.i./ha + Chlorimuron ethyl @ 9 g a.i./ha at 20 DAS	129.88	0.33	83.32	2.75	0.98	30.57
PoE Imazethpyr @ 100 g a.i./ha at 20 DAS.	98.22	0.38	81.06	3.55	1.24	12.06
Pre em. Pendimethalin @ 1000 g a.i./ha *Fb* PoE Imazethpyr @ 100 g a.i./ha at 30 DAS	141.11	0.23	88.10	3.90	1.31	6.95
PoE Propaquizafop @100 g a.i./ha + Chlorimuron ethyl @ 9 g a.i./ha at 20 DAS	116.67	0.24	87.78	3.88	1.31	7.30
CD (P=0.05)	17.85	0.061		0.42	0.22	

Table 2. Effect of different weed management treatments on yieldand weed parameters of wheat (Pooled data)

Treatment	Weed density/m^2	Weed Biomass (t/ha)	WCE (Weed biomass) (%)	Biological yield (t/ha)	Seed yield (t/ha)	Weed index (%)
Absolute control	177.33	1.81	0.00	5.39	2.08	44.76
Two hand weeding at 20 & 40 DAS	21.73	0.20	88.88	9.54	3.76	0.00
Pre em. Pendimethalin @ 1000 g a.i. /ha.	32.67	0.34	81.25	8.72	3.43	8.83
PoE Metsulfuron 4 g a.i./ha + Clodinafop propargyl 60 g a.i./ha at 30 DAS	32.00	0.32	81.98	7.79	3.05	18.99
PoE Mesosulfuron 4 gai/ha + Idosulfuron 400 g a.i./ha at 20 DAS.	24.03	0.23	87.22	9.34	3.68	2.15
Pre em. Pendimethalin @ 750g a.i./ha 2,4-D amine salt @ 1000 g a.i./ha at 30 DAS	25.61	0.24	86.39	8.36	3.28	12.82
Pre em. Pendimethalin @ 750 g a.i./ha *Fb* PoE Metsulfuron 4 g a.i. /ha at 30 DAS	29.73	0.29	83.60	8.04	3.14	16.41
CD (P=0.05)	11.59	0.074		0.815	0.599	

combination at desired rate of application at right time. The present study concluded that insoybean-wheatcropping systembased conservation agriculture weeds can be managed in soybean withpre emergence application of pendimethalin @ 1000 g a.i./ha followed bypost emergence application of imazethpyr @ 100 g a.i./ha at 30 days after sowing for effective weed management and crop productivity and in wheat, weeds can be managed with post emergence application of mesosulfuron + idosulfuron 400 g/ ha at 20 days after sowing. The above treatments were also proved to be economically beneficial.

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Chemical weed management in baby corn (*Zea mays* L.)

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Maize used as a vegetable is known as "baby corn". Baby corn is the young, finger-length fresh maize ear harvested within 2 or 3 days of silk emergence but prior to fertilization.Hundred gram of baby corn contains 89.1 per cent moisture, 0.2 g fat, 1.9 g protein, 8.2 mg carbohydrate, 0.06 g ash, 28.0 mg calcium, 86.0 mg phosphorus and 11.0 mg of ascorbic acid. Baby corn (*Zea mays* L.) cultivation provides tremendous avenues for crop diversification, crop intensification, value addition and revenue generation. Being relatively a new introduction to the domain of study. Manual weeding though very effective in controlling weeds, very often is cumbersome, labour intensive, expensive and time consuming. With the advancement in technology, number of herbicides is now available which can be used effectively and economically. Many herbicides were found effective for controlling weeds in common maize.

METHODOLOGY

Afield experiment was conducted during *kharif,* 2014at IFS farm, Main Agricultural Research Station (MARS), Raichur. The soil of the experimental site was deep black soil with pH of 8.10, 246 kg/ha available N, 35kg/ha available P_2O_5 and 295 kg/ha available K_2O. The experiment was laid out Randomised Block Design with three replications and eleven treatments.The baby corn genotype used was "CPB-472" which is a hybrid. The special character of the genotype is that it doesn't require detasselling. The crop was sown on 10/07/2014 with a spacing of 45 cm x 20 cm and first harvest was done on 04/09/2014 and subsequent harvesting of baby corn was carried out up to a week on alternate days. The study involves the application of atrazine 50 WP @ 1.0 kg a.i./ha as PRE application, alachlor 50 EC @ 1.0 kg a.i./ha as PRE application and pendimethalin38.7 CS @ 1.0kg a.i./ha as PRE application and combination of these three herbicides as PRE application and followed by 2, 4-D as post emergence application at 25 DAS.

RESULTS

The results showed that significantly higher weed control efficiency (82.54%) was recorded in atrazine 50 WP @ 0.5 kg a.i./ha + pendimethalin38.7 CS @ 0.5kg a.i./ha as PRE application and was followed by atrazine 50 WP @ 1.0 kg a.i./ha as PRE application fb 2, 4-D Sodium salt 80 WP @ 1.0 kg a.i./ha as POE application at 25 DAS (79.28%) and it was on par with atrazine 50 WP @ 1.0 kg a.i./ha as PRE application (77.05%) This might be due to the combination of both the chemicals which were found to be more effective in suppressing the weed density as well as weed dry matter. The highest green cob yield and stalk yield (11.91 t and30.59 t/ha, respectively) were recorded in weed free check and atrazine 50 WP @ 0.5 kg a.i./ha + pendimethalin38.7 CS @ 0.5kg a.i./ha as PRE application (10.98 t/ha and 28.83 t/ha, respectively) was on par with it. Weedy check recorded significantly lower green cob yield (6.31 t/ha) due to severe weed competition

Table 1. Weed control efficiency (WCE), yield and economicsin baby cornas influenced by chemical weed management

Tr. No.	Treatment	WCE (%)	Green cob yield(t/ha)	Green Stalk yield (t/ha)	Gross returns (Rs/ha)	Net returns (Rs/ha)	BC ratio
T_1	Atrazine 50 WP @ 1.0 kg a.i. /ha as PRE application	77.0	9.77	27.53	1,74,124	1,30,845	4.02
T_2	Alachlor 50 EC @ 1.0 kg a.i. /ha as PRE application	47.0	7.99	24.54	1,44,329	1,01,530	3.37
T_3	Pendimethalin38.7 CS @ 1.0kg a.i. /ha as PRE application	68.8	8.91	26.45	1,60,037	1,16,247	3.65
T_4	Atrazine 50 WP @ 0.5 kg a.i/. ha + alachlor 50 EC@ 0.5 kg a.i. /haas PRE application	63.0	8.59	26.04	1,54,849	1,11,810	3.60
T_5	Atrazine 50 WP @ 0.5 kg a.i. /ha + pendimethalin38.7 CS @ 0.5kg a.i /ha as PRE application	82.5	10.98	28.83	1,93,497	1,49,963	4.44
T_6	Alachlor 50 EC @ 0.5 kg a.i./ha + pendimethalin38.7 CS @ 0.5kg a.i. /ha as PRE application	61.2	8.44	25.72	1,52,317	1,09,022	3.52
T_7	Atrazine 50 WP @ 1.0 kg a.i. /ha as PRE application fb DAS 2, 4-D Sodium salt 80 WP @ 1.0 kg a.i. /ha as POE application at 25	79.2	10.34	27.93	1,83,008	1,38,829	4.14
T_8	Alachlor 50 EC @ 1.0 kg a.i. /ha as PRE application fb 2,4-D Sodium salt 80 WP @ 1.0 kg a.i. /ha as POE application at 25 DAS	54.8	8.29	25.29	1,49,583	1,05,884	3.42
T_9	Pendimethalin38.7 CS @ 1.0kg a.i. /ha as PRE application fb 2, 4-D Sodium salt 80 WP @ 1.0 kg a.i. /ha as POE application at 25 DAS	9.24 70.4	27.08	1,65,608	1,20,918	3.71	
T_{10}	Weed free check	100.0	11.91	30.59	2,09,164	1,55,145	3.87
T_{11}	Weedy check	0.00	6.31	22.16	1,16,881	74,862	2.78
	S.Em.±	0.90	0.32	0.79	-	5,081	0.11
	C.D. at 5%	2.65	0.95	2.33	-	14,988	0.33

WP: Wettable Powder;EC: Emulsifiable Concentrate; CS: Capsular Suspension;fb: followed by; DAS: Days after sowing ; PRE: Pre-emergence; POE :Post-emergence;*Figures in parenthesesindicate original values; Total weed count (x) data were transformed to $(x+0.5)^{1/2}$

with baby corn which resulted in stunted growth and lower yield. Weed free check recorded higher gross returns (Rs 2,09,164/ha) and it was followed by atrazine 50 WP @ 0.5 kg a.i./ha + pendimethalin 38.7 CS @ 0.5kg a.i./ha as PRE application, atrazine 50 WP @ 1.0 kg a.i./ha as PRE application fb 2, 4-D Sodium salt 80 WP @ 1.0 kg a.i./ha as POE application at 25 DAS. While, lower gross returns was recorded in weedy check (Rs 1,16,881/ha). Significantly higher net returns (Rs1,55,145/ha) was recorded in weed free check which was on par with atrazine 50 WP @ 0.5 kg a.i./ha + pendimethalin 38.7 CS @ 0.5kg a.i./ha as PRE application. Significantly a lower (Rs74,862/ha) net return was recorded in weedy check (T_{11}). Benefit cost ratio was significantly higher in atrazine 50 WP @ 0.5 kg a.i./ha + pendimethalin38.7 CS @ 0.5kg a.i./ha as PRE application (4.44) and it was on par with atrazine 50 WP @ 1.0 kg a.i./ha as PRE application fb 2, 4-D Sodium salt 80 WP @ 1.0 kg a.i./ha as POE application at 25 DAS. The lowest B:C ratio was recorded in weedy check (2.78) and among herbicide treatments alachlor 50 EC @ 1.0 kg a.i./ha as PRE application (T_2) recorded lower B:C ratio.

CONCLUSION

Tank mix application of atrazine 50 WP @ 0.5 kg a.i./ha + pendimethalin38.7 CS @ 0.5kg a.i./ha as PRE application was found to be best treatment for effective control of weeds, yield and economics. The next best treatment was atrazine 50 WP @ 1.0 kg a.i./ha as PRE application fb 2, 4-D Sodium salt 80 WP @ 1.0 kg a.i./ha as POE application at 25 DAS.

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Building lasting impacts for beating terminal heat stress through early wheat sowing in Eastern Indo-Gangetic plain of India

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Late planting in December cause a reduction in wheat yield potential by approximately 50% due to terminal heat and reduced growing season duration.For wheat, having a rice crop grown under puddled soil conditions prior to wheat planting creates many issues affecting the timely planting of the wheat crop. If planting is delayed beyond mid- to late-November wheat yields decline about 1 to 1.5% per days' delay after this optimal date. (Ortiz-Monasterio *et al.,* 1994). Based on diagnostic surveys of farmers done in the region a number of reasons were hypothesized for this planting delay in wheat sowing (Byerlee, *et al*., 1989). The existing recommendations based on short duration varieties to manage temperature extremes fall way short of expectations on realizing the productivity growth potential of cereal based cropping systems in South Asia. Time has come for a new crop management based approach to address this issue. Early wheat sowing and zero tillage are powerful tools to manage terminal heat in EIGP.

METHODOLOGY

The study was conducted for three consecutive years (2011-12 to 2013-14) under Rice-Wheat (RW) system in EIGP of India. The study area covered Bihar and Eastern UP hubs to cover different wheat ecologies of CSISA project. Farmers participatory trials were conducted across CSISA sites (Fig. 1) .The soils of the study sites are alluvial sandy loam to clay in texture and are neutral to alkaline in reaction. Zero tillage (ZT) and conventional tillage (CT) methods were used at most sites.

RESULTS

In 2009, only four farmers in Eastern UP agreed to sow their wheat early. Encouraged by early success, albeit with a small footprint of CSISA steadily increase the area under early sowing. To place these on-farm grain yields in context, the average productivity in CSISA's working domain is around 2 t/ha and those achieved in Punjab (the prime wheat basket of India) average 4.5 t/ha. Our data 1582 plots averaged for three years show clear evidence of gains in grain yield from early sowing (Fig. 2 and 3) and that also when done with zero tillage. In 2012 and 2013, we further mainstreamed our approach

Fig. 1. Trial Locations in EUP and Bihar

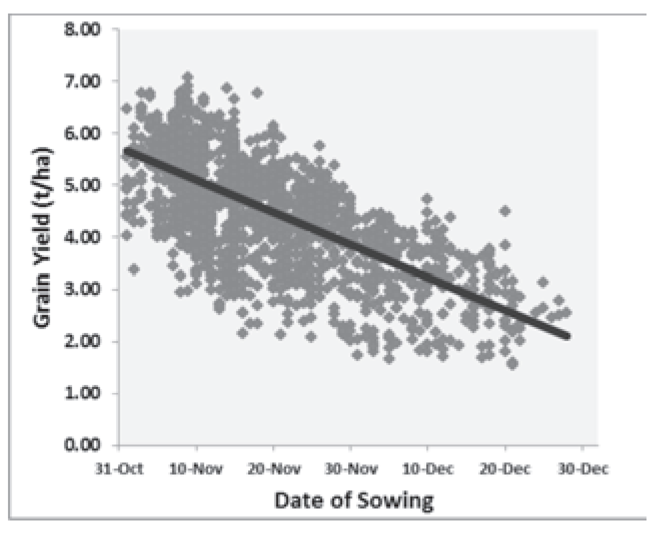

Fig. 2. Three years crop-cut data (n=1582) from CSISA hubs

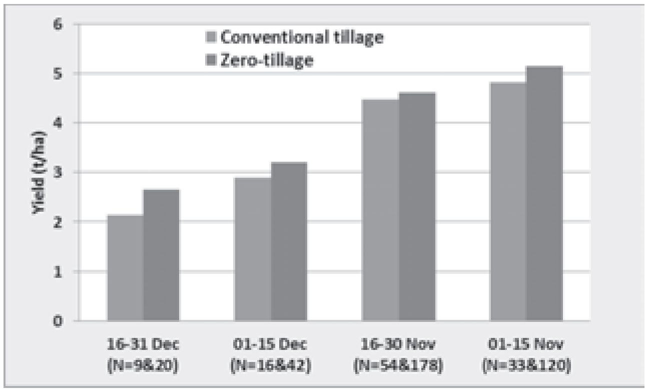

Fig. 3. Crop-cut data from CSISA hubs during 2013-14

by joining the DOA's pre-season planning meetings, where extension workers developed their action plans for the following wheat season—an approach that permitted CSISA to gain significant spill over effects beyond our immediate working areas. Based on recent surveys conducted by CSISA, approximately 0.34 million farmers in Bihar and 0.28 million in EUP hub domains have adopted early sowing. More recently, this is increasing being done through zero tillage though service providers (SPs) created by CSISA and its partners.

CONCLUSION

Data show that it is the early wheat sowing which will solve the problem of terminal heat and the early sowing can best be done by zero tillage.

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Evaluation of different pre and post emergence herbicides against weeds in direct seeded rice

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Direct seeded rice is an emerging production technology in India due to less requirement of water, labour and capital input initially. But direct seeded rice has problem of severe weed infestation (Chauhan, 2012). Success of DSR depends largely on weed control especially with chemical methods as mechanical weed control is labour intensive and not cost effective. Various herbicides have been used for controlling weeds in DSR but efficiency of chemical methods based on single herbicide treatment may be unsatisfactory because of their narrow spectrum of weed control. Therefore, application of several herbicides in combination or in sequence can be more useful (Chauhan and Yadav, 2013).

METHODOLOGY

The study was conducted during the *kharif* 2012 at Students' Farm of College of Agriculture, CCS Haryana Agricultural University; campus Kaul (Kaithal) with 14 treatments and replicated thrice (Table 1). Rice variety PUSA 1121 was seeded on 19th June 2012 in rows 22.5 cm apart using seed drill. Weed density (no. /m^2) were recorded species wise in each plot using quadrate of 50 cm × 50 cm (0.25 m^2) from the area selected randomly for observations

RESULTS

Weed flora of the experimental field was mainly dominated by *Cyperus difformis, Cyperus rotundus, Leptochloa chinensis, Echinochloa glabrescens, Eclipta alba* and *Ammania* spp.All the treatments recorded significant reduction in the density of weeds compared to weedy check. Sequential application of pendimethalin 1000 g/ha *fb*bispyribac sodium 25 g/ha and metsulfuron methyl + chlorimuron ethyl 4 g/ha gave minimum density of *Echinochloa glabrescens*, *Cyperus* spp. and *Ammania* spp. among all herbicidal treatments. However, the minimum density of *Leptochloa*

Table 1. Effect of different weed control treatments on weed density at 75 DAS, yield attributes and grain yield in direct seeded rice

Treatment	Dose g/ha	Time DAS	Effective tillers/m^2	No. of filled grains/ panicle	Grain yield (t/ha)
Pendimethalin *fb* bispyribac-Na	1000 *fb* 25	3 *fb* 25	184.5	79.7	3.57
Pendimethalin *fb* bispyribac-Na +ethoxysulfuron	1000 *fb* 25 +18.75	3 *fb* 25	206.7	82.0	3.83
Pendimethalin *fb* bispyribac-Na +metsulfuronmethyl + chlorimuron ethyl	3 *fb* 25 1000 *fb* 25 +4	209.3	83.7	3.97	
Pendimethalin *fb* fenoxaprop	1000 *fb* 67	3 *fb* 25	180.0	79.3	3.57
Pendimethalin *fb* fenoxaprop +ethxysulfuron	1000 *fb* 67 + 18.75	3 *fb* 25	193.3	82.3	3.71
Pendimethalin *fb* fenoxaprop + metsulfuron methyl + chlorimuron ethyl	3 *fb* 25 1000 *fb* 67 + 4	198.7	83.3	3.77	
Oxadiargyl *fb* bispyribac-Na	100 *fb* 25	3 *fb* 25	174.7	76.3	2.93
Oxadiargyl *fb* bispyribac-Na +ethoxysulfuron	100 *fb* 25 + 18.75	3 *fb* 25	182.3	77.7	3.25
Oxadiargyl *fb* bispyribac-Na + metsulfuron methyl + chlorimuron ethyl	100 *fb* 25 + 4	3 *fb* 25	188.3	79.3	3.47
Oxadiargyl *fb* fenoxaprop	100 *fb* 67	3 *fb* 25	165.3	77.0	2.77
Oxadiargyl *fb* fenoxaprop+ ethoxysulfuron	100 *fb* 67 + 18.75	3 *fb*25	166.7	73.3	2.87
Oxadiargyl *fb* fenoxaprop + metsulfuron methyl + chlorimuron ethyl	100 *fb* 67 + 4	3 *fb* 25	168.0	74.7	2.94
Weed free			210.7	85.3	4.12
Weedy check			97.3	71.7	1.52
CD (P=0.05)			20.0	4.7	0.43

chinensis was reported with herbicidal combination of pendimethalin 1000 g/ha as pre emergence *fb* fenoxaprop 67 g/ha. This may be due to more effectiveness of fenoxaprop 67 g/ha to control *Leptochloa chinensis*. All the treatments produced significantly higher number of effective tillers than weedy check (Table 1). Weed free treatment recorded highest number of effective tillers (210), number of filled grains/ panicle (85.3) and grain yield (4.12 t/ha) being at par with sequential application of pendimethalin 1000 g/ha *fb*bispyribac sodium 25 g/ha and metsulfuron methyl + chlorimuron ethyl 4 g/ha.

CONCLUSION

Sequential application of pendimethalin 1000 g/ha *fb* post emergence application of bispyribac sodium 25 g/ha and metsulfuron methyl + chlorimuron ethyl 4 g/ha produced lowest weed density at 75 DAS among all herbicidal treatments. This treatment also recorded highest number of effective tillers, filled grains and grain yield as compared to all other herbicidal treatments.

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Herbicide x location analysis by AMMI to stratify the weed control treatments in barley trials

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Barley (*Hordeum vulgare* L.) can be utilized as a source of green fodder in rainfed, arid to semiarid conditions where other like berseem, oats, sugarcane etc. cannot be grown due to water shortage. The crop had shown advantageous over oats due its dual utilization as grain crop for human consumption and as fodder for animal feed. Weed control is an essential part of all crop produc-tion systems. Weeds reduce yields of cultivated barley crops by competing for water, nutrients, and sunlight, and may lower crop quality, and producing chemicals which are harm-ful to crop plants. Effective weed control and preven-tion of weed seed production in fellow plots will reduce the risk of weed problems in barley. Large number of studies based on multi-environment trials had compared the widely used AMMI analyses. AMMI model was found as the best model to describe the GEI in maize. The objectives were to study (i) stratification of weed control strategies for effective control (ii) use of AMMI biplots to narrow down better-adapted treatments based on significant principal component scores.

METHODOLOGY

Eleven treatments of pinoxaden and isoproturan in combination with metsulfuron /2,4 D or alone were evaluated to control grasses and broad leaves weeds under the All India coordinated wheat and barley improvement programme at six locations. The experiments were conducted during the crop year 2014-15 at locations viz: Karnal, Ludhiana, Hisar, Durgapura, Bajora and Malan. The randomized complete block design employed, with three replications. All the cultural practices were carried out as per zone recommendations to harvest good yield. AMMI analysis was carried out by Genstat software version 17.1 (VSN International). The AMMI distance statistic coefficient (D) was calculated based on the distances of the interaction principal component (IPC) point from the origin in space. AMMI Distance (D_i)=

$$\sqrt{\sum_{i=1}^{n}\gamma_{is}^{2}} \quad (\text{ i= 1,2,3,.. n})$$

AMMI stability value (ASV) based on IPC1 and IPC2 scores defined as

AMMI Stability Value (ASV) =

$$\sqrt{\left[\frac{SSIPCA1}{SSIPCA2} * \text{IPCA1 score}\right]^2 + \text{IPCA2 score}^2}$$

where SSIPCA1 and SSIPCA2 are sum of squares by the IPCA1, IPCA2 respectively. The genotypes with the lowest ASV value would be more stable.

Sum of IPC scores (SIPC) proposed as:

SIPC = $\sum_{n=1}^{N} \gamma_{in} \lambda_n^{0.5}$

where g_{in} is the genotype eigen value for axis n and λ_n is the eigen value of the IPC analysis axis n

RESULTS

The AMMI analysis of variance showed highly significant ($P<0.01$) environmental effects explained 81.1% of the total sum of squares, H x E interaction contributed 7.9% and 4% to herbicides effects. Highly significant HxE interaction necessitates the further investigation. HxE interaction was further divided into four interaction principal component analysis axis (IPCA). First two IPCA1and IPCA2 explained 39.7% and 32.4% of the variability relating to HxE interaction and jointly accounted for 72% of the interaction sum of squares.

T1	T2	T3	T4	T5	T6
Pinoxadan 30g	Pinoxadan 40g	Pinoxadan 50g	Pinoxadan 40g + Metsulfuron 4g	Pinoxadan 40g followed by metsulfuron 4g	Pinoxadan 40g + Carfentrazone 20g
T7	T8	T9	T10	T11	
Isoproturon 1000g	Isoproturon 750g + 2,4-D 500g	Isoproturon 750g + metsulfuron 4g	Weedy check	Weed free	

Table 1. AMMI analysis of durum genotypes over locations

Source	Degree of freedom	Sum of squares	Variance ratio	% TSS	% GxE
Treatments	65	23424	30.73**	93.0	
Herbicides	10	1010	8.61**	4.0	
Environments	5	20425	135.51**	81.1	
Block	12	362			
Interactions	50	1990	3.39**	7.9	
IPCA 1	14	791	4.82**		39.7
IPCA 2	12	645	4.58**		32.4
IPCA 3	10	411	3.5**		20.7
IPCA 4	8	123	1.31		6.2
Residuals	6	21	0.29		
Error	120	1407			
Total	197	25193			

** denotes significance at 1% level of significance; %TSS: percentage of total sum of squares, % GxE: percentage of GxE total sum of squares

Table 2. AMMI and derived estimates of weed control treatments

Treatment	Tm	IPCA[1]	IPCA[2]	IPCA[3]	IPCA[4]	ASV	D	SIPC4
T1	36.37	0.270	-0.487	-2.313	-0.246	0.59	2.39	-2.77
T2	38.67	0.415	0.272	-0.784	-0.132	0.58	0.94	-0.23
T3	39.07	0.553	0.066	-1.057	0.164	0.68	1.21	-0.27
T4	40.29	-2.462	1.482	0.154	0.345	3.36	2.90	-0.48
T5	41.72	-0.737	-1.483	0.429	0.201	1.74	1.72	-1.59
T6	40.66	1.105	-0.147	-0.151	-1.008	1.36	1.51	-0.20
T7	38.92	-0.098	1.800	0.387	-0.687	1.80	1.97	1.40
T8	42.9	0.422	-0.635	1.780	-1.296	0.82	2.33	0.27
T9	41.74	-1.705	-0.155	0.130	0.309	2.10	1.75	-1.42
T10	35.76	2.182	1.375	0.858	1.419	3.01	3.07	5.83
T11	42.54	0.056	-2.089	0.565	0.931	2.09	2.36	-0.54

Tm - Mean Yield , ASV- AMMI Stability Value , D- AMMI Distance , SIPC4 – Sum of 4 IPC

ASV

AMMI distance

The index 'D' incorporates the scores of significant IPCA towards the interaction SS (Zhang et al 1998) and the lower D values indicate stable performance across the tested environments and vice versa. Ranking of treatments in ascending order of 'D' values was those in T2 (0.94) < T3 (1.21) < T6(1.51). Treatment T10 with lowest barley yield exhibited largest D values 3.07.

SIPC4

The values of the SIPC4 parameter could be useful in identifying treatments expressing stable performance (Mohammadi *et al.*, 2015) and so T1, T5 and T9 were the stable performer whereas T10 was the unstable treatment. Interesting to observe the stable treatments T9 and T5 had higher average barley yield.

AMMI BIPLOT ANALYSIS

AMMI biplot analysis considers the average effects of herbicides and locations on the abscissa and IPCA1 scores of both effects, simultaneously on the ordinate (Figure 1). Treatments T7,T11, T2 and T3 with IPCA1 scores close to zero have small interactions and would be widely adaptation to the tested environments. The high yielder environments Ludhiana and Durgapura observed in quadrant-III, with maximum interaction effects, positive IPCA1 scores. Another potential environment Bajura was in quadrant- II, with negative IPCA1 and higher yield. Malan environment showed lower yield with negative IPCA1.The environments Ludhiana, Malan and Bajura were most discriminating as indicated by long distance from the biplot origin (Oliveira *et al*., 2014). Treatments 6,8,11 with positive IPCA1 responded positively (adaptable) to the environments Ludhiana, and Durgapura that had IPCA1 scores > 0 (positive interaction), but responded negatively to Malan and Bajura with negative IPCA1 values IPCA scores were plotted in the x-axis and the y-axis respectively (Figure 2). T2, T3, T6, T1 and T8 located near to the origin as compared to T10, T7, T4 and T11 located distant from the origin. The positive correlation observed between environments (Karnal, Durgapura and Hissar) as per acute angles within respective environments; pair of environments are not correlated (Malan, Karnal), (Bajura, Ludhiana) as approx right angles between them.

CONCLUSION

AMMI analysis has been observed useful to detect significant HxE interaction for weed control treatments for barley trials under multi-location trials. Highly significant environmental and H x E interaction necessitated further analysis. ASV mentioned treatments T2 and T1 with stable performance as compared to T4 and T10. AMMI distance ranked treatments as T2 < T3 < T6. AMMI biplot observed treatments T7,T11, T2 and T3 would be widely adaptation to the tested environments. Positive correlation between Karnal, Durgapura and Hisar expressed by acute angles whereas pair of uncorrelated environments (Malan, Karnal), (Bajura, Ludhiana) with right angles.

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Moisture stress mitigation strategies for clusterbean (*Cyamopsis tetragonoloba*) under rainfed conditions

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Clusterbean locally known as guar is an important multipurpose leguminous *kharif* crop of arid and semiarid regions of India. Due to tap root system it is a drought tolerant crop. It is mostly grown on light textured soils with poor moisture retention capacity, deficient in nutrients like N, Zn, S and Fe; and low to medium in P & K. In India, Haryana and Rajasthan (contributing about 95% of total clusterbean area of the country) have around 52 and 85 % area under clusterbean as rainfed, respectively. Thus the crop suffers from moisture stress either at vegetative or reproductive stage of crop growth which may cause hindrance in absorption and translocation of nutrients particularly N, P, K and S by the plants, thereby resulting into forced maturity and ultimately low productivity as compared to potential of newly released high yielding varieties of clusterbean. Hence, in rainfed clusterbean, if N, P, K and S supply is managed through seed priming and foliar application of agro-chemicals like thiourea (37% N and 42% S), potassium nitrate (13% N and 45% K_2O) and NPK fertilizer (20% N, P_2O_5 and K_2O each), the yield losses can be avoided. Therefore, the present investigation was carried out to evaluate the effectiveness of different agrochemicals in relation to productivity and economic viability of rainfed clusterbean.

METHODOLOGY

A field experiment was conducted during *kharif* season of 2015 in aridisols at Chaudhary Charan Singh Haryana Agricultural University, Regional Research Station, Bawal (Rewari), India. The location has a typical semi-arid climate. The soils of the experimental field classified as a Typic Ustochrept were loamy sand in texture, slightly alkaline in reaction (pH 8.01), low in organic carbon (0.18 %), available nitrogen (165 kg N/ha) and phosphorus (8.34 kg P/ha); and medium in available potash (164 kg K/ha). The mean annual rainfall is low (300-550 mm) and most of it (above 80 %) is received in rainy season (July to September) which is also unpredictable, inadequate and erratic in nature.

RESULTS

Foliar spray of 1% NPK (20:20:20) fertilizer at pod formation stage super imposed over recommended package of practices (RP) recorded highest seed yield (1.22 t /ha) followed by RP + seed soaking in thiourea solution (500 ppm) for 30 minutes + foliar spray of thiourea (500 ppm) at pod formation stage (1.20 t/ha) which were higher to the tune of 19.6 and 17.6%, respectively than that recorded under RP i.e. control (1.02 t/ha). Foliar spray of 1% NPK fertilizer (20:20:20) at pod formation stage super imposed over RP and treatment RP + seed soaking in thiourea solution (500 ppm) for 30 minutes + foliar spray of thiourea (500 ppm) at pod formation stage fetched net returns of Rs. 10208 and 9517/ha (Rs. 6446 and 5755 /ha more than control) and benefit: cost ratio of 1.30 and 1.27, respectively. These two treatments were found most economical over other treatments.

CONCLUSION

It is concluded that foliar application of 1% NPK fertilizer (20:20:20) at pod formation stage super imposed over recommended package of practices (RP); and RP + seed soaking in thiourea solution (500 ppm) for 30 minutes + foliar spray of thiourea (500 ppm) at pod formation stage helped clusterbean to tolerate moisture stress under rainfed conditions; increased the seed yield and net returns.

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Efficacy of bensulfuron methyl and pretilachlor against weeds in transplanted rice

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The problem of extensive weed incidence during early stages of rice crop growth can not be determined which competes with crop plants for moisture, nutrients, light, space and other growth factors. This crop competition leads to significant yield losses to the tune of 35-55% in transplanted rice (Gautam and Mishra, 1995). Traditionally weed control in rice is done by manual and mechanical means which are most effective and common methods but they are tedious, costly, time taking and are difficult due to continuous rains during *kharif* season. Besides, adequate laborious are also not available during critical period of crop weed competition.

METHODOLOGY

The present investigation was conducted at the Krishi Nagar Farm, Department of Agronomy, JNKVV, Jabalpur during *kharif* 2015.The soil of the experimental field was sandy clay loam in texture, medium in organic carbon and available nitrogen, Phosphorus and potassium content and neutral in soil reaction. The experiment was laid out in randomized block design with seven weed control treatments comprising of Bensulfuron methyl + Pretilachlor @ (48+480), (60+600) and (72+720) g a.i./ha as pre-emergence, Pendimethalin @1300 g a.i./ha, Butachlor @1500 g a.i./ha, hand weeding twice at 20 and 40 DAT and weedy check replicated four times.Seedlings of rice variety JRH-5 were raised in nursery and transplanted in main field on 14rd July 2015 after its thorough puddling and leveling.

RESULTS

The data was recorded on density and dry weight of weeds and the comparison in the treatment means were done on transformed values. There was predominance of monocot (*Cyperus difformis*, *Cyperus iria* and *Echinochloa colona)* and broad leaved (*Ludwigia perennis* , *Eclipta alba* and *Monochoria vaginalis*) weeds in the experimental field. Among the weeds *Cyperus difformis*followed by *Cyperus iria* were more rampant (47.83 and 22.43 % at 30 DAT and 29.50 and 26.65 at harvest) due to their continuous regrowth during the crop season. Grain and straw yields were significantly higher under all the weed control treatments over weedy check plots. Application of Bensulfuron methyl + Pretilachlor @ (60+600) g a.i./ha recorded higher of grainand straw yields (5153 and 9302 kg/ha) followed by Bensulfuron methyl + Pretilachlor @ (72+720) g a.i./ha. Even though the highest yields were recorded with hand weeding twice (5889 and 9964 kg/ha). Bensulfuron methyl + Pretilachlor @ (60+600) g a.i./ha was the economically viable treatment among all the weed control treatments. The cost of cultivation was maximum under hand weeding twice owing to an additional expenditure of Rs 8000/ha on weeding, showing that control of weeds through hand weeding was more expensive than the use of herbicide in rice crop. Although the gross monetary returns

Table 1. Effect of different weed control treatments on grain yield, straw yield, harvest index and weed index

Treatment	Grain yield (kg/ha)	Straw yield (kg/ha)	Harvest index (%)	Weed index
Weedy check (Control)	2877	6254	31.51	51.15
Bensulfuron methyl + Pretilachlor (48+480) g/ha	4340	7952	35.31	26.30
Bensulfuron methyl + Pretilachlor (60+600) g/ha	5153	9302	35.65	12.50
Bensulfuron methyl + Pretilachlor (72+720) g/ha	5010	9072	35.58	14.93
Pendimethalin 1300 g/ha	3606	7499	32.47	38.76
Butachlor 1500 g/ha	3571	7560	32.09	39.35
Hand Weeding 20 and 40 DAT	5889	9964	37.15	0.00
CD (P=0.05)	230.05	107.85	-	-

was maximum in hand weeding twice among all the treatments. Whereas, the net monetary returns and B: C ratio were maximum under Bensulfuron methyl + Pretilachlor @ (60+600) g a.i. /ha (Rs 79045/ha and 3.37) as pre-emergence to rice followed by Bensulfuron methyl + Pretilachlor @ (72+720) g a.i./ha (Rs 75609/ha and 3.25).

CONCLUSION

Application of Bensulfuron methyl + Pretilachlor @ (60+600) g a.i./ha recorded higher of grainand straw yields (5153 and 9302 kg/ha).

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Economic feasibility of herbicide for weed control in wheat under eastern U.P. condition

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At the current rate of population growth (1.55%) in India, the wheat requirement by 2020 A.D. would be around 110 million tonnes. To safeguard food security in India, it is quite important to raise the productivity levels of wheat. The states of India viz. Uttar Pradesh, Punjab, Haryana, Bihar, M.P., Rajasthan, Gujarat and Maharashtra are major contributors of wheat area and production but due to infestation of weeds productivity become less and sometime complete failure of crop.Weed poses a major problem in wheat production, as they not only reduce crop yield but also impair the quality of produce. Manual weeding is common in India, but its use is decreasing because of labour scarcity at the critical time of weeding due to implementation of the Mahatma Gandhi National Rural Employment Guarantee Act, 2005 (MNREGA) introduced by the Indian Government and also due to increasing labour wages. The weeds viz. little seed canary grass and wild oat look morphologically similar upto flowering, makes hand weeding difficult. Moreover, shortage of labour, increased wages and lack of suitable weed control implements have compelled farmers to think for alternative strategies of weed management. Chemical method of weed control is an option for weed management in wheat crop. Several herbicides are now available in our country and have been reported to provide effective weed control. The choice of the right herbicide depends on major weed flora and response of weeds to various herbicides. There is a need to explore an effective herbicide for weed control of wheat crop particularly wheat based cropping system region like eastern U.P. Hence a study was carried out to keep the weeds below threshold level and assess the effect of various herbicides on growth and yield of wheat crop.

METHODOLOGY

The field experiment was conducted during *rabi* season of 2013-14 and 2014-15 at Research Farm (PiliKothi) of TilakDhariP.G. College Jaunpur to evaluate the efficacy of various herbicide on weed density and dry weight, growth and yield of crop and their economics in wheat crop. The experiment was laid out in randomised block design with three replication and 10 treatmentsviz. weedy, weed-free, hand weeding at 30 and 60 DAS, pendimethalin, isoproturon, 2,4-D, metsulfuron, sulfosulfuron, metribazin and clodinoform.

RESULTS

The experimental field was infested with weeds from all three categories viz. grasses, broadleaved and sedges. The dominant weed specie were *Partheniumhysterophorus, Chenopodium album, Convolvulus arvensis, Solanumnigrum, Anagallisarvensis, Cornopusdidymus, Cynodondactylon* and *Cyperusrotundus*. Among various applied herbicides 2, 4-D treated plot registered minimum total weed density and weed dry weight at 60 DAS which led maximum grain yield and economic return. Second most effective herbicide was metsulfuron in respect to limiting the growth of weed and ultimately increases the economic yield of experimental crop.

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Integrated weed management in direct seeded rice

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A field experiment was planned and carried out during *Kharif seasons* of the year of 2006 and 2007 with the objectives: 1) to study the growth and productivity of direct seeded rice under integrated weed management system, 2) to investigate the effect of weed management practices on weed dynamics and weed control efficacy under direct seeded rice, 3) to find out most economic integrated weed control practice for direct seeded rice.

METHODOLOGY

The soil of experimental field was low in organic matter and available nitrogen and medium in available phosphorus and available potassium and neutral in soil reaction. The total Fourteen treatments consisted of Pendimethalin @ 1.0 kg *a.i.*/ha PE, Pendimethalin @ 1.0 kg *a.i.*/ha PE fb almix @ 4g *a.i.*/ha at 25 DAS, Pendimethalin @ 1.0 kg *a.i.*/ha PE *fb* one manual weeding at 45 DAS, Anilophos @ 400 g *a.i.*/ha PE, Anilophos @ 400 g *a.i.*/ha PE *fb* almix @ 4g *a.i.*/ha at 25 DAS, Anilophos @ 400 g *a.i.*/ha PE *fb* one manual weeding at 45 DAS, Almix @ 4g *a.i.*/ha at 25 DAS, Almix @ 4g *a.i.*/ha at 25 DAS *fb* one manual weeding at 45 DAS, *Sesbania* (Killed by 2,4-D at 30 DAS), *Sesbania* (Killed by 2,4-D at 30 DAS) *fb* one manual weeding at 45 DAS, one manual weeding at 30 DAS, two manual weedings at 20 and 45 DAS, Weed free and Weedy. Experiment was laid out in Randomized Block Design with three replications.

RESULTS

Among weed control treatments, pendimethalin @ 1.0 kg *a.i.* /ha along with one manual weeding at 45 days after sowing recorded efficient control of weeds and recorded maximum weed control efficiency and lowest weed index as compared to weedy check as well as other weed control treatments during both the years. This treatment gave equivalent grain yield to weed-free treatment which was significantly higher than other treatments. Increase in grain yield in this treatment due to more number of shoots per meter square, dry matter production by crop and less dry matter accumulated by weeds at all the stages of crop growth. Pendimethalin @ 1.0 kg *a.i.* /ha fb one manual weeding at 45 DAS produced grain yield and straw yield significantly higher than other treatments during both the years. Srivastava and Vaishya (1995) reported that pre-emergence application of pendimethalin @ 1.0 kg *a.i.* /ha supplemented with one manual weeding at 40 days after sowing was very effective in reducing weed biomass in direct seeded rice. Similar results were also reported by and Singh *et al.* (2007). The grain yield which is the resultant of growth, development and yield attributing character is increased in all weed management practices. The competition decreased under various weed control treatments as compared to weedy check due to control of weeds which resulted in more crop growth as evident from the data on shoot number and plant height. Increased crop growth led to increase in the yield attributes as number of panicles, total number of grains/ panicle, number of filled grains/ panicle and 1000 grain weight and finally producing the more yield of crop.

CONCLUSION

It may be concluded that the application of pendimethalin @ 1.0 kg *a.i.* /ha PE accompanied by one manual weeding at 45 DAS treatment gave at par yield and net return to weed free treatment but significantly higher than other treatments during both the years. Thus in order to get maximum yield and net return from direct seeded rice, weed control through pendimethalin @ 1.0 kg *a.i.* /ha PE accompanied by one manual weeding at 45 DAS treatment is recommended.

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Weed flora management in cotton through glufosinate ammonium

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Field experiments was conducted to evaluate the bio-efficacy of herbicide, glufosinate ammonium 13.5% SL against major weed flora in cotton during *Kharif* season, 2015 at Rajasthan College of Agriculture, MPUAT, Udaipur. The trial was laid down in randomized complete block design with seven treatments and replicated thrice. Results revealed that post-emergence directed spraying of glufosinate ammonium 13.5% SL at the rate of 375 to 450 g a.i./ha can be recommended for effective management of weeds in cotton crops which is lead to higher seed cotton yield without sowing any symptoms and sign of crop phytotoxicity.

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Weed management in dry direct seeded rice through integrated approaches

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Direct-seeded rice (DSR) is a feasible alternative of transplanted rice to mitigate methane emission, besides saving water, labour and energy. The yields under DSR are comparable with transplanted rice if the crop is properly managed (Pathak*et al*., 2013). But the productivity of the DSR is often reported to be lower, mainly due to infestation of weeds which may cause yield losses of 50–91% (Duary *et al*., 2005; Mathew *et al*., 2013). Manual weeding is effective and safe for the crop but involvement of greater physical energy and cost make it difficult for its timely implication in large areas. Herbicides are considered to be an alternative supplement to hand weeding. Cultural practices like use of locally available weeds as bio-organic mulch to suppress the growth of other weeds may also be a viable option. But no single method of weed management is effective and sustainable in long run. With this perspective the present experiment was conducted to study the effect of integration of diversified weed management practices on weed population dynamics, weed growth and productivity of direct seeded rice.

METHODOLOGY

A field experiment was conducted during rainy (*kharif*) season of 2014 in the Agricultural Farm of Institute of Agriculture, Visva-Bharati, Sriniketan, Birbhum, West Bengal. Ten treatments comprising of pendimethalin at 0.75 kg/ha at 2 days after sowing (DAS)+ one hand weeding at 35 DAS, pendimethalin at 0.75 kg/ha at 2 DAS+ mulching with *Saccharumspontaneum*, pendimethalin at 0.75 kg/ha at 2 DAS+ mulching with water hyacinth, pendimethalin at 0.75 kg/ha at 2 DASand *Sesbania* + 2,4-D (sodium salt) at 400 g/ha at 30 DAS, bispyribac sodium at 25 g/ha at 18 DAS, pendimethalin at 0.75 kg/haat 2 DAS followed by bispyribac sodium at 25 g/ha at 18 DAS, closer spacing (20 cm row to row) + pendimethalin at 0.75 kg/ha at 2 DAS, closer spacing (20 cm row to row) + pendimethalin at 0.75 kg/ha at 2 DAS followed by bispyribac sodium at 25 g/ha at 18 DAS, hand weeding thrice at 15, 30 and 45 DAS and unweeded control were assigned in a randomized block design (RBD) replicated thrice. Rice variety '*MTU 1010*' with a seed rate of 60 kg/ha

Table1. Effect of treatments on density and dry weight of weeds, weed control efficiency, grain yield and net return of direct seeded rice

Treatment	Weed density (No./m^2) at 60 DAS	Weed dry weight (g/m^2) at 60 DAS	WCE (%) at 60 DAS	Grain yield (t/ha)	Net return (Rs/ha)
Pendimethalin at 0.75 kg/ha +1 HW at 35 DAS	6.92(47.33)	4.30(17.97)	91.38	3.54	22092
Pendimethalin at 0.75 kg/ha + mulching with *Saccharumspontaneum*	8.72(75.67)	4.93(23.89)	88.52	3.92	29552
Pendimethalin at 0.75 kg/ha + mulching with water hyacinth	8.10(65.33)	4.82(22.77)	89.06	4.61	36132
Pendimethalin at 0.75 kg/ha and *Sesbania* + 2,4-D-Na salt	4.78(22.33)	2.57(6.10)	97.08	4.17	31382
Bispyribac- sodium at 25 g/ha at 20 DAS	4.32(18.33)	1.77(2.73)	98.74	3.66	25702
Pendimethalinat 0.75 kg/ha fbbispyribac-sodium at 25 g/ha at 20 DAS	3.62(12.67)	1.54(1.90)	99.10	4.27	31622
Closer-spacing (20 cm)+ pendimethalin at 0.75 kg/ha	10.60(112.33)	6.61(43.13)	79.29	3.49	25082
Closer-spacing (20 cm)+ pendimethalin at 0.75 kg/ha fbbispyribac-sodium at 25 g/ha	2.73(7.00)	1.27(1.12)	99.47	4.20	30892
Three hand weeding at 15, 30 and 45 DAS	0.71(0)	0.71(0)	100.00	4.53	27642
Unweeded control	15.18(231.00)	14.50(210.19)	0	2.13	11322
CD (P=0.05)	0.93	0.51	-	0.59	-

Figures in parentheses are the original values. The data was transformed to SQRT (x + 0.5) before analysis.

was line sown with a row to row spacing of 25 cm in the second week of July. The crop was fertilized with 60 kg N, 30 kg each of P_2O_5 and K_2O per hectare. All other recommended agronomic practices and plant protection measures were adopted to raise the crop.

RESULTS

The weed flora of experimental field consisted of twenty one speciesout of which *Ludwigiaparviflora, Melochiachorchorifolia, Cyanotisaxillaris, Spilanthesacmella,* among broadleaved, *Cynodondactylon* and *Echinochloacolona* among grasses and *Fimbristylismiliacea* and *Cyperusiria* among sedges were predominant. Hand weeding thrice at 15, 30 and 45 DAS excelled with the lowest density and dry weight of weeds among the various treatments at 60 DAS (Table 1). Among the other treatments closer spacing (20 cm row to row) + pendimethalin at 0.75 kg/ha followed by bispyribac sodium at 25 g/haregistered the lowest number as well as dry weight of total weeds at 60 DAS and was statistically at par with pendimethalin at 0.75 kg/ha followed by bispyribac sodium at 25 g/ha and pendimethalin at 0.75 kg/ha+ mulching with water hyacinth. The highest weed control efficiency (WCE) of 99.47 % at 60 DAS was recorded with closer spacing (20 cm row to row) + pendimethalin at 0.75 kg/ha followed by bispyribac sodium at 25 g/ha which was closely followed by pendimethalin at 0.75 kg /ha followed by bispyribac sodium at 25 g/ha (Table 1). The highest grain yield was recorded with the treatment pendimethalin at 0.75 kg/ha+ mulching with water hyacinth and it was statistically at par with hand weeding thrice at 15, 30 and 45 DAS, pendimethalin at 0.75 kg/ha followed by bispyribac sodium at 25 g/ha and closer spacing (20 cm row to row) + pendimethalin at 0.75 kg/hafollowed by bispyribac sodium at 25 g/ha(Table 1). Pendimethalin at 0.75 kg/ha+ mulching with water hyacinth recorded the highest net return also. Higher weed control efficiency in these treatments facilitated better availability of space, light and nutrients resulting in higher values of growth attributes and yield components and ultimately higher yield and net return.

CONCLUSION

It may be concluded that integrated approach involving pre-emergence application of pendimethalin at 0.75 kg/ha at 2 DAS + mulching with water hyacinth appeared to be promising for effective weed management, higher yield and net return of dry direct seeded rice. However, it was comparable with pendimethalin at 0.75 kg/ha at 2 DAS followed by bispyribac sodium at 25 g/ha at 18 DAS.

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Integrated weed management studies on jute (*Corchorus olitorius*) in the West Bengal Delta

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Jute, a principal crop in pre *kharif* season of West Bengal delta is predominantly a rainfed crop and is seriously affected by weeds in fibre yields. Weeding operations in jute involves considerable overhead. The composition of weed flora in jute is changing. A field experiment was conducted during the pre- *kharif* season of 2013 and 2014 under randomized block design involving hand weeding, mechanical and herbicidal weed control measures. Nail weeder first at 5-6 DAE and second at 10 DAE + 1 hand weeding within row at 15 DAE performed best having significantly less weed biomass and resulting in more yields over the other treatments scoring mean fibre yield of 37.74 q/ha. Despite good yield performance by different chemical herbicides treatments they failed to outperform the mechanical control in growth, development or fibre yields in jute. Increase in fibre yield varied from 114.9 to 154.46 % and 131.64 to 172.71% in 2 seasons respectively. This is an important finding in the recent wake of eco-efficiency considerations in modern agriculture.

Table 1. Plant height and basal diameter in jute as influenced under different weed control methods

Treatment	Plant height (cm)		Basal diameter (cm)	
	2013	2014	2013	2014
T_1	296.0	302.6	1.20	1.29
T_2	315.3	316.6	1.37	1.39
T_3	320.6	326.3	1.48	1.52
T_4	317.3	328.3	1.42	1.44
T_5	310.0	304.6	1.32	1.26
T_6	310.3	313.6	1.34	1.34
T_7	318.6	326.6	1.44	1.42
T_8	220.0	243.6	0.90	1.04
SEm±	7.24	0.45	0.05	0.05
CD (P=0.05)	21.9	1.36	0.15	0.15

T_1, Pretilachlor 50% EC @450 ml/ha at 45–48 hours of sowing with irrigation + one hand weeding (15 DAE); T_2, Pretilachlor 50% EC @900 ml/ha at 45–48 hours of sowing with irrigation + one hand weeding (15 DAE); T_3, Nail weeder- first at 5 DAE (at field capacity) and second at 10 DAE + 1 hand weeding (within the row) at 15 DAE; T_4, Nail weeder- at 5 DAE + Scrapper at 15 DAE + 1 hand weeding (within the row) at 15 DAE; T_5, uizalofop ethyl 5% EC @ 60 g/ha at 15 DAE + one hand weeding (21 DAE); T_6, Butachlor 50 % EC or 5% G @ 1.5 kg ai/ha + 1 hand weeding (15 DAE); T_7, Hand weeding twice (15 & 21 DAE) and T_8, Un-weed check

METHODOLOGY

The experiment was designed in RBD with three replications and eight treatment combinations of different weed control tactics. Jute crop (cv. JRO 204) was harvested at 120 and 124 DAS in first and second year respectively. Observations were taken following 5 plants destructive plant sampling method for various fibre yield attributes. Data on periodic production of weed biomass at 15, 30 and 45 DAS were also recorded. The experimental site was with the following meteorological situation during the whole growing season of the crop. The experiment has the experience of 5.62 and 5.80 hrs/month bright sunshine hours, 929.4 and 1,013.3 mm total rainfall, 59 and 52 total number of rainy days and 92.06 and 23.12 mm/month average evaporation during first and second year respectively during the crop season. Soil of the experimental site was sandy loam in texture, low in organic carbon and medium in available phosphorus and potassium content. The RDF based application of plant nutrients was taken in practice. Traditional method of retting in pond water was followed. The CRIJAF-ICAR made *Nail weeder* and *Scrapper* were used in the experiment.

RESULTS

Among the herbicides, Pretilachlor 50% EC when applied @900 ml/ha at 45–48 hours of sowing with irrigation followed by one hand weeding at15 DAE was best though poor performer as compared to T_3 and T_4 in respect of both plant height and basal girth of stem. Differential absorption owing to variable degree and type of selectivity towards various weeds was probably the key factor behind this expression (Islam, 2014). All the treatments increased the fibre yield significantly over un-weeded check in both the years (Table 1 and Table 3). Discouraged level of competition imposed by the weed flora in all the treatments at variable extents other than unweeded check had the obvious contribution towards the remarkable improvement in two key yield determining parameters viz. plant height and basal stem dimension over T_8 in both the seasons. The treatments T_3 and T_4 were proved to be impressive in improvement of height of the plants almost equally indicating the fact that use of scrapper at 10 days and

Table 2. Weed biomass production in jute as influenced under different weed control methods

Treatment	Green biomass production (q/ha)					
	2013			2014		
	15 DAS	30 DAS	45 DAS	15 DAS	30 DAS	45 DAS
T_1	0.10	0.26	0.30	1.24	3.15	4.48
T_2	0.08	0.23	0.25	1.09	2.75	3.67
T_3	0.06	0.16	0.17	0.85	1.97	2.50
T_4	0.08	0.20	0.21	0.89	2.09	3.19
T_5	0.08	0.24	0.25	1.18	3.28	3.80
T_6	0.08	0.23	0.25	1.06	2.72	3.69
T_7	0.07	0.17	0.17	0.94	2.06	2.61
T_8	0.28	0.84	0.96	3.58	9.99	13.17
SEm±	0.01	0.03	0.03	0.10	0.38	0.34
CD (P=0.05)	0.02	0.09	0.11	0.30	1.15	1.03

Table 3. Fibre productivity in olitorius jute as prejudiced under different weed control methods

Treatment	Green biomass (q/ha)		Fibre yield (q/ha)		
	2013	2014	2013	2014	Pooled data of 2 years
T_1	561.6	638.1	32.00	31.92	31.96
T_2	586.8	680.3	33.55	34.03	33.79
T_3	703.2	751.4	37.89	37.58	37.74
T_4	625.2	749.1	35.16	37.47	36.32
T_5	583.2	629.4	35.16	31.50	33.33
T_6	584.4	695.5	32.55	34.81	33.68
T_7	717.6	736.9	37.61	36.86	37.24
T_8	266.2	275.3	14.89	13.78	14.34
SEm±	23.05	17.6	1.07	0.87	0.69
CD (P=0.05)	69.9	53.3	3.26	2.63	1.99

nail weeder at 5 days after making first use of nail weeder at 5 DAE failed to show remarkable dominance over one another in this respect.

Threat by the weeds as exhibited in terms of rivalry for the cause of basic needs with the jute crop, when lessened by the use of nail weeder followed by one hand weeding at 15 DAE , influenced the dimensional growth of stem favorably and ultimately the basal diameter of plants. The highest fibre yield was recorded in T_3 in all the seasons. Minimum extent of competition tendered by the weed flora as revealed through the minimal production of weed biomass helped in better accumulation productive photosynthates in crop plants and consequently in significantly higher fibre yield (Sarkar, 2006). All the weed control treatments particularly the nail weeder treatments were able to reduce the production of weed biomass significantly as compared to un-weeded check at the growth stages (Table 2). It was exposed from the result of pooled data analysis of the year 2013 and 2014 that use of nail weeder along with hand weeding (T_3 and T_4) was proved to produce significantly higher quantity of fibre over chemical weed control measure practiced with hand weeding. Encouraged plant growth as indicated by the observations regarding improvement in height as well as basal diameter of plants was the accelerating factor behind the total biomass production by the crop.

CONCLUSION

The wind up may be drawn in this way that *nail weeder*, when used alone or in combination with *scrapper* followed by 1 hand weeding may be a promising measure of weed management in olitorius jute in this region.

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Management of complex weed flora in wheat

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India is the second largest producer of wheat in the world contributing about 93.5 million tonnes of grains with the productivity of 3.11 t/ha from the area of 30.0 million hectares. Area under wheat cultivation is 1.02 m ha and productivity is 2.88 t/ha in Gujarat. Weed infestation is one of the major barriers in realizing potential yield of wheat. Weeds are reported to causes up to 66% reduction in wheat grain yield if not timely controlled (Kumar *et al*., 2011). Wheat is infested with narrow and broad leaf weeds and to combat these weeds, continuous use of 2, 4-D, pendimethalin or metsulfuron-methyl has resulted in shift in weed flora. To overcome the problems of weed shift, tank mix or pre-mix herbicides mixture have been recommended by Chhokar and Malik (2002). So, there is a need to evaluate alternative herbicide or herbicide mixture for the management of complex weed flora in wheat. Thus, the present experiment was conducted with objective to study the bio-efficiency of combination of herbicides against weed complex and their effect on growth and yield of wheat.

METHODOLOGY

A field experiment was conducted at AICRP-Weed Management Farm, B. A. College of Agriculture, Anand Agricultural University, Anand (Gujarat) during *rabi* 2014. The soil of the experimental field was sandy loam in texture having low in available nitrogen, medium in available phosphorus and high in available potassium with pH 8.2. The experiment was laid out in randomized complete block design with three replications. There were twelve treatments comprised of different herbicides either alone or combination of herbicides including HW at 30 & 60 DAS and weedy check. Wheat cv. GW-496 was sown keeping the distance of 22.5 cm between two rows with adoption of all the recommended package of practices. The weed density and dry biomass of weeds were recorded at 60 DAS.

RESULTS

The major monocot weeds were *Phalaris minor, Avena fatua, Asphodelus tenuifolius, Setaria tomentosa* and *Cyperus*

Table 1. Weed dry biomass, grain yield and economics as influenced by different weed management practices in wheat

S. No.	Treatment	Total weed dry biomass (g/m^2) at 60 DAS	Effective tillers at harvest (no./m row length)	Grain yield (kg/ha)	Straw yield (kg/ha)	WCE (%) at 60 DAS	B:C ratio
T_1	Pendimethalin 500 g/ha PE	18.69^{ab}(348.6)	50.4^{b}	2417^{b}	4201^{b}	7	1.36
T_2	2,4-D 750 g/ha POE	15.53^{c}(240.7)	48.0^{b}	2685^{b}	4870^{b}	36	1.55
T_3	Metsulfuron methyl 4.0 g/ha POE	17.18^{b}(294.7)	43.3^{b}	2363^{b}	4674^{b}	21	1.38
T_4	Clodinafop propargyl 60 g/ha POE	8.76^{d}(76.2)	84.5^{a}	3696^{b}	6378^{a}	80	2.07
T_5	Sulfosulfuron 25 g/ha POE	1.51^{e}(1.8)	97.1^{a}	3756^{a}	6639^{a}	99	2.12
T_6	Sulfosulfuron (75%) + Metsulfuron methyl (5 %) 32 g/ha POE	99.5^{a} 2.23^{e}(7.1)	4265^{a}	6876^{a}	98	2.35	
T_7	Clodinafop (15 %) + Metsulfuron methyl (1 %) 64 g/ha POE	1.00^{e}(0.0)	92.9^{a}	4346^{a}	6885^{a}	100	2.38
T_8	Mesosulfuron (3 %) + Iodosulfuron (0.6 %) 14.4 g/ha POE	1.00^{e}(0.0)	92.6^{a}	3930^{a}	6665^{a}	100	2.17
T_9	Hand Weeding at 20 & 40 DAS	2.81^{e}(7.0)	83.3^{a}	3954^{a}	6713^{a}	98	1.88
T_{10}	Weedy check	19.34^{a}(373.2)	46.1^{b}	1611^{b}	3907^{b}	-	1.01

* Values in parentheses are original. Data transformed to square root transformation. Treatment means with the letter/letters in common are not significant by Duncan's New Multiple Range Test at (P=0.05) level of significance.

iria and dicot weeds were *Chenopodium murale, Chenopodium album, Melilotus indica, Amaranthus viridis, Oldenlandia umbellata,* and *Digera arvensis* observed in the experimental field. Weed dry biomass recorded at 60 DAS (Table 1) showed significant influence due to different weed management practices. Significantly the lowest weed dry biomass of total weeds were recorded in PoE emergence application of clodinafop + metsulfuron methyl 64 g/ha and mesosulfuron + iodosulfuron 14.4 g/ha followed by sulfosulfuron 25 g/ha, sulfosulfuron + metsulfuron methyl 32 g/ha PoE and HW carried out at 20 & 40 DAS with more than 98% WCE. Weed control efficiency of different weed management treatments were ranging from 7 to 100 % at 60 DAS. Significantly more numbers of effective tillers (99.5 no./m) was recorded in the application of sulfosulfuron + metsulfuron methyl 32 g/ha PoE, but it was remained at par with all PoE emergence application of herbicides except 2,4-D 750 g/ha, and metsulfuron methyl 4.0 g/ha because these herbicides were found not effective to control complex weed flora. Significantly higher grain (4346 kg/ha) and straw (6885 kg/ha) yield of wheat were recorded in application of clodinafop + metsulfuron methyl 64 g/ha PoE with maximum B:C ratio (2.38), but remained at par with sulfosulfuron + metsulfuron methyl 32 g/ha PoE, HW carried out at 20 and 40 DAS, mesosulfuron + iodosulfuron 14.4 g/ha PoE and sulfosulfuron 25 g/ha PoE. The growth parameters of succeeding greengram, maize and pearlmillet were not influenced significantly due to different herbicides applied in preceding wheat crop as individual or as mixtures at 30 DAS in bioassay study. This indicated that there was no any carry over/residual effect of herbicide applied in wheat noticed on succeeding crops.

CONCLUSION

Application of clodinafop + metsulfuron methyl 64 g/ha PoE or sulfosulfuron + metsulfuron methyl 32 g/ha PoE can be used to control complex weed flora of monocot and dicot weeds in wheat, especially *Phalaris minor, Avena fatua, Chenopodium murale and Chenopodium album* without any residual/carry over effect on succeeding greengram, maize and pearlmillet crops.

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Effects of wheat residue incorporation and weed control on yield components, weeds and weed seed bank in groundnut (*Arachis hypogaea*)

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The groundnut crop ranks most important oilseed and food crop of the world. Gujarat is the leading producer contributing 29.63% of the total production. Weeds, the essential component of agro-ecosystems, interfere with crops and lead to enormous crop losses. The main problems limiting production of groundnut are poor cultural practices and inadequate weed management.Therefore, it is essential to keep groundnut fields weed free at the critical stages of crop-weed competition.Soil weed seedbanks are reserves of viable seeds present on the surface and in the soil. The weed seedbank is an important part of crop-weed ecology. These relationships make understanding the weed seedbank even more important for increasing the efficiency of weed management. Wheat (*rabi*)-fallow (summer)-groundnut (*kharif*) is the pre-dominant crop sequence in the Saurashtra region of Gujarat. Harvesting of wheat is mostly carried out by combine harvester, which left large quantities of wheat residue. Now their usefulness considered as an important resource that can bring significant physical, chemical, biological changes into the soil and suppresses weeds and prevent weed seeds to recycle in soil

(Sharma, 2014). Considering the facts and views highlighted above, the field experiment was undertaken for two years to study effect of residue management and weed management practices in *kharif* groundnut.

METHODOLOGY

A field experiment was conducted at Weed Control Research Scheme, Department of Agronomy, Junagadh Agricultural University, Junagadh (Gujarat) during *kharif* seasons of 2014and 2015. The soil of the experimental plot was clayey in texture and slightly alkaline in reaction (pH 8.1 and EC 0.43 dS/m), low in available N (245 kg/ha), medium in available P_2O_5 (36 kg/ha) and available K_2O (275 kg/ha). The experiment was laid out in split plot design with three replications. The main plots comprised residue management treatments *viz*., (i) burning of wheat residues, (ii) wheat residue incorporation by rotavator *fb* soil solarization with 25 µm polythene sheet for 15 days and (iii) wheat residue incorporation by rotavator *fb* application of *Trichoderma viride* + 20 kg N/ha and sub plots contained weed management treatments *viz*., (i) stale seedbed *fb* IC & HW at 45 DAS, (ii) suicidal germination (Application of Ethylene 2000 ppm + KNO_3 2000 ppm with pre-sowing irrigation) *fb* tillage *fb* IC & HW at 45 DAS, (iii) pendimethalin 900 g/ha as PRE*fb* IC & HW at 45 DAS, (iv) HW & IC at 15 DAS *fb* pre-mix imazethapyr + imazamox 70 g/ha as POE at 25 DAS, (v) pendimethalin 900 g/ha as PRE*fb* pre-mix imazethapyr + imazamox 70 g/ha as POE at 25 DAS, (vi) weed free and (vii) unweeded check. The groundnut (cv. Gujarat Groundnut-20)was sown at 60 cm x 10 cm spacing using seed rate of 120 kg/ha. The crop was fertilized with 12.5-25-50 kg N-P_2O_5-K_2O/ha.

RESULTS

Among the residue management, significantly the highest pod yield (1467 kg/ha) was recorded under the wheat residue incorporation *fb* soil solarization with increased magnitude of 14.2% over the burning of residues (Table 1).Among the weed management, significantly, the highest pod yield (1684 kg/ha) and haulm yield (3353 kg/ha) was recorded under the weed free, which was statistically at par with the treatments pendimethalin *fb* imazethapyr + imazamox and pendimethalin *fb* IC & HW with increased magnitude of 124.9 and 124.5%. Conversely, the unweeded check registered significantly the lowest pod yield (722 kg/ha). While the reduction in pod yield due to uncontrolled weeds.The higher yield under these treatments could be ascribed to lower dry weight of weeds ultimately reduced the crop-weed competition as compared to under heavy weed infestation. Conversely, burning of residues and unweeded check recorded lowest pod and haulm yields. Deprived growth and development of the crop under the treatment owing to severe crop-weed competition for resources might have poor yields. These findings are in agreement with earlier reports (Anonymous, 2006; Dubey *et al.,* 2010and Sharma, 2014).Significantly the lowest dry weight of weeds

Table 1. Effect of residue and weed management on yield, weed dry weight, weed seedbank and economics of groundnut

Treatment	Pod yield (kg/ha)	Haulm yield (kg/ha)	Dry weight of weeds (kg/ha)		Number of weed seeds/core		Gross returns (Rs./ha)	Cost of cultivation (Rs./ha)	BCR
			2014	2015	2014	2015			
Residues management					215 (Initial)	181 (Initial)			
Burning of wheat residues	1284	3110	1142	1419	259	242	71589	28439	2.49
Wheat residue incorporation *fb* soil solarization	1467	2857	687	951	161	171	78774	34382	2.27
Wheat residue incorporation *fb T. viride* + N	1358	3135	813	1229	234	245	75064	31512	2.36
SEm±	22	79	38	51	11	13	-	-	-
CD (P=0.05)	73	NS	151	200	45	51	-	-	-
Weed management									
Stale seedbed *fb* IC & HW	1084	2876	979	1272	168	170	61640	30370	2.03
Suicidal germination *fb* tillage *fb* IC & HW	1587	3144	788	870	99	95	85506	32846	2.61
Pendimethalin *fb* IC & HW	1624	3222	521	553	86	78	87500	31150	2.82
HW & IC *fb* imazethapyr + imazamox	1265	3163	770	1188	191	180	70933	31468	2.26
Pendimethalin *fb* imazethapyr + imazamox	1621	3270	489	628	89	80	87597	32095	2.74
Weed free	1684	3353	40	58	68	58	90727	34764	2.62
Unweeded check	722	2210	2577	3825	824	876	42092	27421	1.54
SEm±	27	104	45	55	17	19	-	-	-
CD (P=0.05)	77	292	128	159	50	56	-	-	-
InteractionM x T									
SEm±	47	180	77	96	30	34	-	-	-
CD (P=0.05)	NS	NS	221	275	86	97	-	-	-

Note: Groundnut yields and economics are of pooled of two years.

and weed seedbank was recorded under the wheat residue incorporation *fb* soil solarization and weed free (Table 1). Among the weed management, the next superior treatments in this respect were pendimethalin *fb* imazethapyr + imazamox, pendimethalin *fb* IC & HW and suicidal germination *fb* tillage *fb* IC & HW.This might be attributed to the effective control of weeds under these treatments through hand weeding or integration of hand weeding with herbicides, which reflected in less number of weeds and ultimately lower weed biomass and weed seedbank. In addition to this, dense crop canopy might have suppressed weed growth and ultimately less biomass.

CONCLUSION

It was concluded that effective management of wheat residues, weeds and weed seedbank along with profitable cultivation of groundnut in *kharif* season can be achieved by incorporation of wheat residues in soil by rotavator followed by eithersoil solarization for 15 days during hot summer or application *Trichoderma viride* 5 kg/ha + 20 kg N/ha and pre-emergence application of pendimethalin 900 g/ha supplemented witheither IC & HW at 45 DAS or pre-mix imazethapyr + imazamox 70 g/ha as post-emergence at 25 DAS according to availability of labourers under south Saurashtra Agro-climatic conditions.

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Weed dynamics and yield of transplanted rice as influenced by chemical weed management

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Rice (*Oryza sativa* L.) is one of the world's most important food crops.Weed competition is one of the important biotic constraints in rice production. Weeds can cause a reduction of 28-45% of grain yield in transplanted rice (Singh *et al.*, 2003).The crops suffer heavily in early growth stage from the weeds. The critical period for weed free condition for higher productivity is reported to be 30-35 days in transplanted rice, whereas, in direct seeded low land and upland condition, the weed free period ranges from 40-60 days. In the early stage of the crop grasses are predominant as compared to others, but at later stage, sedges and broadleaf weeds create interference in crop growth.

METHODOLOGY

A field experiment was carried out during *Kharif* 2013-2014 at the Instructional-Cum Research Farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.). The experiment was laid out in randomized block design, comprising three replications and twelve treatments. Medium duration rice cultivar MTU-1010 was taken as a test crop. Fertilizer dose was 100, 60 and 40 kg/ha of N, P_2O_5 and K_2O respectively. Full dose of phosphorus and potash along with one third of nitrogen was applied as basal. Rest of nitrogen was applied in two splits at tillering and panicle initiation.

RESULTS

Grain and straw yield of transplanted rice varied significantly due to weed control treatments. Significantly maximum grain and straw yield (5200 kg/ha and 6306 kg/ha respectively) was obtained with hand weeding at 25 and 45 DAT over rest of the treatments. Among the herbicides, application of bispyribac-Na + (chlorimuron-ethyl+ metsulfuron-methyl) @ 20 + 4 g/haat 25 DAT (T_5) recorded maximum grain and straw yield (5060 and 6218 kg/ha) which was obvious due to its higher values of yield attributes and minimum sterility percent as compared to rest of the treatments. However, this treatment was at par with treatment bispyribac-Na+ ethoxysulfuron @ 25 + 18.75 g/haat 25 DAT (T_4). Minimum

Table 1. Effect of weed management on weeds and yield of rice

Treatment	Total weed density (no/ meter square)	Total weed biomass (g/meter square)	Grain yield (t/ha)	Straw yield (t/ha)
Bispyribac –Na @ 25 g/ha	3.29 (10.53)	2.10 (3.96)	4.86	6.05
Pretilachlor @ 1000 g/ha	5.58 (30.65)	4.31 (18.28)	4.19	5.26
Pyrazosulfuron-ethyl @ 20g/ha	5.64 (31.32)	4.30 (18.01)	4.25	5.42
Bispyribac-Na +Ethoxysulfuron @ 25 + 18.75 g/ha	2.70 (6.81)	1.92 (3.19)	5.00	6.14
Bispyribac-Na + (chlorimuron-ethyl + metsulfuron-methyl) @ 20 + 4 g/ha	2.77 (7.32)	1.79 (2.73)	5.06	6.21
Azimsulfuron @ 35 g/ha	3.55 (12.17)	2.18 (4.26)	4.52	5.75
Pretilachlor *fb* Ethoxysulfuron @ 750 /18.75 g/ha	3.91 (14.87)	2.46 (5.67)	4.46	5.60
Pretilachlor *fb* (chlorimuron-ethyl + metsulfuron-methyl) @ 750/ 4 g/ha	3.63 (12.71)	2.28 (4.69)	4.50	5.69
Pyrazosulfuron-ethyl @ 20 g ha^{-1} *fb* manual weeding	2.53 (5.52)	1.54 (1.94)	4.98	6.13
Pretilachlor(6%) + bensulfuron (0.6%) 6.6% GR@ 660 g/ha	4.04 (15.87)	3.00 (8.63)	4.32	5.59
Hand weeding at 25 and 45 DAT	1.56 (1.99)	1.03 (0.62)	5.20	6.30
Weedy check	7.62 (57.77)	6.95 (47.97)	2.18	4.07
CD (P= 0.05)	0.54	0.54	0.63	0.69

density and dry weight of weeds was recorded under the treatment pretilachlor (6 %) + bensulfuron (0.6%) 6.6% GR @ 660 g/ha (T_{10}), while it was at par to treatment pyrazosulfuron- ethyl @ 20 g/ha (T_3), pretilachlor fb ethoxysulfuron @ 750 / 18.75 g/ha (T_7), pretilachlor fb (chlorimuron-ethyl + metsulfuron-methyl) @ 750 / 4 g/ha(T_8) and pyrazosulfuron-ethyl fb manual weeding @ 20 g/ha (T_9). At later time interval of observations, significantly lowest total dry matter was recorded under hand weeding at 25 and 45 DAT (T_{11}), while highest was noted under weedy check (T_{12}). Treatment pyrazosulfuron- ethyl fb manual weeding @ 20 g/ ha (T_9) at 40 DAT was also statistically similar to hand weeding at 25 and 45 DAT (T_{11}) (Table 1).

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AMMI analysis to identify maize hybrids adapted under drought stress and normal ecologies in tropical climate

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Maize (*Zea mays* L.) is one of the most versatile crops having wider adaptability to diverse ecologies. The area, production and productivity of maize in India have been increasing since last several decades. Around 80% of maize in India is grown as rainfed crop where drought stress is a major problem. Low moisture stress is one of the highly variable and unpredictable abiotic stresses, which reduces maize yield significantly in rainfed ecosystem. To improve maize production and productivity in rainfed ecology, the development of maize hybrids with adequate tolerance to drought stress is the important objective in maize breeding. There are several statistical procedures to identify better performing genotypes in various treatments. The additive main effect and multiplicative interaction (AMMI) method integrates analysis of variance (ANOVA) and principal component analysis (PCA) into a unified approach that can be used to analyze multi-location trials (Gauch and Zobel, 1997). The results of AMMI analysis are useful in supporting breeding program decisions such

Table 1. The winning genotypes identified through AMMI analysis suitable for both environment and only drought stress conditions in late to medium maturity group

Genotype	Both conditions (Medium and late maturity)		Drought stress only (late maturity)	
	Yield (kg/ha)-Drought stress	Yield (kg/ha)-Optimal environment	Genotype	Yield (kg/ha)
C0H (M)11	5785	6680	PMH 3	5044
PMH 4	5851	6242	DHM 111	5259
DMRH 1306	5014	6347	C0H (M)10	4958

as specific adaptations of genotype to target traits and selection of suitable environments for evaluation of genotypes (Gauch and Zobel, 1997). In addition, AMMI simultaneously quantifies the contribution of each genotype and environment to the $SS_{G\times E}$, and provides an easy graphical interpretation of the results by the biplot technique to simultaneously classify genotypes and environments. Therefore, with this technique, one can readily identify productive cultivars with wider and or specific adaptability along with effective sites for testing of genotypes (Ferreira *et al*., 2006). Considering usefulness of this methodology, the present study was undertaken to identify better performing maize hybrids for drought stress and normal ecologies using additive main effects and multiplicative interaction (AMMI) analysis

METHODOLOGY

Multi location trials were constituted and conducted at four locations (Delhi, Udaipur, Karimnagar and Karnal). A set of 26 genotypes for late maturity and 17 genotypes for early maturity were evaluated in replicated trials under managed low moisture stress at flowering and grain filling stage. The experiment was laid out in randomised block design with three replications and 2 rows of 4m length per genotype following row to row and plant to plant spacing of 75 cm and 25 cm respectively. The data was recorded on yield and its component traits. The final grain yield per hectare was calculated at 15% grain moisture for each genotype at various environments and was used for AMMI analysis using GENSTAT Version 17 software.

RESULTS

The average grain yield reduction due to drought stress was found to be 26-30% across environments and maturity groups. AMMI analysis was done to select the winning genotypes under drought and optimal environments. Three genotypes viz. C0H (M) 11, PMH 4 and DMRH 1306 in late to medium maturity were identified as high yielding and suitable for drought as well as optimal condition however, PMH 3, DHM 111 and C0H (M) 10 were found suitable with consistence high yield performance under drought conditions only (Table 1). In early to extra early trials four maize hybrids viz., CMH 10-531, FH 3664, JH 31613, and PRAKASH were found high yielding under drought and three viz., DMRH 1305, Vivek hyb 39-G14 and VIVEK QPM 9 under optimal environments (Table 2). The identified cultivars using AMMI based selection here could be useful to sustain maize productivity in diverse ecology.

Table 2. The genotypes performed better under low moisture stress and optimal environment in early to extra early maturity group

Drought stress		Optimal environment	
Genotype	Yield (kg/ha)	Genotype	Yield (kg/ha)
CMH 10-531	4167	DMRH 1305	5202
FH 3664	4530	VIVEK QPM 9	5460
JH 31613	4365	Vivek hyb 39	4799
PRAKASH	4362	-	-

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Sustainable production with *in-situ* moisture conservation under maize based cropping system in North East Hill region

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Maize is cultivated in sequence with different crops under various agro-ecologies of the country. It has a wide adaptability and compatibility under diverse soil and climatic conditions. In North-Eastern Himalayan region, maize is the second most important food grain after rice. Maize is mostly grown under *rainfed* condition in upland as main crop. After harvesting of *kharif* crops, lack of sufficient soil moisture availability limit the cultivation of *rabi* crops. Retention of crop residue on the soil surface in combination with zero tillage initiates process that lead to improve soil quality and overall enhancement of resource use efficiency.Thus, zero tillage is a viable option for conserving moisture besides saving energy and promoting soil health. In addition to zero tillage, mulching could conserve residual soil moisture to be utilized by a winter crop.

METHODOLOGY

The experiment was conducted at ICAR research complex for NEH Region in 2012 with five cropping system viz, Maize-Fallow (CS_1), Maize-Toria (CS_2), Maize-French bean {(Bush type) (BT)} (CS_3), Maize-French bean {(Pole Type) (PT)} (CS_4), Maize-Blackgram (CS_5) and four soil moisture conservation (SMC) measures as sub plot treatments viz, no mulch (M_0), *in-situ* maize stalk mulch (MSM) (M_1), M_1+*Ambrosia* sp. 10 t/ha(M_2), M_1+*Tephrossia*sp. 10 t/ha (M_3) in split plot design. In *kharif,* maize was sown on 30th April, and harvested on 9th August. After maize in *rabi*, French bean (bush and pole type) and blackgram were shown on 24th August, and toria on 21st September and harvested on 2nd November, 16th November, 1st December and 16th December, respectively.After the harvest of maize, furrows were opened in between two maize rows using a manual furrow and recommended doses of fertilizers and seeds were placed in the furrows and covered with soil and the mulch materials were adjusted back between the rows to cover the soil surface on the same day immediately after sowing. After the germination of seeds, the maize stovers were cut and spread all over the field just above the mulches to cover the soil surface. This way, there were two layers of mulch i.e. MSM and *Ambrosia/ Tephrossia* mulch to cover the soil surface.

RESULTS

The result from the experiment revealed that highest maize equivalent yield (MEY) was obtained from Maize-French bean (PT) system under M_1+ *Tephrossia* mulch (9.50 t/ ha) followed by M_1+ *Ambrosia* mulch (8.83 t/ha) (Table 1). The MEY of maize-French bean (PT) system under MSM+

Table 1. Interaction effect of maize equivalent yield as influence by cropping systems and soil moisture conservation measures (t/ha).

Treatments	Maize - Fallow	Maize - Toria	Maize – F. bean (BT)	Maize – F. bean(PT)	Maize - Blackgram	Mean
No mulch	3.12	4.31	6.42	7.22	5.58	4.7
*In-situ*MSM	3.12	4.53	6.59	8.01	6.25	5.1
MSM+ *Ambrosia*	3.12	4.56	7.14	8.83	6.93	5.5
MSM+ *Tephrossia*	3.12	4.75	7.94	9.50	7.46	5.9
Mean	3.12	4.54	7.02	8.39	6.55	
				SEm±	CD (P=0.05)	
Cropping systems	0.10	0.33				
SMC measures	0.07	0.20				
For SMC at same or different level of CS	0.15	0.48				
For CS at different level of SMC	0.14	0.40				

MSM-maize stalk mulch, BT-bush type, PT-pole type, SEm±- Standard error of mean, CD-Critical difference

Tephrossia mulch was 120% higher than maize-toria cropping system under no mulch. The higher MEY of maize-French bean (PT) under MSM+ *Tephrossia* mulch might be due to higher yield of French bean seed and subsequently higher price of bush type French bean seed. Mulching practices helps in the conservation of soil moisture in the root zone thus facilitates root proliferation and availability of nutrients to crop roots. As a result, grain yield under mulch plot are higher than that of no mulching. Cropping systems and soil moisture conservation measures on system productivity was interacted significantly. The higher system productivity was in maize-French bean (PT) under MSM+ *Tephrossia* mulch (49.8 kg/ha/day). The higher system productivity in maize-French bean (PT) system was due to short duration and higher productivity of French bean (PT) as compared to other *rabi* crops. The higher system productivity with the inclusion of shorter duration crop in maize-based cropping systems was reported by Walia *et al*. (2011).

CONCLUSION

Maize-French bean (PT) cropping system recorded highest maize equivalent yield and system productivity. Thus, it can be concluded that maize-French bean cropping system under retention of maize stalk mulch along with *Tephrossia* or *Ambrosia* mulch is a recommendable option for sustainable production for North East Hill Region.

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Influence of *in-situ* moisture conservation practices on yield and economics of rainfed *rabi* sorghum (*Sorghum bicolor* L.) under receding soil moisture conditions

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Rabi sorghum (*Sorghum bicolor* L.) is the most important post rainy season cereal crop in peninsular India, grown predominantly under rain fed conditions. A major share accounting for almost 60% of coarse grain production is obtained from dryland areas. Adequate soil moisture is the key to successful crop production in dry land areas (Kumar and Rana, 2007). Recently, productivity of rainfed *rabi* sorghum has failed to attain a plateau due to lack of efficient conservation and utilization of the natural resources like soil and water and poor management practices to exploit the conserved soil moisture. The most important constraint for low yields is the inadequate supply of soil moisture during the Rabi season. So, in situ moisture conservation practices known to aid in increased retention of rain water and its conservation in the soil. The success of the dry land crops like RabiSorghum mainly depends on the efficiency of various moisture conservation practices in supplying the crop with adequate amounts of water at critical stages of crop growth.

METHODOLOGY

The field experiment was conducted on a medium black soilat Agricultural Research Station, Tandur, during three consecutive Rabi seasons from 2011-12 to 2013-14. The trial was laid out in a randomized block design with four replications comprised of six Soil moisture conservation treatments including control (T1- Compartmental bunding at 5m x 5m, T2-Tied ridge and furrow at 5m, T3-Flat bed method, T4-Flatbed sowing and opening furrows in alternate rows at 3 weeks after sowing, T5-In-situ mulching with Greengram crop residue and T6- Control (Farmers practice of keeping fallow during *kharif* and sowing sorghum in *rabi*). T1 and T2 treatments were imposed during k*harif* season. The recommended dose of fertilizers (60-30-30 kg N, P and K were applied uniformly to all the treatments as basal. Observations were recorded on sorghum grain yield (t/ha), stover yield (t/ha), monetary returns (/ha) and benefit cost ratio under each treatment.

RESULTS

The grain and stover yields of rabi sorghum were significantly influenced by moisture conservation practices during all the three years. Pooled results (2011-12 to 2013-14) revealed that, compartmental bunding to retain and impound the

Table 1. Enhancement of *Kharif* fallow *rabi* sorghum productivity through *in-situ* moisture conservation (Pooled 2011-12 to 2013-14).

Treatments	Grain yield (t/ha)	Fodder yield (t/ha)	Gross returns (/ha)	Net returns (/ha)	B:C Ratio
T_1 – Compartmental bunding (5m x 5m) during kharif and flat sowing during rabi	3.36	6.82	91560	75293	4.63
T_2 – Tied ridging during kharif at 5m and flat sowing during rabi	2.71	6.11	75083	60316	4.07
T_3 – Flat bed method of sowing	2.17	4.89	60150	46384	3.36
T_4 – Flat bed sowing and opening furrows in alternate rows at 3 weeks after sowing	2.40	5.31	66343	51577	3.48
T_5 – *In-situ* mulching with green gram during kharif and flat sowing during rabi	3.04	6.52	83552	66785	3.99
T_6 – Opening furrows at 45 cm during kharif and flat sowing during rabi	2.71	5.88	74701	59935	4.06
SEm$\pm$	0.0964	1.648	2428	2428	0.16
CD (P=0.05)	0.292	4.966	7316	7316	0.49

incidental rainfall during *kharif* (T1) was found to be significantly superior among the *in-situ* moisture conservation practices in terms of Grain yield (3.36 t/ha.), fodder yield (6.82 t/ha.), gross returns (91560 /ha.), net returns (75293 /ha.) compared to that of rest of the treatments (Table 1). This could be ascribed due to the reduced surface runoff, greater soil water retention and also due toincreased water holding capacity of the soil. The results are in conformity with the findings of *Kalhapure and shete (2013).*

CONCLUSION

From the three years experimentation, the conclusion can be drawn that adoption of compartmental bunding is the best suitable and efficient technique for in situ moisture conservation and sowing of *rabi* sorghum produced higher seed and dry fodder yield and net return under rainfed condition.

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Productivity and economics of non-spiny safflower (*Carthamus tinctorius* L.) in comparison with other *rabi* crops and cropping systems on vertisols

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Saffloweris an important *rabi* oilseed crop of Maharashtra. There is continuous decline in area under safflower during last decade due to other competing crops and constraints. Safflower is potential crop having medicinally valued oil and petals besides drought and salt tolerance. Safflower florets are used to colour and flavour soups, sauces and pickles (Sarojini *et al*.,1995). The field investigation was conducted during *rabi* season of 2012 at experimental Farm, AICRP on Safflower VNMKV, Parbhani for assessing the production potential and economics of non-spiny safflower to other *rabi* crops and intercropping systems under minimal irrigation.

METHODOLOGY

The experiment consists of 10 treatments viz.T_1 PBNS-40(Non-spiny Variety), T_2 SSF-658(Non-spiny Variety), T_3 NARI-6(Non-spiny Variety), T_4Annigeri-1(spiny Variety), T_5-(Sole chickpea variety Akash), T_6 (Sole linseed variety RLC-4), T_7 (Sole sorghum variety Parbhani Moti), T_8-chickpea + safflower (3:1), T_9-linseed + safflower (3:1) and T_{10}-sorghum + safflower (2:1) in randomized block design along with three replications. In intercropping systems spiny safflower variety Annigeri-1 was used. The experimental soil was clayey in texture. It was low in nitrogen, medium in phosphorus and high in potash, while medium in organic carbon and slightly alkaline in reaction. The sowing was done by dibbling method.

RESULTS

Results revealed that non-spiny safflower cultivars viz.PBNS-40 (N.V.), SSF-658 (N.V.) and NARI-6 (N.V.) recorded similar safflower equivalent yield which was significantly superior over other *rabi*crops including spiny safflower. The increased safflower equivalent yield in non spiny safflower was due to high sale price of petals. Grossmonetary returns and net monetary returns followed the similar trend.Sole sorghum recorded the higher B:C ratio than non spiny safflower cultivars this might be due to high cost for petal collection.

CONCLUSION

Cultivation of non spiny safflower is profitable than other competing *rabi*crops and safflower based intercropping systems practiced on vertisols of Marathwada region of Maharashtra provided both seed and petals are sold.

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Evaluation of frontline demonstrations on weed management in rice

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Out of the losses due to various biotic stresses, weeds are known to account for nearly one third. Irrespective of the method of rice establishment, weeds are a major impediment to riceproduction through their ability to compete for resources and their impact on product quality.Uncontrolled weeds reduced the grain yield by 75.8, 70.6 and 62.6% under dry-seeded rice (DSR), WSR and transplanted rice (TPR), respectively (Singh *et al.,* 2009). Despite availability of several new generation selective herbicides for rice with different mechanisms of action, farmers continue to use the same herbicide season after season, which results in reduced efficacy of the herbicide as well as development of herbicide resistance. Further, severe labour scarcity and very high cost of labour hiring in intensively cultivated canal command areas is forcing the farmers to rely entirely on herbicides for weed management. In view of the above factors, frontline demonstrations were conducted on farmer's fields to demonstrate the weed management technology in rice exclusively with herbicides and comparing it with the farmer's practice in terms of yield and economics.

METHODOLOGY

The present study was carried out by KrishiVigyan Kendra, Wyra, of Acharya N. G. Ranga Agricultural University, during *kharif*season of 2011 and 2012 years).In total10 demonstrations on 2 hectare (each demonstration in 2000 m^2area) were conducted on farmers' fields. Farmer's practice (FP) involved application of pretilachlor (0.5 kg/ha) as pre-emergence (PE)at 3 days after transplanting (DAT) followed hand weeding at 30 DAT. Demonstration practice(DP) included application of oxadiargyl (75g/ha)as PE followed by bispyribac sodium (25 g/ha) as post-emergence spray at 25 DAT. All other recommended package of practices fertilizer application, plant protection) wereuniformly followed in both methods.Yield was recorded in the farmer's fields at the time of harvest. The extension gap, technology gap and the technology index were worked out as per formulae.Technology gap = Potential yield – Demonstration yield; Extension gap = Demonstration yield - yield under Farmers practice; Technology index = {(Potential yield – Demonstration yield)/Potential yield} × 100.

RESULTS

Yield advantage of 6.25 % and 7.37 % were recorded during two years demonstration, respectively. Narrow extension gap than the technology gap indicate resource related constraints such as soil fertility, climate suitability, general pest and disease load during the season. The difference in technology gap in different fields is due to better performance of recommended varieties with recommended practices and more feasibility of recommended technologies during the course of study with the other factors like monitoring by farmers, soil

Table 1. Seed yield and gap analysis of FLDs on rice at farmers' field

Year	Potential Yield (kg/ha)	DP Yield (kg/ha)	FP yield (kg/ha)	Yield hike over FP(%)	Extension Gap (kg/ha)	Tech. gap (kg/ha)	Technology index
2011-12	7500	6160	5775	6.25	385	1340	17.87
2012-13	7500	6380	5910	7.37	470	1120	14.93

Table 2. Economic analysis of weed management in rice on farmers' field

Year	Cost of Cultivation (COC)		Gross Returns		Net Returns		Additional returns	Benefit : Cost	
	DP	FP	DP	FP	DP	FP		DP	FP
2011-12	40,010	44,500	70,840	66,142	30,830	21,642	9,188	1.77	1.49
2012-13	41,840	45,600	76,560	70,920	34,720	25,320	9,400	1.83	1.56

type and fertility status of the fields. Lower cost of cultivation due to exclusion of hiring the manual labour for weeding was noticed during both years. Higher yields and lower COC in DP resulted in higher gross and net returns during both years. However, higher B:C in DP (1.77 and 1.83) during both years clearly indicate the potential of this technology (weed management in transplanted rice exclusively with selective combination of herbicides) for adoption, which resulted in efficient weed control and higher yields resulting higher B:C in DP compared FP.

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Effect of weed management practices and fertility levels on weed control and yields of soybean [*Glycine max* (L.) Merr.] in *Hadoti* region of Rajasthan

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Rajasthan is a major soybean growing state having an area of 0.92 m ha next to Madhya Pradesh and Maharashtra. In rainy season, about 85 % area of south-eastern Rajasthan covers by soybean crop without any substitute. Among the various factors of low productivity of soybean, competition by weeds is the major one. In order to achieve enhanced crop production and higher benefits from applied inputs, weeds must be controlled using any of the safe and effective weed control measures. Next to weed management in soybean, nutrient management has also a significant factor in augmenting its production. Hence, the present investigation was undertaken to evaluate the effect of weed management practices and fertility levels on weed control and yields of soybean.

METHODOLOGY

A field experiment was conducted at Agricultural Research Station, Ummedganj, Kota (Rajasthan) during *kharif* 2013 and 2014 to evaluate the impact of weed management practices and fertility levels on weed control and productivity of soybean. The soil of the experimental field was clay loam in textures, alkaline in reaction, medium in organic carbon, available nitrogen and phosphorus, high in available potash and low in available sulphur. The experiment was laid out in split plot design comprising of seven weed management practices in main plot and four fertility levels in sub plots with three replications. Sowing of soybean *cv.* RKS-45 was done in July 2013 and 2014 by drilling 80 kg/ha in rows 30 cm apart. Nitrogen, phosphorus, potash and sulphur were applied through urea (after adjusting N available through di-ammonium phosphate), di-ammonium phosphate, muriate of potash and gypsum, respectively as per treatment at sowing. The RDF for soybean in the zone is 40 kg N, 40 kg P_2O_5, 40 kg K_2O and 30 kg S /ha, respectively.

RESULTS

In the experiment site the most prominent monocot were *Echinochloa* spp, *Cynodondactylon, Cyperusrotundus* whereas among dicot *Celosia argentea, Digeraarvensis, Acalyphaindica and Trianthemaportulacastrum* were dominant species. It can be inferred from results (Table 1) that application of ready mix of imazamox + imazethapyr 75 g/ha at 15 DAS and two hand weeding at 20 and 40 DASwere significantly superior in lowering down weed dry matter of total weeds at harvest in comparison to rest of the treatments during both the years.Pooled results further showed that two hand weeding at 20 and 40 DAS, ready mix of imazamox + imazethapyr 75 g/ha at 15 DAS, imazethapyr 100 g/ha at 15 DAS and pendimethalin 1.0 kg/ha as PE + 1 HW (30 DAS) exhibited 83.6, 77.0, 73.6 and 63.9% reduction in total dry matter of weeds, respectively over weedy check. Similarly, mean weed control efficiency of total weeds at harvest was the highest due to two hand weeding closely followed by ready mix of imazamox + imazethapyr 75 g/ha, imazethapyr alone, pendimethalin +1 HW, quizalofop-ethyl and clodinafop-propargyl with a mean value of 83.71, 77.14, 73.76, 64.24, 34.40 and 32.08 %, respectively. Different fertility levels were also significantly affected the weed dry matter of total weeds during both the years. Pooled data revealed that in comparison to 100 % NPK without sulphur the increase in dry matter of total weed was recorded 9.3, 10.7 & 12.8 % due to 100 % NPK along with sulphur, 125 % NPK without and with sulphur, respectively. All the weed management practices significantly enhanced seed and haulm yield of soybean over weedy check during the study period. On pooled basis, increase in seed yield by two hand weeding, ready mix of imazamox + imazethapyr 75 g/ha, imazethapyr 100 g/ha at 15 DAS,pendimethalin 1.0 kg/ha PE + 1 HW (30 DAS), quizalofop-ethyl 50 g/ha and clodinafop-propargyl60 g/ha was 1311.6, 1121.0, 1051.6, 1007.0, 757.9 and 636.0 kg/hahigher, respectively over weedy check. Similarly, two hand weeding registered the highest soybean haulm yield (3338.3 kg/ha) followed by ready mix of imazamox + imazethapyr 75 g/ha (3058.3 kg/ha) which were significantly superior over weedy check. Weed control treatments facilitated higher photosynthates production and translocation from source to sink, resulting in overall improvement in yield attributing traits and yields as compared to weedy check. Among the fertility levels, application of 100 and 125 % NPK along with sulphur were significantly influenced yields of soybean over 100 % NPK without sulphur, both of these maximized seed yield (1736.5 & 1816.4 kg/ha) and haulm yield (2642.6 & 2755.6 kg/ha) over 100 % NPK without sulphur. Fertility levels can be clearly attributed to better nutritional supply which ultimately favoured better growth environment for the crop.

CONCLUSION

Based on the two years experimentation, it could be concluded that among the herbicidal treatments, post emergence application of ready mix of imazamox + imazethapyr 75 g/ha at 15 DAS produced highest seed yield (2013.79 kg/ha) with

Table 1. Effect of weed management practices and fertility levels on weed dry weight at harvest, weed control efficiency at harvest and yields of soybean (pooled data of two years)

Treatment	Total weeds dry matter (kg/ha) at harvest	Weed control efficiency (%) at harvest	Seed yield (kg/ha)	Haulm yield (kg/ha)
Weed management practice				
Weedy check	2391.31	-	892.79	1371.50
HW (20 and 40 DAS)	390.00	83.71	2204.42	3338.38
Pendimethalin 1.0 kg/ha+ HW (30 DAS)	856.77	64.23	1899.79	2892.71
Imazethapyr 100 g/ha(15 DAS)	626.20	73.76	1944.47	2959.08
Imazamox + Imazethapyr 75 g/ha (15 DAS)	546.09	77.14	2013.79	3058.33
Clodinafop-propargyl 60 g/ha (15 DAS)	1624.41	32.08	1528.79	2342.58
Quizalofop-ethyl 50 g/ha (15 DAS)	1569.60	34.40	1650.75	2520.08
CD (P= 0.05 %)	68.75		101.80	152.65
Fertility level				
100 % NPK without S	1056.71	-	1594.10	2446.71
100 % NPK with S	1155.06	-	1736.50	2642.69
125 % NPK without S	1169.85	-	1787.10	2716.52
125 % NPK with S	1192.32	-	1816.48	2755.60
CD (P= 0.05 %)	42.09		59.57	88.79

77.14 % weed control efficiency of total weeds and crop should be fertilized with 100 % NPK along with sulphur.

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Neem (*Azadirachta indica*) and eucalyptus (*Eucalyptus tereticornis*) tree leaves for soil moisture conservation and weed control in rainfed cotton

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Mechanization resulted in replacement of farm animals leading to FYM scarcity. Furthermore,quantity of crop residues producedis low in a single crop of cotton grown during an entire year. Neem and eucalypt trees are abundant and grown on field bunds and road sides. Neem has been widely researched for itsnitrification inhibition (Prasad *et al*.,2007) and insect pest control (Saxena, 1989). Eucalyptus is also known to emit several volatiles and is grown as an energy plantation crop. Both these trees have potential allelopathic effects and offers possibility to control weeds (Babu and Kandaswamy, 1997; Tilander and Bonzi, 1997). Thus, leaves and wood chippings of these trees can be utilized as a mulching material to conserve soil moisture and control weeds. Afield study was conducted to test the hypothesis that neem and eucalypt tree leaf mulch suppresses weeds.

METHODOLOGY

A field experiment was conducted on the experimental farm of the Central Institute for Cotton Research, Panjri Farm, Nagpur (21° 90′N and 17° 70′E). The soil at the site was a deep Vertisol (Typic Chromustert) with low organic C (4.7 g/kg) and available P (6.1 mg/kg) and high in exchangeable K (300 mg/kg). The soil was alkaline in reaction with a pH of 8.1. Transgenic Bt cotton hybrid (Bunny BG II) was sown with the onset of rains at a row spacing of 0.90 m and plant to plant spacing of 0.60 m. Treatments included mulch application of tree leaves, namely neem and eucalypt (discussed in this paper) besides inter-row cover crops. Weed free (cotton alone) and weedy check treatments were also included. Every treatment was replicated thrice andarranged in a randomized block design. Mulch from the neem and eucalypt trees were collected and surface placed in between the cotton rows at an application rate of 5 Mg/ha (dry weight basis). To determine the soil moisture content, soil was sampled from 0-10 and 10-20 cm soil depth at periodic intervals during the crop season. Soil moisture content was determined gravimetrically. Weed count of the monocot and dicot weeds were taken in all the plots from one square metre quadrants. Weeds from the quadrant were removed and their dry weight recorded. At harvest, seed cotton yield was determined from the 5.4 m long three central rows and ginned to obtain the lint yield. All the data were statistically analyzed using the ANOVA technique. Weed count data were log transformed prior to statistical analysis.

RESULTS

Weed count and dry weight: Application of neem and eucalypt tree leaf mulch significantly reduced weed count of both the monocots and dicots during the crop season (Table 1). Weed count was the least with the eucalypt tree leaf mulch plots followed by the neem leaf mulch and the plots without mulch.Because the eucalypt tree leaf mulch plots had the least weed count, it resulted in the least weed dry matter accumulation. Weed control efficiency of applying mulch ranged from 76 to 87% compared to the normal weed control practice followed in sole cotton (44 to 50%). Weed control efficiency was better with the eucalypt leaf mulch than the neem leaf mulch plots. This indicates that application of mulch further improves weed control efficiency. Soil moisture: From the data on the soil moisture content presented in Figure 1, it is clear that the application of tree leaf mulch improved the soil moisture content in the 0-10 and 10-20 cm soil depth. Soil moisture in the cover treatment plots was nearly 2% greater than the sole cotton plots. Soil samples (0-10 cm) collected on 14 December contained 11.8 to 13.9% the mulched plots compared to 7.1% without mulch. In the lower layers (10-20 cm), the mulch applied plots contained soil moisture

Table 1. Effect of neem and eucalypt tree leaf mulch on weed count

	Broad leaf weeds					Grassy weeds				
	30 Aug	17Sept	5 Oct	22 Oct	7 Nov	30 Aug	17Sept	5 Oct	22Oct	7 Nov
Weedy	10.0c*	10.3c	8.3c	9.3c	7.1c	4.6b	5.7b	11.0b	9.0c	7.0b
Cotton	2.3b	3.7a	6.7b	5.3b	5.7b	1.8a	4.7ab	11.3b	7.0b	6.7b
Eucalypt	0.7a	3.3a	4.7a	3.7a	3.0a	1.0a	3.7a	5.7a	5.3a	3.7a
Neem	1.8ab	5.7b	5.7ab	4.0a	4.0ab	0.3a	3.0a	4.7a	4.3a	5.3ab

*Values followed by the same letter in a column are not significantly different ($P_{0.05}$)

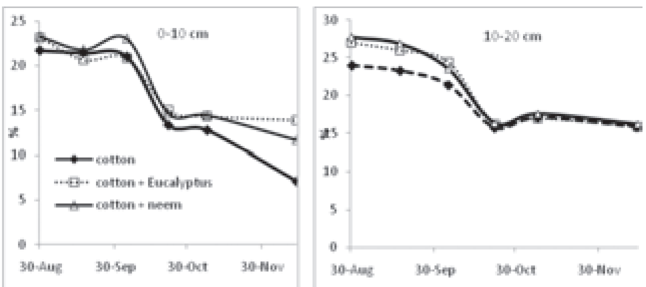

Fig. 1. Effect of neem and eucalypt tree leaf mulch on soil moisture content

content ranging from 24.0 to 27.7%. On the other hand, those without mulch had soil moisture content of 21.4 to 24.0% during the samples collected between 30 August and 5 October. This suggests that the mulch application resulted in better soil moisture conservation due to better infiltration of rain water received. Crop yield: Treatments of neem and eucalyptus leaf mulch produced significantly greater seed cotton yield than those without mulch (2049 kg/ha). Seed cotton yield was the least in the weedy check treatment (707 kg/ha). Among the mulch treatments, neem mulch had higher yield (2788 kg/ha) than the eucalyptus mulch (2635 kg/ha). However, these differences were not significant. This could be due to higher nitrogen supplied by the neem mulch compared to the eucalyptus mulch. Furthermore, neem residues are known to inhibit nitrification which may have contributed to the improvements in nitrogen use efficiency. Overall, yield advantages with the mulch treatments were probably due to combined effects of (i) effective weed control and (ii) soil moisture conservation

CONCLUSION

Leaves of neem and eucalyptus trees applied as mulch resulted in significant weed reduction, higher soil moisture content and significantly higher seed cotton yield than the treatment without mulch. Thus, leaves of neem and eucalypts as mulch can substitute herbicides in conservation tillage systems. Furthermore, it could be utilized as a component in organic production systems.

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Productivity and profitability of cluster bean as influenced by different weed management practices

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Cluster bean[*Cyamopsis tetragonoloba* (L.) Taub.], commonly known as guar, chavli kayi, guari, khutti etc. is a drought-tolerant, annual, arid and semi-arid legume crop grown during kharif season in India. The entire plant as green could be used as fodder and it is one of the most important and potential vegetable cum industrial crop grown for its tender pods for vegetable and for endospermic gum (30-35 %) of course cultivars differ. In India the total area of cluster bean is 5.15 m ha with a production of 2.46 m t green pod and a productivity of 478 kg ha^{-1} (Anonymous. 2013). As cluster bean is a rainy season crop and due to frequent rains, weed population increase tremendously and compete for nutrients, moisture and space with crop causing considerable yield reduction. Besides, this period coincides with the season of peak labour activity and scarcity of labour for weeding is a major constraint. This also adds up to high cost of production. Proper weed management is therefore the prime need and it is very much essential to recommend the growers with proper and effective herbicideto obtain maximum productivity from cluster bean cultivation. Today many herbicides are available and among them Imazethapyr is a imidazolinone herbicide and may be applied pre plant (incorporated), pre-emergence, ground cracking, or post-emergence for effective weed control (Wilcut *et al*., 1995) in many crops and vegetables. Besides, Pendimethalin and Alachlor are used in wide variety of crops. However, information on herbicide usage in cluster bean is lacking. Therefore keeping these points in view, present study was carried out to find out suitable method of weed control/herbicide and their dose for controlling weeds in cluster bean crop.

METHODOLOGY

A field study was conducted during *Kharif* 2014 and 2015 on deep black soil of Agricultural Research Station, Dhadesugur, Raichur district coming under Northern dry zone of University of Agricultural Sciences, Raichur, Karnataka to know the "productivity and profitability of cluster bean as influenced by different herbicidal weed management". The

Table 1. Weed control efficiency, green pod yieldand economicsof cluster bean crop as influenced by integrated weed management practices

Treatment	Weed control efficiency (%)	Green pod yield (t/ha)	Economics (in lakh /ha)			
			Cost of cultivation	Gross returns	Net returns	B:C
T_1: Imazethapyr 10% SL @ 475 ml per ha (47.5 g a.i.)	72.00	10.13	0.57	1.01	0.44	1.77
T_2: Imazethapyr 10% SL @ 625 ml per ha (62.5 g a.i.)	93.14	12.57	0.63	1.26	0.63	2.00
T_3: Imazethapyr 10% SL @ 775 ml per ha (77.5 g a.i.)	95.55	12.65	0.63	1.26	0.63	1.99
T_4: Propaquizafop 10% EC @ 750 ml per ha (75.0 g a.i.)	78.53	10.19	0.60	1.02	0.42	1.70
T_5: Pendimethalin 30% EC @ 5000 ml per ha (1500 g a.i.)	79.28	11.36	0.61	1.14	0.53	1.87
T_6: Alachlor 50% EC @ 4000 ml per ha (2000 g a.i.)	76.26	11.19	0.61	1.12	0.51	1.82
T_7: Hand weeding (weed free)	100.00	13.05	0.82	1.30	0.48	1.59
T_8: Control (weedy check)	0.00	5.34	0.46	0.53	0.08	1.17
CD (P=0.05)	5.18	1.46	0.04	0.15	0.15	0.27

Men and women labour @ 342 each, Tractor hiring @ 500/hr, FYM @ 750 /kg, Urea @ 5.72 /kg, DAP @ 25.32 /kg, MoP @ 18.22/ kg, Mancozeb @ 750/ kg, Monocrotophos@ 400/l, Imazethapyr @ 1820/l, Propaquizapop @ 2400/l, Pendimethalin @ 482/l, Clusterbean green pod @ Rs 10.00/ kg, B:C – Benefit : cost ratio, DAS - Days after spraying,SL- Soluble liquids and EC- Emulsifiable concentrates.

experiment consisted of eight treatments, laid out in randomized complete block design (RCBD) with three replications. The soil of the experimental site was deep black, neutral in pH (8.04), EC (0.47 dS/m) and medium in organic carbon content (0.41 %), low in nitrogen (186 kg/ha), medium in phosphorus (57 kg/ha) and potassium (288 kg/ha). The total rainfall received during first and second seasons was 344.3 mm and 655.6 mm, respectively. The overall pest and disease incidence was least during experimentation period. All recommended agronomic practices were followed to obtain good crop. Pre-emergence herbicide was applied on a day after sowing and Post-emergence herbicide (Imazethapyr 10% SL) was applied 20 days after sowing (2-3 leaf stage). In the different treatments of Imazethapyr 10% SL, 1.5 ml/l of surfactant and 2.0 g/l of ammonium sulphate were added as a tank mix and a spray volume of 500 litres of water per hectare were used with flat fan nozzle attached to the knapsack sprayer. Cluster bean seeds were sown at a spacing of 45 cm X 30 cm and the recommended package of practices were adopted for crop production. Species wise, weed population were recorded before spraying, 15, 30 and 45 days after application of herbicide using quadrates of 0.25 m^2. Further, total dry weight of weeds were recorded and used for calculating weed control efficiency (WCE). The data on weeddensity and dry weight were transformed using square root transformation (Square root of (X + 0.25)) and analyzed statistically.Cluster beanyield was recorded from each plot and converted into $kgha^{-1}$. The cost of inputs, labour charges and prevailing market rates of farm produce were taken into consideration for working out cost of cultivation, gross and net returns per hectare. All the parameters were statistically analyzed by adopting procedure as outlined by Gomez and Gomez (1984).

RESULTS

The major weeds observed in the experimental fields were *Dinebra retroflex, Brachiaria reptans, Panicum javanicum, Cynodon dactylon* (among grasses). The broad leaf weeds observed were *Abutilon hirtum, Achyranthus aspera, Corchorus trilocularis, Datura metal, Merremia emarginata, Parthenium hysterophorus, Clitorea ternate, Phyllanthus mederaspatensis and Solanum nigram.* Hand weeding (weed free) thrice was found superior in terms of weed control efficiency(100%) and green pod yield (13.05 t/ha). However, application of Imazethapyr 10% SL either at 775 ml/ha (77.5 g/ha) or at 625 ml/ha (62.5 g a.i./ha) at 2-3 leaf stage as early postemergence treatment were comparable and at par (Table 1). Among all herbicide treatments, application of Imazethapyr 10% SL @ 775 ml/ha (77.5 g a.i.) at 2-3 leaf stage as early postemergence treatment recorded maximum gross returns(1,26,474/ha) and net returns (63,072/ha) and it was on par with Imazethapyr 10% SL @ 625 ml/ha (62.5 g a.i.) as early pre emergence spray (1,25,658 and 62,849/ha, respectively) compared to Propaquizafop 10% EC 750 ml/ha (75.0 g a.i.)and weedy check treatments. The varied performance of the herbicide on the expected line as former is a broad spectrum herbicide while later is graminicide and the weed flora in the experiment was a mixture of both types. Imazethapyr at lower doses (475 ml/ha) and other broad spectrum herbicide alachlor were also not effective. Again, among all the benefit: cost ratio (2.00) was maximum with Imazethapyr 10% SL @ 625 ml/ha and it was on par with Imazethapyr 10% SL @ 775 ml/ha (1.99).The lowest gross returns (53,442/ha), net returns (7,723/ha) and benefit: cost ratio (1.17) was recorded with weedy check (Table 1).

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Evaluation of weed control efficiency and productivity of herbicide tolerant transgenic maize by post emergence application of glyphosate K salt

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The major yield reducing factors for maize cultivation are weeds and insects. Weeds cause considerable yield loss due to competition for resources with maize crop. Season long competition reduced the grain yield of maize in as much as 70 per cent (Malviya and Singh, 2007). Among the various weed control methods, chemical method is the most economical and effective tool to suppress weeds in order to get healthy crop stand and good yield. Genetic engineering is one form of biotechnological tool that is used to enhance the agronomic characteristics of plants by inserting a gene or sequence of genes that express desirable traits. Herbicide tolerant corn plants that confer tolerance to glyphosate by production of the glyphosate-tolerant CP4 5-enolpyruvylshikimate-3phosphate synthase (*CP4 EPSPS*) proteins. NK603 is the Glyphosate tolerant technology for the effective weed management system. The transgenic corn hybrids were evaluated during w*inter* 2009 and *summer* 2009-10 at experimental site of Tamil Nadu Agricultural University, Coimbatore. Glyphosate was applied as early post emergence application at various doses in transgenic corn hybrids and it's compared with non-transgenic counterparts with pre-emergence application of atrazine with hand weeding. The results revealed that transgenic maize hybrids with various doses of glyphosate application registered higher weed control efficiency higher grain yield.

METHODOLOGY

Field experiment was conducted at Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore during *kharif,* 2009 and *rabi,* 2009-10. Glyphosate was applied as early post emergence application at 900, 1800 and 3600 ga.e./ha in Hishell and 900 M Gold transgenic maize hybrids and these were compared with non-transgenic counterparts with PE atrazine at 0.5 kg/ha *followed by* hand weeding on 40 DAS and with and without insect management. Observations on weeds, crop growth parameters such as germination, plant height, yield attributes and yield were recorded.

RESULTS

Weed flora of the experimental fields consisted of predominantly broad leaved weeds, grassy weeds and a sedge weed. The predominant broad leaved weeds were *Trianthemaportulacastrum*, *Cleome gynandra*, *Digeraarvensis* and *Cyanotisaxillaris*. Among the grassey weeds, *Cynodondactylon* and *Dactylocteniumaegyptium* were dominant. *Cyperusrotundus* was the only sedge weed found in the experimental fields. Significantly lesser and comparable density of total weeds was achieved with PE application of atrazine at 0.5 kg/ha *followed by* hand weeding under non-transgenic Hishell. Relatively, higher density and dry weight were observed under unweeded checks and transgenic maize plots before imposing post emergence application of glyphosate. At 40 DAS, significantly lesser and comparable density of weeds were observed under transgenic 900 M Gold with POE application of glyphosate at 3600 g a.e./ha during *kharif*, 2009. Whereas during *rabi*,2009-10 POE application of glyphosate at 1800 and 3600 g a.e./ha under transgenic Hishell and 900 M Gold registered significantly lesser density of weeds. This was closely followed by POE glyphosate at 900 g a.e ha^{-1} under the same hybrids at 40 DAS.The findings are in accordance with Reddy and Boykin (2010) who reported that three post emergence application of glyphosate reduced total weed density and weight by at least 97 per cent. Higher weed control efficiency of 86.42% and 81.21% was recorded with the application of atrazine at 0.5 kg/ha*fb* HW under CoHM 5 maize hybrid during *khraif*, 2009 and *rabi*, 2009-10 respectively. Whereas at 40 DAS, transgenic 900 M Gold maize hybrid applied with POE glyphosate at 3600 g a.e./ha recorded maximum weed control efficiency of 99.68% and 98.51% during *khraif*, 2009 and *rabi*, 2009-10 seasons respectively.Among the treatments evaluated, POE applica-

Table 1. Effect of weed control methods on weed control efficiency and yield of maize

Treatment	Weed Control Efficiency at 60 DAS		Grain yield (t/ha)	
	Kharif, 2009	*Rabi,* 2009-10	*Kharif,* 2009	*Rabi,* 2009-10
T_1 - T. Hishell POE glyphosate @ 900 g/ha	95.10	91.58	11.19	8.96
T_2 - T. Hishell POE glyphosate @ 1800 g/ha	96.77	97.27	11.64	9.86
T_3 - T. Hishell POE glyphosate @ 3600 g/ha	98.45	98.69	11.78	10.12
T_4 - T. 900 M Gold POE glyphosate @ 900 g/ha	93.59	92.05	11.3	9.33
T_5 - T. 900 M Gold POE glyphosate @ 1800 g/ha	96.00	96.87	12.01	10
T_6 - T. 900 M Gold POE glyphosate @ 3600 g/ha	98.65	99.31	11.68	9.92
T_7 - Hishell PE atrazine @ 0.5 kg/ha+ HW+ IC	90.20	87.28	10.52	8.89
T_8 - Hishell No WC and IC	-	-	7.57	6.36
T_9 - 900 M Gold PE atrazine @ 0.5 kg/ha+ HW+ IC	89.51	85.04	10.27	9.27
T_{10} - 900 M Gold No WC and IC	-	-	7.61	7.19
T_{11} - Proagro PE atrazine 0.5 @ kg/ha+ HW+ IC	88.61	82.99	8	6.95
T_{12} - Proagro 4640 No WC and IC	-	-	5.98	5.62
T_{13} - CoHM 5 PE atrazine @ 0.5 kg/ha+ HW+ IC	89.27	84.73	8.04	7.15
T_{14} - CoHM 5 No weeding & IC	-	-	6.08	5.73
SEd±	-	-	0.72	1.09
CD (P=0.05)	-	-	1.46	2.18

tion of glyphosate at 1800 g a.e./ha in transgenic 900 M Gold maize hybrid resulted in higher grain yield of 12.01 t ha^{-1}during *kharif*, 2009 and POE application of glyphosate at 3600 g a.e./ha in transgenic Hishell maize hybrid resulted in higher grain yield of 10.12 t/haduring *rabi*, 2009-10. The findings are in accordance with observation of Tharp *et al.,* 1999 who had earlier reported that maize yields of herbicide resistant hybrids were maximum with glyphosate at 0.84 kg a.e./ha of glyphosate when applied at fifth leaf stage of maize.

CONCLUSION

Post emergence application of glyphosate at 1800 and 3600 g a.e./ha in transgenic maize hybrids resulted in lower weed density and weed dry weight with higher weed control efficiency. Higher grain yield was recorded with post emergence application of glyphosate at 1800 g a.e./ha in transgenic 900 M Gold and 3600 g a.e./ha in transgenic Hishell during *kharif,* 2009 and *rabi,* 2009-10 seasons, respectively.

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Weed dynamics and productivity of kharif greengram under pre and post-emergence application of herbicides

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Greengram (*Vignaradiata*L.) is one of the most important and extensively cultivated pulse crops. Due to severe infestation of annual and perennial weeds in *kharif*greengram, the potential yield is generally not realized. Adoption of physical methodsintime on a large scale in different situations may not be feasible under such circumstances use of herbicides under such conditions is found to be advantageous as the operation is not only economical but also provides timely controls of weeds. It was evident that application of certain selective herbicide effectively controls group of weed species. Hence, the experiment was conducted with objectives to find out appropriate dose of herbicide/herbicide mixtures either pre-emergence or post-emergence for timely control of weeds in *kharif* greengram.

METHODOLOGY

A field experiment was conducted at AICRP-Weed Management farm, B.A. College of Agriculture, Anand Agricultural University, Anand (Gujarat) during *kharif*2014. The soil of the experimental field was sandy loam in texture having low in available nitrogen, medium in available phosphorus and high in available potassium with pH 8.1. The experiment was laid out in randomized complete block design with four replications. Twelve treatments comprised of imazethapyr70 and 80 g/ha as PRE and POST imazethapyr + imazamox (RM) 70 and 80 g/ha asPRE and POST pendimethalin 1000 g/ha PE, imazethapyr + pendimethalin (RM) 1000g/ha PE, hoeing at 20 and 40 DAS and weedy check. Greengram cv. Meha wassown keeping the distance of 45 cmbetween two rows with adoption of all the recommended packageof practices. Theweed density and dry biomass of weeds wererecorded at 40 DAS. Weed control efficiency (WCE) wascalculated on the basis of standard formula assuggested by Maity and Mukherjee (2011). Benefit cost ratio was also worked out byconsidering the prevailing market price.

RESULTS

The predominant weed species of monocot and dicot was *Eleusineindica*and *Digeraarvensis,* respectively observed in experimental field. The results indicated that pre-emergence application of imazethapyr + pendimethalin 1000g/ha recorded significantly lowertotal dry biomass of weeds (8.6 g/m^2) with 95% weed control efficiency at 40 DAS, but it was remained at par with hoeing at 20 and 40 DAS(Table 1). The highestWCE with IC *fb*HW at 20 and 40 DAS was also observed by Chhodavadia*et al*. (2013).The dry biomass of *Rhizobium* root nodule at 35 DAS was not significantly influenced due to different weed management practices. All the

Table 1. Effect of weed management practices on weed dry biomass, seed and haulm yield and economics as influenced by different weed management practices in greengram

S. No.	Treatment	Total weed dry biomass (g/m²) at 40 DAS	Dry biomass of *Rhizobium* root nodule (mg/plant)	Seed yield (kg/ha)	Haulm yield (kg/ha)	WCE (%) at 40 DAS	B:C ratio
T_1	Imazethapyr 70 g/ha PE	5.81[cd](33.2) *	69.4	1258[ab]	2099[ab]	81	2.54
T_2	Imazethapyr 80 g/ha PE	5.10[de](25.4)	67.4	1366[a]	2062[ab]	85	2.72
T_3	Imazethapyr 70 g/ha PoE	5.65[cd](31.0)	68.5	1373[a]	2025[ab]	82	2.76
T_4	Imazethapyr 80 g/ha PoE	5.10[de](24.0)	68.7	1466[a]	1914[ab]	86	2.90
T_5	Imazethapyr + imazamox 70 g/ha PE (RM)	6.38[c](40.0)	68.2	1366[a]	1957[ab]	77	2.70
T_6	Imazethapyr+imazamox80 g/ha PE (RM)	4.46[ef](19.0)	64.8	1281[ab]	1946[ab]	89	2.51
T_7	Imazethapyr + imazamox70 g/ha PoE (RM)	6.31[c](39.0)	63.2	1281[ab]	1874[ab]	77	2.53
T_8	Imazethapyr + imazamox80 g/ha PoE (RM)	6.02[cd](35.4)	61.7	1011[bc]	1640[bc]	80	1.99
T_9	Pendimethalin 1000 g/ha PE	8.76[b](76.3)	63.5	1173[ab]	1645[bc]	56	2.31
T_{10}	Imazethapyr + pendimethalin 1000g/ha PE (RM)	3.03[g](8.6)	66.9	1435[a]	2275[a]	95	2.80
T_{11}	Hoeing at 20 and 40 DAS	3.63[fg](12.6)	72.3	1335[ab]	2062[ab]	93	2.80
T_{12}	Weedy check	13.19[a](173.4)	70.5	818[c]	1227[c]	-	1.81
	SEm ±	3.54	2.31	105.16	136.36	-	-
	CD (P=0.05)	S	NS	S	S	-	-
	CV %	16.4	6.9	16.65	17.04	-	-

* Values in parentheses are original. Data transformed to square root transformation. Treatment means with theletter/letters in common are not significant by Duncan's New Multiple Range Test at 5 % level of significance.

weed management practices produced significantly higher seed and haulm yield of greengram as compared to weedy check (Table 1). Among the weed management practices, post-emergence application of imazethapyr 80 g/ha resulted in significantly higher seed yield (1466 kg/ha) whereas, application of imazethapyr + pendimethalin 1000 g/ha gave significantly higher haulm yield (2275 kg/ha) of greengram,but both were remained at par with all the treatments except imazethapyr + imazamox 80 g/ha POST for seed yield and imazethapyr + imazamox 80 g/ha POST and pendimethalin 1000 g/ha PE for haulm yield. Further it was observed thatimazethapyr + imazamox 80 g/ha gave significantly lower seed yield due to phytotoxic effect of applied herbicide on crop at early growth stage. Significantly thelowest seed and haulm yield (818 and 1227 kg/ha) was recorded in weedy check due to higher density and vigorous growth of weedscreated more competition with crop resulted in lower seed yield. Similar line of results was also reported by Raj *et al.* (2012) in greengram. The growth parameters and seed yield of succeeding mustard crop were notinfluenced significantly due to different herbicides applied in preceding greengram crop as individual or as mixtures. This indicated that there was no any carry over/residual effect of herbicide noticed on succeeding crop. The results of the economic analysis of the weed management practices revealed that maximum benefit cost ratio (2.90) was recorded in imazethapyr 80 g/ha POST followed by imazethapyr + pendimethalin 1000 g/ha PE, hoeing at 20 and 40 DAS, imazethapyr 70 g/ha POST, imazethapyr 80 g/ha PE and imazethapyr + imazamox 70 g/ha PE. Similarly, Patel *et al*. (2016) also observed higher B:C ratio with IC*fb*HW at 20 and 40 DAS and use of imazethapyr with integration of IC*fb*HW at 30 DAS in greengram.

CONCLUSION

In paucity of labours, imazethapyr 80 g/ha PoE or imazethapyr + pendimethalin 1000 g/ha PE or hoeing at 20 and 40 DAS or imazethapyr 70 g/ha PoEor imazethapyr 80 g/ha PE or imazethapyr + imazamox 70 g/ha PEcan safely be used to control weeds in green gram without any residual carry over effect on succeeding mustard crop.

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Efficacy of herbicides on growth, yield attributes and yields of soybean

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Soybean (*Glycine max* (L.) Merill) plays an important role in boosting oilseed production in the country. It stands second, among the nine oilseed crops, next only to groundnut in production in the Country. It has outstanding nutritive value with 43% biological protein, 20% oil and is also very rich in vitamins, iron, mineral, salts and amino acids. The various grassy and broad leaf weeds emerge simultaneously with the crop plants and compete for essential nutrients, moisture, sunlight and space, causing substantial loss in yield (35-55%), depending on the types of weed flora and density. Due to intermittent rainfall during rainy season and scanty labour, manual weeding at right stage is difficult and time consuming and expensive, so farmers rarely adopt this practice for weed control. Under such situation, the use of herbicides could be more effective and time saving. Therefore, this study was conducted on weed management in soybean grown in Marathwada to find out agro-economic feasibility and its impact on grain yield.

METHODOLOGY

The field experiments were conducted at Research Farm, Department of Agronomy, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani during *kharif* seasons of 2013-14. The experimental site was clayey in texture, slightly alkaline in reaction, low in organic carbon, low in available nitrogen, medium in available phosphorus and high in available potassium. The experiment was laid out in randomized block design (RBD) with three replications. Six weed control treatments *viz.,* (W_1) imazethapyr + imazamox (PoE) 70% WG @100 g/ha at 30 DAS, (W_2) chlorimuron (PE) @ 9 g a.i./ha *fb* quizalfop ethyl @ 20 g a.i./ha at 30 DAS, (W_3) pendimethalin (PE) @ 750 g a.i./ha *fb* one hand weeding at 30 DAS, (W_4) imazethapyr (PoE) @ 750 g a.i./ha at 30 DAS,(W_5) weed free, W_6) weedy check. POE herbicides are applied at 25 to 30 days after sowing (DAS) in 500 litres water/ha using flat fan nozzle during the year 2013, respectively. While observations on grain yield and yield attributing parameters *viz*., number of branches/plant, pods/plant, seeds/pods and seed index were recorded at harvest. All the data were subjected to analyses with standard statistical procedure.

RESULTS

Weed free treatment gave maximum and significantly higher plant height (49.31 cm), branches/plant (5.19), pods/plant (23.04), weight of pods/plant (5.95) and seed yield (1462.87 kg/ha) compared to weedy check (Table 1). Application of imazethapyr + imazamox (Odyssey) 70% WG (PoE) @ 100 g/ha at 30 DAS recorded maximum yield attributes and seed yield (1332.66 kg/ha). Application of imazethapyr + imazamox (Odyssey) as early post-emergence produced better yield attributing characters as compared to weedy check an account of maximum reduction in weed growth coupled with no inhibitory effects on soybean plants. The lowest seed yield (965.80 kg/ha) was observed in weedy check treatment and it was due to severe computational stress right from crop establishment up to the end of critical period of crop growth, leading to poor growth, yield attributing traits and finally the yield. However, it may be inferred that weed free environment can be facilitated for better growth and crop development.

Table 1. Efficacy of herbicides on growth, yield attributes and yields of soybean

Treatment	Plant height (cm)	Pods/plant (g)	Weight of pods/plant (g)	Seed yield (kg/ha)
W_1 - Imazethapyr + Imazamox 70% WG (PoE) @ 100 g/ha at 30 DAS	46.79	20.48	5.39	1332.66
W_2 - Chlorimuron @ 9 g a.i./ha *fb* Quizalfopethyl @ 20 g a.i./ha at 30 DAS	44.74	18.00	4.86	1200.11
W_3 - Pendimethalin (PE) @ 750 g a.i./ha *fb* one hand weeding at 30 DAS	45.61	18.46	4.91	1267.11
W_4 - Imazethapyr (PoE) @ 750 g a.i./ha at 30 DAS	43.83	16.34	4.52	1164.11
W_5 - Weed free	49.31	23.04	5.95	1462.87
W_6 - Weedy check	39.00	14.20	3.93	965.80
SEm±	1.80	0.96	0.29	90.40
CD (P=0.05)	5.56	2.96	0.91	278.56

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Critical period of crop-weed competition in *rabi* castor

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India is the global leader in the production and trade of castor having 14.69 lakh hectare area and 23.39 lakh tonnes production with a productivity of 1592 kg/ha in the year 2011-12 (Anonymous, 2013). Weeds are one of the major causes for the poor yield of castor as they compete with the crop for moisture, nutrients, light and space. Therefore, determination of critical period becomes imperative for planning weed management programme and to curtail unwise expenditure towards weed management practices. Less scientific information is available for castor in South Gujarat in this matter and hence, this experiment was planned with an objective to find out critical period of crop-weed competition in *rabi* castor.

METHODOLOGY

A field experiment was conducted during *rabi* season in two consecutive years from 2010-11 to 2011-12 at Instructional Farm, N.M. College of Agriculture, Navsari Agricultural University, Navsari. Twelve treatments were evaluated with three replications in a randomized block design (RBD). The sowing of castor var. GCH-7 was done at a spacing of 120 cm x 60 cm by manual labourers and fertilized as per recommended dose (80-17.4-0 kg NPK/ha). The whole dose of phosphorus in the form of SSP and half dose of nitrogen in the form of urea were applied evenly in furrows before sowing. Remaining half dose of nitrogen was top dressed in two equal splits at 50 and 75 days after sowing. Data on weed growth, castor yield and economics were recorded.

RESULTS

The experimental field was infested by number of weed species comprising of monocot weeds *viz., Echinochloa crusgalli* (L.) Beauv, *Digitaria sanguinalis* L. and *Eragrostis major,* dicot weeds viz., *Amaranthus viridis* L., *Alternanthera sessilis*., *Digera arvensis* Forsk., *Convolvulus arvensis* L., *Trienthma portulacastrum* L., *Euphorbia hirta* L., *Physalis minima* L., *Euphorbia mudarosptiensis* and among sedges *Cyperus rotundus* L. was predominant during the course of experimentation. Significantly higher seed yield (254.2 g/plant and 2.365 t/ha) were recorded under treatment of weed free up to harvest which was remained statistically at par with the treatment weed free up to 90 DAS and weed free up to 120 DAS. Weedy condition up to 90 DAS, 120 DAS and up to harvest recorded 47.7, 56.5 and 56.5 percent yield reduction, respectively, as compared to the treatment weed free up

Table 1. Castor seed **y**ield, quality, economics, weed index (%) and weed control efficiency (%) as influenced by different treatments (Pooled data over 2 years).

Treatment	Yield (t/ha)	Oil yield (t/ha)	Net realization ($x10^3$/ha)	BCR	Weed index (%)	Weed control efficiency (%)
Weed free up to 30 DAS	1.37	0.64	24.3	2.31	37.05	11.52
Weed free up to 60 DAS	1.84	0.86	35.4	2.61	19.71	37.24
Weed free up to 90 DAS	2.23	1.04	46.6	3.02	4.69	65.01
Weed free up to 120 DAS	2.35	1.10	46.3	2.72	0.73	89.80
Weed free up to harvest	2.37	1.11	45.4	2.59	-	100.00
Weedy up to 30 DAS	2.06	0.97	39.4	2.58	11.03	88.34
Weedy up to 60 DAS	1.56	0.73	26.8	2.22	30.11	59.67
Weedy up to 90 DAS	1.24	0.58	17.8	1.85	42.80	35.96
Weedy up to 120 DAS	1.03	0.48	12.6	1.65	50.62	19.06
Weedy up to harvest	1.01	0.46	15.6	1.97	51.31	0.00
Two hand weeding and interculturing at 30 and 60 DAS	2.11	0.99	43.8	2.99	9.37	59.53
Pendimethalin @ 1 kg/ha (as pre-emergence) + one hand weeding and interculturing at 60 DAS	2.14	1.00	46.3	3.26	8.18	57.31
CD (P=0.05)	0.29	0.14				

to harvest. Oil content in seed was found unaffected due to different treatments. However, the highest oil yield (1.11 kg/ha) was recorded with treatment weed free up to harvest and remained at par with the treatment weed free up to 90 DAS and weed free up to 120 DAS. These findings are in close agreement with those reported by Patel (2011) in castor. Treatment weed free up to 120 DAS recorded the lowest weed index (0.73 %) followed by the treatment weed free up to 90 DAS (4.69 %). Similarly, highest weed control efficiency was recorded under the treatment weed free up to harvest (100%) followed by the treatment weed free up to 120 DAS (89.80), weedy up to 30 DAS (88.34) and weed free up to 90 DAS (65.01). This might be due to effective weed control achieved under these treatments in terms of reduced biomass of weeds and higher weed control competence. Results were also almost similar reported by Patel *et al.* (2007) in long duration sugarcane crop. The highest net realization (46.6 x 10^3/ha) was obtained in treatment of weed free up to 90 DAS with BCR value of 3.02 followed by the treatment weed free up to 120 DAS and weed free up to harvest among different treatments of critical period of crop weed competition in castor.

CONCLUSION

Thus, it can be concluded that to realize the potential economical yield of castor with reducing the weed competition, crop should be kept weed free up to initial 90 days after sowing, which is more crucial for crop weed competition.

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Bioefficacy evaluation of herbicides for weed management in pre-monsoon groundnut (*Arachis hypogaea*)

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Groundnut is the predominant *kharif* crop of Saurashtra region. In irrigated area of south Saurashtra, pre-monsoon sowing of groundnut is very common. Generally farmers do not apply pre-emergence herbicides, which cause subsequent heavy infestation of weeds. So farmers are doing repeated manual weeding and interculturing leading to increased cost of cultivation besides creating interference to pegging and pod development. The problem can be further aggravated by unpredictable weather conditions as well as rising price and scarcity of farm labourers. These all together warrants for alternate effective and economical weed management specifically by pre- and post-emergence herbicides. In search of new herbicide molecules, the present field investigation was, therefore, conducted to tackle the weed problem in pre-monsoon groundnut.

METHODOLOGY

A field experiment was conducted at Junagadh (Gujarat) during *kharif* seasons of 2012 to 2014. The soil of the experimental plot was clayey in texture and slightly alkaline in reaction (pH 7.9 and EC 0.39 dS/m) as well as low in available nitrogen (226-239 kg/ha), available phosphorus (19-22 kg/ha) and medium in available potash (275-363 kg/ha). The experiment comprising of 10 treatments *viz*., T_1: Pendimethalin 30% EC @ 0.90 kg a.i./ha PE *fb* IC & HW at 40 DAS, T_2: Pendimethalin 38.7% CS @ 0.75 kg a.i./ha PPI *fb* IC & HW at 40 DAS, T_3: Oxyfluorfen 0.24 kg/ha PE *fb* IC & HW at 40 DAS, T_4:Quizalofop-ethyl 40 g/ha POE at 20 DAS *fb* IC & HW at 40 DAS, T_5:Imazethapyr 75 g/ha POE at 20 DAS *fb* IC & HW at 40 DAS, T_6: Oxadiargyl 90 g/ha POE at 20 DAS *fb* IC & HW at 40 DAS, T_7:Propaquizafop 90 g/ha POE at 20 DAS *fb* IC & HW at 40 DAS, T_8: IC & HW at 20 & 40 DAS, T_9: Weed free (IC & HW at 15, 30, 45 & 60 DAS) and T_{10}:Unweeded controlwas laid out in randomized block design with three replications. The groundnut variety 'GG 20 was sown at 60 cmrow spacing using seed rate of 120 kg/ha. The

Table 1. Effect of integrated weed management on growth and yield attributes of groundnut (Pooled over three years).

Treatment	Plant height (cm)	Pods/ plant	100-kernel weight (g)	Shelling (%)	Oil content (%)
Pendimethalin 30% EC	30.09	11.87	52.66	71.52	49.51
Pendimethalin 38.7% CS	30.52	12.52	53.12	72.26	49.64
Oxyfluorfen	29.12	11.07	52.39	70.94	49.43
Quizalofop	27.42	9.76	50.43	68.81	48.58
Imazethapyr	28.00	10.13	50.84	69.73	48.93
Oxadiargyl	26.71	8.48	49.32	67.47	47.75
Propaquizafop	27.11	9.23	49.83	68.32	48.11
IC & HW twice	28.53	10.66	51.10	70.44	49.22
Weed-free check	30.70	12.84	53.60	72.80	49.70
Weedy check	23.10	5.39	41.70	65.07	47.13
S.Em.±	0.76	0.32	0.82	1.38	0.61
CD (P=0.05)	2.15	0.90	2.33	3.91	1.73

Table 2. Effect of integrated weed management on yield of groundnut and weed dry weight (Pooled over three years).

Treatment	Pod yield (kg/ha)	Haulm yield (kg/ha)	Weed dry weight (kg/ha)	WCE (%)	B:C
Pendimethalin 30% EC	1538	2472	247	87.93	1.81
Pendimethalin 38.7% CS	1580	2533	156	92.40	1.87
Oxyfluorfen	1487	2318	335	83.64	1.71
Quizalofop	1112	1841	1011	50.66	1.32
Imazethapyr	1182	1991	928	54.68	1.39
Oxadiargyl	827	1477	1688	17.62	0.98
Propaquizafop	942	1724	1520	25.81	1.12
IC & HW twice	1378	2194	613	70.06	1.58
Weed-free check	1676	2643	41	98.02	1.69
Weedy check	441	1042	2048	0.00	0.61
S.Em.±	46	84	44		
CD (P=0.05)	131	237	124		

crop was fertilized with 12.5-25-0 kg N-P_2O_5-K_2O/ha as basal. The pre-emergence herbicides were applied to soil on next day of sowing, while post-emergence spray was done at 40 DAS. The spray volume herbicide application was 500 L/ ha. The crop was raised as per the recommended package of practices.

RESULTS

Significantly the highest plant height, pods/plants, 100-kernel weight, shelling percentage and oil content were recorded under the weed-free check, however it remained mostly at par with pendimethalin 38.7% CS @ 0.75 kg a.i./ha PPI *fb* IC & HW at 40 DASand pendimethalin 30% EC @ 0.90 kg a.i./ha PE *fb* IC & HW at 40 DAS.Whereas, significantly the lowest values of these growth and yield attributes were registered under the weedy check. The weed-free check out yielded by producing significantly the highest mean pod yield of 1676 kg/ha and haulm yield of 2643 kg/ha over three years. The next best treatments in this regard were pendimethalin 38.7% CS @ 0.75 kg a.i./ha PPI *fb* IC & HW at 40 DAS and pendimethalin 30% EC @ 0.90 kg a.i./ha PE *fb* IC & HW at 40 DAS. These treatments increased pod yield by 280, 258 and 249% over the unweeded control having B:C ratio of 1.69, 1.87 and 1.81, respectively. Efficient control of weeds and improved growth and yield attributes under these treatments might have reflected in increased pod and haulm yields. The weed-free recorded significantly the lowest dry weight of weeds, followed by pendimethalin 38.7% CS @ 0.75 kg a.i./ha PPI *fb* IC & HW at 40 DAS and pendimethalin 30% EC @ 0.90 kg a.i./ha PE *fb* IC & HW at 40 DAS having WCE of 98.02, 92.40 and 87.93%, respectively.

CONCLUSION

It was concluded that effective control of weeds in pre-monsoon groundnut along with higher yield could be achieved by pre-plant incorporation of pendimethalin 0.75 kg/ha or pre-emergence application of pendimethalin 0.9 kg/ha supplemented with IC & HW at 40 DAS under south Saurashtra agro-climatic conditions of Gujarat.

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Weed management in coriander

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India is known as the 'Home of spices' from very ancient times. Spices play pivotal role in human diet as well as they give an agreeable flavor and aroma to food, which add greatly to the pleasure of eating. Among the various factors known to augment the crop production, the weed management is the key factor. Coriander, a short-stature crop, seed takes longer time for germination and also having slow early vegetative growth, the crop is very sensitive to early weed competition. Uncontrolled weed can reduce coriander seed yield by 82% (Sagarka *et al*., 2005).

METHODOLOGY

A field experiment was conducted during 2012-13 and 2013-14 at the Research Farm, Navsari agricultural University, Navsari, Gujarat. The soil was clay in texture, having 0.53% organic C, medium in available nitrogen (267 kg/ha) and phosphorus (32.1 kg/ha), fairly rich in available potassium 152 (342 kg/ha) and slightly alkaline in reaction (pH 7.9) with normal electrical conductivity (0.33). The experiment consisted of ten weed management treatments *viz*., Pendimethalin 1.0 kg/ha (PE), Pretilachlor 1.5 kg/ha (PE), Pendimethalin 1.0 kg/ha (PE) + Quizalofop ethyl 0.04 kg/ha at 20 DAS, Pendimethalin 1.0 kg/ha (PE) + Metribuzin 0.30 kg/ha at 20 DAS, Pretilachlor 1.5 kg/ha (PE) + Quizalofop ethyl 0.04 kg/ha at 20 DAS, Pretilachlor 1.5 kg/ha (PE) + Metribuzin 0.30 kg/ha at 20 DAS, Quizalofop ethyl 0.04 kg/ha at 20 DAS + One hand weeding 40 DAS, Metribuzin 0.30 kg/ha at 20 DAS + One hand weeding 40 DAS, Two hand weeding at 20 and 40 DAS and Weedy check (Control) were evaluated on coriander *cv*. Gujarat coriander-2. The experiment was laid out in Randomized Block Design with four replications.

RESULTS

The lower dry weight of weeds were recorded at 40 DAS (16.9 g) and at harvest (549 kg/ha) with treatment W_9 (Two hand weeding at 20 and 40 DAS) due to hand weeding (Table 1). It was statistically at par with treatment W_3 at 40 DAS and treatment W_7 at harvest. Treatment W10 (weedy check) recorded significantly the highest dry weight of weeds (1744 kg/ha). The highest weed control efficiency (WCE) was registered under W_9 (Two hand weeding at 20 and 40 DAS) as

Table 1. Weed growth and weed control efficiency as influenced by weed management

Treatment	Dry weight of weeds 40 DAS (g/m²)	Dry weight of weeds At harvest (kg/ha)	WCE (%)	WI (%)	Seed yield (kg/ha)	Straw yield (kg/ha)	BCR
Pendimethalin 1.0 kg/ha (PE)	75.7	1207	34.01	27.82	539	1319	1.29
Pretilachlor 1.5 kg/ha(PE)	86.2	1413	24.83	33.40	498	1297	1.24
Pendimethalin 1.0 kg/ha(PE) + Quizalofop ethyl 0.04 kg/ha at 20 DAS	23.8	882	79.30	–	747	1977	1.66
Pendimethalin 1.0 kg/ha (PE) + Metribuzin 0.30 kg/ha at 20 DAS	47.5	946	58.56	8.24	686	1714	1.57
Pretilachlor 1.5 kg/ha (PE) + Quizalofop ethyl 0.04 kg/ha at 20 DAS	35.8	1015	68.81	18.46	609	1592	1.39
Pretilachlor 1.5 kg/ha (PE) + Metribuzin 0.30 kg/ha at 20 DAS	57.5	1084	49.87	14.13	642	1605	1.52
Quizalofop ethyl 0.04 kg/ha at 20 DAS + One hand weeding 40 DAS	41.4	697	63.89	21.81	584	1577	1.33
Metribuzin 0.30 kg/ha at 20 DAS + One hand weeding 40 DAS	59.2	783	48.39	18.77	607	1581	1.42
Two hand weeding (20 & 40 DAS)	16.9	549	85.27	3.28	723	1928	1.65
Weedy check (Control)	114.7	1744	0	41.08	440	1169	1.18
SEm±	2.96	82.78			25.04	73.90	
CD (P=0.05)	9.48	264.83			80.10	236.43	

*Data in parentheses indicate actual values and outside parentheses indicate (X+1) transformed values, WCE: weed control efficiency, WI: weed index weed free and lowest in W_{10} (Weedy check). Amongst treatments, the highest WCE (79.30%) was registered under treatment W_3 (Pendimethalin 1.0 kg/ha as pre-emergence + Quizalofop ethyl 0.04 kg/ha at 20 DAS) followed by treatment W_5, W_7 and W_4. The lower WI of 0.00, 3.28 and 8.24% were recorded under treatments W_3 (Pendimethalin 1.0 kg/ha as pre-emergence + Quizalofop ethyl 0.04 kg/ha at 20 DAS), W_9 and W_4, respectively. Seed and haulm yield were produced significantly higher under treatment W_3 and it was found at par with treatment W_9. The increase in seed and haulm yield over weedy check was 69.77 and 69.11% due to treatments W_3 and W_9, respectively. Among the various weed management treatments, pre-emergence application of Pendimethalin 1.0 kg/ha as pre-emergence + Quizalofop ethyl 0.04 kg/ha at 20 DAS (W_3) secured highest BCR of 1.66, which was closely followed by BCR of 1.65 under treatment W_9 (Two hand weeding at 20 and 40 DAS).

CONCLUSION

Application of pendimethalin 1.0 kg/ha *fb* quizalofop ethyl 0.04 kg/ha at 20 DAS were found most effective by reducing dry weight of weeds with higher seed (747 kg/ha) and straw yields (1977 kg/ha) and BCR of 1.66 in coriander.

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Disease suppression and improvement in yield of turmeric (*Curcuma longa*) through biologically means

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Traditional agricultural systems increase food production per acre but can deplete natural resources and degrade crop and environmental health. By implementing organic farming as an alternative production system, growers may substitute cultural and biological inputs for synthetically-made chemicals and fertilizers that still provide effective pest and disease management.Organic farming is a crop production method which encourages sustainable agriculture by enhancing the biological cycles in nature. It is targeted for producing healthy, nutritive and pollution free food, by maximizing the use of on farm resources and minimizing the use of off-farm resources. It seeks to avoid the use of chemical nutrients and pesticides. In this direction, a field experiment was carried out during 2015 and 2016 with the concept of organic nutrient management for cultivation of turmeric. The experiment was laid out in randomized block design and replicated three times with 11 treatments *i.e.* Control (T_1), Mancozeb seed treatment (T_2), Neemcake soil treatment (T_3), *Trichoderma viride* seed treatment (T_4), *Pochoniachla mydosporia* Bioagents (T_5), Bordeaux mixture 1% spray- when acute problem (T_6), Neem oil (0.5%) spray (T_7), *Bacillus subtilis* seed treatment (T_8), Neemgold (0.5%) spray (T_9) were examined. Different treatments of organic input significantly affected the growth attributing characteristics of turmeric. However, seed treatment with *Trichoderma viride* (T4) was found more effective in comparison to all other treatments followed by chemically seed treatment with Mancozeb (T2). Seed treatment with *Trichoderma viride* also significantly affect the growth characteristics of the plant like height, leaf length and leaf width per plant showing the value of 104.45 cm, 48.13 cm and 13.75 cm respectively in comparison to all the treatments. Number of leaves per plant was found non-significant in all the treatments. The disease incidence score (%) was showed up to 11.54% in the control and minimum (2.17%) in the treatment T_4 (*Trichoderma viride* seed treatment).

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Effect of herbicides on seed yield, economics and oil content of linseed

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Globally, linseed is an important oilseed crop grown widely in Asia, America and Europe for both seed and fibre with its production of 22.39 lakh tonnes from 22.70 lakh ha with productivity of 986 kg/ha, while our national production is 1.47 lakh tonnes from an area of 3.38 lakh ha with productivity of 435 kg/ha only. India is the third largest (14.88%) linseed growing countries in the world and production wise it ranks fourth (6.57%) in the world after Canada (31.80%), China (14.74%) and Kazakhistan (13.18%). Linseed is a major *rabi* oilseed crop of the country next to rapeseed and mustard. The major impediments for the lower national productivity are its cultivation under starved input and poor management conditions. The present productivity of 502 kg/ha is still very low as compared to the production potential realised at experimental (1800-2000 kg/ha) and frontline demonstration (965 kg/ha) level. Due to slow initial growth and small leaves size of the crop, linseed is highly infested with weeds causing 30-40% loss in seed yield (Mahere *et al*., 2000). Though, hand weeding is most common method of weed control but it is labour intensive and costly too in comparison to herbicides. Under such conditions, weed management through use of herbicides may be a viable option .To find out suitable herbicides and their doses for effective weed management in linseed is an important task to control weeds effectively and minimize the cost. It is also important to know the effects of herbicides on oil content of linseed. To address these challenges a field experiment was carried out to evaluate the effect of herbicides on seed yield, economics and oil content under irrigated conditions in central plain zone of Uttar Pradesh during the *rabi* seasons of 2012-13, 2013-14 and 2014-15.

METHODOLOGY

A field experiment was laid out in completely randomized block design with three replications at C.S. Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh during three consecutive *rabi* seasons of 2012-13, 2013-14 and 2014-15.The experiment comprised of9treatments *viz*. hand weeding twice at20 -25 and 35 - 45 DAS,pendimethalin30 EC1.0 kg/ha pre emergence, pendimethalin 30 EC+ imazethapyr 2 EC 0.75 kg/ha pre emergence,pendimethalin30 EC+ imazethapyr 2EC1.0 kg/ha pre emergence, isoproturon 1.0 kg/ha post emergence, clodinafop 60g/ha post emergence, imazethapyr 10EC 75g/ha post emergence,imazethapyr10 EC 100g/ha post emergence and weedy check. Soil of the experimental field was sandy loam in texture, slightly alkaline in reaction, low in organic carbon and available N, medium in available P and available K. The experimental site was infested with *Phalaris minor,Chenopodium album, Cyperus rotundus ,Convolvulus arvensis and Anagalis arvensis*. Linseed variety 'shekhar' was sown in lines 25cm, apart using seed rate of 25 kg/ha and fertilized with 80 kg N+ 40 kg P_2O_5 +30 kgK_2O /ha through urea, diammonium phosphate and muriate of potash, respectively. The experiment was irrigated twice besides pre sowing irrigation. The oil content from dried seeds (<10% moisture) were analyzed with the help of Nuclear Magnetic Resonance Oxford Model MQA 7005.Economic analysis was done on the basis of prevailing market price of inputs used and output obtained from each treatment. The data were subjected to pooled analysis.

RESULTS

The research findings revealed that twice hand weeding recorded significantly higher seed yield (1.60t/ha), but it was at par to clodinafop 60g per ha (1.40 t/ha). Among the tested herbicides clodinafop 60 g/ha recorded significantly superior seed yield (1.44 t/ha) of linseed compared to others except pendimethalin30 EC + imazethapyr 2 EC 1.0 kg/ha (1.15 t/ha). It is also clear from table 1 that twice hand weeding had significantly lowest weed dry weight (0.19 t/ha) in comparison to other treatments. There were no significant difference noted with regards to dry weight of weeds among herbicidal treatments except to imazethapyr10 EC 75 g/ha which recorded maximum weed dry weight (0.60 t/ha). The maximum oil content was recorded with the treatment twice hand weeding followed byimazethapyr 10 EC 75 g/ha applied as post emergence. Whereas pendimethalin 30 EC + imazethapyr 2 EC 1.0kg/ha recorded least oil content. The treatment clodinafop 60 g/ha recoded least weed competition index (10.11%), whereas weedy check recorded highest weed competition index (63.96%). This indicates that lower weed index resulted into higher seed yield of linseed. This also indicates a negative association between weed biomass and seed yield.

Table 1. Seed yield, oil content and economics of irrigated linseed as affected by herbicides

Treatment	Seed yield (t/ha)	Weed dry weight (t/ha)	Oil content (%)	Weed Index (%)	Net monetary returns (x10^3 Rs./ha)
Hand weeding at 20-25 and 35-45 DAS	1.60	0.19	36.16	-	44.27
Pendimethalin 30 EC 1 kg/ha preemergence	0.96	0.44	34.97	40.03	21.07
Pendimethalin 30 EC + imazethapyr 2 EC 0.75 kg/ha pre emergence	1.05	0.43	33.28	34.16	24.50
Pendimethalin30 EC +imazethapyr 2 EC 1kg/ha pre emergence	1.15	0.41	33.02	28.16	29.33
Isoproturon 1 kg/ha post emergence	0.96	0.47	34.19	40.84	21.07
Clodinafop 60 g/ha post emergence	1.44	0.46	33.06	10.11	46.68
Imazethapyr 10 EC 75 g /ha post emergence	0.84	0.60	35.75	27.28	16.35
Imazethapyr10 EC 100 g /ha post emergence	0.98	0.34	34.67	48.72	21.66
Weedy check	0.58	1.27	34.4	63.96	8.67
CD (P=0.05)	0.35	0.46	0.39	-	14.50

The herbicide 'clodinafop 60g/ha' recorded significantly higher net monetary return (Rs 46.67 x10^3/ha) followed by twice hand weeding (Rs 44.27 x10^3//ha). Though, both treatments were at par in terms of net monetary return. The weedy check recorded least monetary return (Rs. 8.67 x10^3/ha). This is due to highest weed index and poor seed yield. This also indicates that net monetary return is directly related with seed yield. In spite of having highest seed yield with treatment 'twice hand weeding', it could not gain maximum net monetary return because of higher investment on labour.

CONCLUSION

Based on the study it can be concluded that clodinafop 60 g/ha could be an alternative of twice hand weeding for effective management of weeds in irrigated linseed. This treatment not only controlled the weeds effectively but also recorded at par seed yield to twice hand weeding along with maximum net monetary return.

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Sequential application of herbicides for enhanced weed control efficiency and productivity in rainy-season greengram

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Greengram (*Vigna radiata* L. Wilczek) is the third most important pulse crop in India. Considering the shortage of pulses in the country productivity of this crop needs to be increased, but weeds cause severe yield losses in greengram ranging from 30–85 % depending on type of weeds, variety, season, soil type, rainfall and duration and time of weed competition (Punia *et al*., 2004). Weed infestation is severe in rainy season due to continuous rains and slow initial growth of crop. Greengram is more sensitive to weed competition in the first 4–5 weeks after emergence (Kumar *et al.*, 2005). Pre-emergence application of herbicides, such as, pendimethalin is effective in reducing weed growth only during initial growth period, but crop suffers considerably during later part of the crop growth. Thus, late-season emerging weeds need to be controlled effectively to achieve higher greengram yield. Sequential application of pendimethalin and imazethapyr has been found useful in blackgram (Rao *et al*., 2010) which is quite akin to greengram. Hence the present study was conducted to determine the effect of sequential application of herbicides on weed suppression and productivity and profitability of greengram under north Indian plains condition.

METHODOLOGY

A field experiment was conducted during *kharif* (rainy) season of 2013 at the research farm of the Indian Agricultural Research Institute. This field experiment had 12 weed control treatments including pendimethalin @ 1 kg/ha pre-emergence (PE), pendimethalin @ 1 kg/ha PE + 1 hand-weeding (HW) at 30 day after sowing (DAS), pendimethalin @ 0.75 kg/ha PE + imazethapyr @ 50g/ha at 30 DAS, pendimethalin @ 0.75 kg/ha PE + imazethapyr @ 75g/ha at 30 DAS, imazethapyr @ 50 g/ha at 20 DAS, imazethapyr @ 75 g/ha at 20 DAS, pendimethalin @ 0.75 kg/ha PE + quizalofop @ 50g/ha at 30 DAS, pendimethalin @ 0.75 kg/ha PE + quizalofop @ 75g/ha at 30 DAS, quizalofop @ 50 g/ha at 20 DAS, quizalofop @ 75 g/ha at 20 DAS, weed free condition and weedy check laid-out in a randomised block design with 3 replication. A uniform recommended dose of 30 kg N/ha and 26 kg P/ha through diammonium phosphate and 40 kg K/ha through MOP was applied as basal. In this experiment 'Pusa Ratna' cultivar of greengram was used. The crop was sown in lines spaced 30 cm apart, using a seed rate of 15 kg/ha. Herbicides were applied with the help of a manually operated knapsack sprayer fitted with flat-fan nozzle at spray volume of 500 litres/ha. All the necessary observations were recorded as per the established norms.

RESULTS

The major weed flora in the experimental field included *Cyperus rotundus* L., *Digitaria sanguinalis* (L.) Scop, *Dactyloctenium aegyptium* (L.) P. Beauv., *Trianthema portulacastrum* L. and *Digera arvensis* Forsk. Different weed control treatments exhibited a significant influence on seed yield. The highest grain yield (1.1 t/ha) was recorded with pendimethalin @ 1 kg/ha PE + 1 HW at 30 DAS, and was comparable with pendimethalin @ 0.75 kg/ha PE + imazethapyr @ 75g/ha at 30 DAS. Pendimethalin @ 1 kg/ha PE + 1 HW at 30 DAS recorded 58% higher seed yield as compared to weedy check and 27.3 to 35.5% higher seed yield compared to one time herbicide application treatments. Among the weed control treatments, pendimethalin @ 1 kg/ha PE + 1 HW at 30 DAS was found most effective in reducing the weed population and dry weight, and was closely followed by pendimethalin at 0.75 kg/ha PE + imazethapyr @ 75 g/ ha at 30 DAS. The lowest reduction in weed growth was observed with pendimethalin @ 1 kg/ha at 30 DAS. It indicates that application of pendimethalin alone without combining it with HW or other herbicides in sequence proved less effective in controlling the weeds. The highest weed control efficiency (WCE) of 75.2% was recorded with use of pendimethalin @ 1 kg/ha PE + 1 HW at 30 DAS followed by pendimethalin @ 0.75 kg/ ha PE + imazethapyr @ 75 g/ha (68.7%) at 30 DAS. The lowest WCE was recorded with pendimethalin @ 1 kg/ha PE (33.7%) and quizalofop @ 50 g/ha (34.5%) and @ 75 g/ha (36%) at 20 DAS. The lowest weed index (8.3%), total weed density (7.1/ m^2) and total weed dry weight (6 g/m^2) was recorded with pendimethalin @ 1 kg/ha PE + 1 HW at 30 DAS which was found at par with pendimethalin @ 0.75 kg/ha PE + imazethapyr @ 75g/ha at 30 DAS. The herbicide efficiency index (HEI) was the highest under pendimethalin @ 1 kg/ha PE + 1 HW at 30 DAS (4.57%) and pendimethalin @ 0.75 kg/ha PE + imazethapyr @ 75g/ha @ 30 DAS (2.15%) was the next best treatment. Pendimethalin @ 1 kg/ha PE + 1 HW at 30 DAS fetched the highest net monetary return (Rs 41,167/ha) and benefit: cost ratio (2.91) closely followed by pendimethalin @ 0.75 kg/ha PE + imazethapyr @ 75g/ha at 30 DAS (Rs 33,321/ha and 2.40, respectively). Pendimethalin @ 1 kg/ha PE + 1 HW at 30 DAS received 77% and pendimethalin @ 0.75 kg/ha PE + imazethapyr @ 75g/ha at 30 DAS 71% higher net returns compared to weedy check.

CONCLUSION

From this field investigation it could be concluded that pre-emergence application of pendimethalin @ 1kg/ha fb 1 HW at 30 DAS and pendimethalin @ 0.75 kg/ha PE fb imazethapyr @ 75g/ha @ 30 DAS were equally effective in managing weeds and improving greengram productivity and thus sequential application of herbicides can be an efficient alternative to control weeds in greengram, particularly under labour constrained conditions.

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Effect of land configuration and weed management on mungbean productivity under temperate conditions of Kashmir

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Mungbean (*Vigna radiata*), belongs to legume family. It is one of the important pulse crops in Jammu and Kashmir plays a major role in augmenting the income of small and marginal farmers of Valley. Mungbean contains 25% of highly digestible protein and is consumed both as whole grain as well as dal. It is a soil building crop which fixes atmospheric nitrogen through symbiotic action and can also be used as green manure crop adding 35 kg N/ha. Among the various constraints responsible for low yield of mungbean like scarcity of water, delayed sowing, inadequate seed replacement rate, lack of transfer of technology, inadequate weed management etc. Method of sowing and weed management holds an utmost importance as weeds harbor insect-pests and act as an alternate and secondary source for the dispersal and persistence of diseases and insect pest complex. Keeping in view the above facts, a field experiment entitled, "Effect of land configuration and weed management on mungbean productivity" was conducted during *Kharif* season of 2015 under AICRP on MULLaRP.

METHODOLOGY

The soil of the experimental field was silty clay in texture, high in organic carbon and potassium, medium in nitrogen and phosphorus. The experiment consisted of land configuration treatments viz., Flat Bed Method (FBM) and Ridge method (RM) in main plot and weed management treatments viz. Weedy check, Pendimethalin 30 EC @ 0.75/1.0 kg/ha – PE, imazethapyr 10 % SL @ 40/55 g/ha at 15 – 20 DAS and Pendimethalin 30 EC PE fb imazethapyr 10 % SL @ 40/55 g/ha at 15-20 DAS laid out in strip plot design (SPD) with three replications.

RESULTS

The experimental results revealed that the grain yield of Flat Bed Method (FBM) was at par with ridge method (RM) and there was non-significant difference with respect to yield attributing characters. Weed density (No. /m^2) and weed dry matter (g/m^2) also exhibited non-significant difference at 30 and 60 days after sowing (DAS) of crop. Among weed management practices, weedy check recorded the lowest grain yield of 552 kg/ha and showed significant difference when compared with rest of the treatments, whereas highest grain yield of 818.75 kg/ha was recorded with pendimethalin 30 EC @ 0.75/1.0 kg/ha-PE followed by imazethapyr 10 % SL @ 40/55 g/ha at 15-20 DAS followed by imazethapyr 10 % SL @ 40/55 g/ha at 15-20 DAS and Pendimethalin 30 EC @ 0.75/1.0 kg a.i /ha PE in decreasing order. Pendimethalin 30 EC @ 0.75/1.0 kg/ha-PE fb imazethapyr 10 % SL @ 40/55 g/ha at 15-20 DAS, imazethapyr 10 % SL @ 40/55 g/ha at 15-20 DAS and Pendimethalin 30 EC @ 0.75/1.0 kg a.i /ha PE recorded 48.04 %, 33.92% and 18.62% increase in grain yield respectively than weedy check. The major weeds identified in the experimental field were *Cynodon dactylon*, *Sorghum halepense, Conyza* spp., *Matricaria* spp., *Poa* spp. among Grassy weeds; *Convolvulus arvensis, Amaranthus viridis, Chenopodium album* among broadleaved weeds and *Cyperus rotundus* among sedges. Among weed management practices, uncontrolled weedy check resulted in 32.58% reduction in grain yield of mungbean.

CONCLUSION

As the experiment was conducted under dry land conditions there is scope where FBM and RM may give better results in rest of the low lying areas of the Kashmir valley.

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Performance of erase strong and eros against weeds in transplanted rice under temperate conditions

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Weeds are at present the major biotic constraint to increase rice production worldwide (Zhang *et al*., 1996). Weed infestation is regarded as one of the major causes of low crop yields throughout the world and can cause 50-60 per cent reduction in grain yield under puddled conditions and 91 per cent yield reduction in non-puddled conditions (Ali and Sankaran, 1984). Weed control helps to enhance the production environment, thereby allowing more of the inherent capacity of the plant to express itself. Therefore, cost effective and consistent weed management system needs to be identified in order to boost the rice cultivation. In this regard, the following experiment entitled "to evaluate the effectiveness of herbicides Erase Strong and Eros against weeds in transplanted rice" was initiated to check the efficacy of new herbicide molecules in rice during *kharif* 2014 and 2015 at MRCFC Khudwani, SKUAST-Kashmir.

METHODOLOGY

A field experiment was conducted at Mountain Research Centre for Field Crops, SKUAST-Kashmir, Khudwani (33°43'15'' N, and of 75°5'39''E and altitude 1,596 m amsl). The site falls in mid-altitude temperate zone characterized by hot summers and very cold winters with an average annual precipitation of 812 mm (average of past 20 years). The soil of the experimental site was silty clay loam, neutral in pH (6.78), low in nitrogen (215 kg/ha), medium in available phosphorus (15.0 kg/ha) and potassium (205 kg/ha). The experiment comprised of 5 weed control methods {W_1 Erase strong @ 10 kg /ha(bensulfuron methyl 0.6% + pretilachlor 6% GR); W_2 Eros @ 10 kg /ha (pyrazosulfuron-methyl 0.15 % + Pretilachlor 6% GR); W_3 butachlor @ 1.5 kg a.i /ha ; W_4 weedy check and W_5 weed free } was laid out in a randomized block design with three replications. The weeds uprooted from each plot were washed and after sun drying these were oven dried at 60-65^{o}C for 48 hours to a constant weight. Both weed number and weed dry weight were subjected to square root transformation to normalize their distribution.

RESULTS

The results presented in table 1 corroborate that panicles m^2, grains /panicle, 1000 grain weight and grain weight were significantly influenced by weed management practices. Highest panicles/m (402), grains/ panicle(110.8), 1000 grain weight (25.26) and grain yield were recorded under weed free condition. Among the herbicide treatments pre emergence application of Eros @10 kg/ha significantly recorded higher panicles m^2 (378), grains panicle^{-1} (91.0), 1000 grain weight (25.22) and grain yield (70.4) over weedy check followed by application of Erase @10 kg /ha, which in turn was statistically superior to butachlor and weedy check treatments. The mean yield superiority exhibited by the application of Eros over Erase, butachlor and weedy check treatment was 4.5, 9.5

Table 1. Efficiency of New Herbicide molecules on Weed density, Weed dry matter, Weed control efficiency (at 90 DAT), yield and yield parameters in transplanted rice

Treatment	Weed density (No./m^2)	Weed dry matter (g/m^2)	Weed control efficiency (%)	Panicle (per m^2)	Grains/ panicle (No.)	1000 grain weight (g)	Grain yield (t/ha)
W_1 Erase @ 10 kg ai /ha	5.31(27.2)	7.50 (55.2)	53.1	372	88.3	24.68	6.72
W_2 Eros @ 10 kg ai /ha	4.83 (22.4)	6.59 (42.57)	56.9	378	91.0	25.22	7.04
W_3 Butachlor @ 1.5 kg a.i. /ha	5.36 (28.0)	8.10 (64.3)	47.9	342	83.7	24.63	6.37
W_4 Weedy check	6.91 (46.9)	10.90 (118.1)	0.0	260	63.2	23.48	4.03
W_5 Weed Free	1.00 (0.00)	1.00 (0.00)	100.0	402	110.8	25.26	7.22
C.D. (p=0.05)	0.22	0.20	-	13.4	7.9	0.49	0.32

Figures in parenthesis are original values, data subjected to $\sqrt{x+1}$ transformation; (DAT = days after transplanting) and 42.7 % and the mean superiority exhibited by Erase over butachlor and weedy check was 5.2 and 40.0 %, respectively. Higher grain yield with application of Eros @10 kg /ha and Erase @10 kg /ha could be attributed due to significant improvement in all yield attributes and reduction in crop-weed competition. Pre-emergence application of Eros @ 10 kg /ha proved significantly superior in recording lowest values of weed density (4.83) and weed dry matter (6.59), however, highest weed control efficiency was recorded under the same treatment at 90 days after transplanting. Similarly application of Erase @ 10 kg /ha followed the same trend in recording lowest values for weed density (5.31), weed dry matter (7.50) and highest values for weed control efficiency (53.1) as against weed check and butachlor.

CONCLUSION

From the two year study it was concluded that pre emergence application of Eros @ 10 kg / ha and Erase @ 10 kg / ha are more effective than application of butachlor in transplanted rice under Kashmir valley conditions.

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Efficacy of pre and post-emergence herbicides on growth of weeds, nodulation and productivity of mungbean

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Weeds compete with crop plants for moisture, nutrients, space and sunlight. In *kharif* season, due to frequent and heavy rains, weeds grow luxuriantly and pose a serious threat to short statured crops such as mungbean. Therefore, weed control is essential to ensure the proper crop growth especially in early stage whenthe effect of weed competition is greater in the crop. Single herbicide may not be able to control all types of weed flora. Therefore, there was an urgent need to study the effect of pre- and post-emergence herbicides on weeds, symbiotic traits and grain yield of mungbean.

METHODOLOGY

A field experiment was conducted during *kharif* 2013 at the Research Farm of Punjab Agricultural University, Ludhiana (30° 54´N, 75° 48´E altitude 247 m), Punjab, India on a loamy sand soil. A total 380 mm (14 rainy days) rainfall was received during the crop growing season. The experiment, with three replications, was conducted in randomized complete block design with tentreatments as given in Table 1. Pendimethalin 30 EC, pendimethalin 30 EC + imazethapyr 2EC as pre-emergence andimazethapyr was sprayed at 15-20 days after sowing (DAS). These herbicides were sprayed using 375 litre of water per hectare with a knapsack sprayer fitted with a flat fan nozzle. In the case of two hand weedings, weeds were removed manually with a *khurpa* 20 and 40 DAS. In case of unweeded check plots, weeds were allowed during the whole crop growing season.The sowing of cultivar 'PAU 911' was done on 23 July, 2013 in rows 30 cm apart using a seed rate of 20 kg/ha. Each plot measured 6.0 m × 2.70 m. The crop was harvested on 4 October, 2013. Data were subjected to analysis of variance (ANOVA) in a randomized complete block design as per the standard procedure.

RESULTS

Application of pendimethalin 30 EC + imazethapyr 2 EC (Valor 32) @ 1.0 kg/ha (PE) recorded the highest nodule number and dry weight of nodules/plant (Table 1). As compared to hand weeding, the herbicide treatments did not adversely affect number and dry weight of nodules except pendimethalin 0.75 kg/ha followed by imazethapyr @ 40 or 55 g/ha which adversely affected nodule dry weight. The number of pods/plant and grain yield were recorded significantly higher in all the weed control treatments than weedy check.Highest grain yield of mungbean was obtained with pre-emergence (PE) application of pendimethalin 30 EC + imazethapyr 2 EC (Valor 32) @ 1.0 kg/ha which was statisti-

Table 1. Influence of different weed control treatments on nodulation, yield attributes, grain yield of mungbean and dryweight of weeds

Treatment	Nodule number/ plant	Nodule dry weight/plant (mg)	Pods/ plant	Grain yield (kg/ha)	Weed dry weight at harvest (kg/ha)
Pendimethalin @ 0.75 kg/ha PE	29.3	43.3	27.3	1136	412
Pendimethalin 30 EC + imazethapyr 2 EC (Valor 32) @ 0.75 kg/ha PE	30.3	43.5	33.7	1272	247
Pendimethalin 30 EC + imazethapyr 2 EC (Valor 32) @ 1.0 kg/ha PE	33.3	48.8	42.8	1407	175
Pendimethalin @ 0.75 kg/ha PE + imazethapyr @ 40 g/ha POE 15-20 DAS	28.3	39.1	28.7	1235	206
Pendimethalin @ 0.75 kg/ha PE + imazethapyr @ 55 g/ha POE 15-20 DAS	31.3	41.1	36.6	1321	185
Pendimethalin @ 0.75 kg/ha PE + HW at 35-40 DAS	32.3	44.5	38.2	1333	144
Pendimethalin 30 EC + imazethapyr 2 EC (Valor 32) @ 0.75 kg/ha PE + HW at 35-40 DAS	32.0	46.7	38.3	1358	134
Hand weeding twice at 20 and 40 DAS	33.0	48.8	39.9	1383	103
Pendimethalin 30 EC @ 0.45 kg/ha PE + HW at 25-30 DAS	30.3	41.4	33.4	1222	298
Weedy check	13.7	13.0	15.3	444	2160
CD (P=0.05)	4.9	5.8	5.5	182	80

cally at par with pendimethalin 30 EC + imazethapyr 2 EC (Valor 32) @ 0.75 kg/ha (PE), pendimethalin 30 EC + imazethapyr 2 EC (Valor 32) @ 0.75 kg/ha + HW at 35-40 DAS, pendimethalin @ 0.75 kg/ha PE + imazethapyr @ 40 g/ha or 55 g/ha POE 15-20 DAS and significantly higher than all other weed control treatments. Imazethapyr has been reported to provide effective control of weeds in mungbean (Singh *et al*., 2014). The major weed flora was *Cyperus rotundus* (Nut grass), *Eleusineaegyptiacum* (Crow foot grass) and *Commelinabenghalensis* (Day flower). At harvest, weedy check recorded the highest dry weight of weeds whereas hand weedings recorded the lowest dry weight of weeds. The pre-emergence application of pendimethalin 30 EC+imazethapyr 2 EC (Valor 32) @ 0.75 or 1.0 kg/ha and pre-emergence application of pendimethalin 30 EC @ 0.75 followed by post-emergence application of imazethapyr @ 40 or 55 g/ha provided effective controlling of weeds as reflected in lower weed dry weight than pendimethalin 30 EC @ 0.75 kg/ha alone.

CONCLUSION

The pre-emergence application of pendimethalin 30 EC + imazethapyr 2 EC (Valor 32) @ 1.0 kg/ha) and pre-emergence application of pendimethalin 30 EC @ 0.75 kg/ha followed by post-emergence application of imazethapyr @ 55 g/ha are more effective in controlling the weeds and improving the grain yield than pendimethalin @ 0.75 kg/ha alone.

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Effect of herbicides for managing weeds in barley (*Hordeum vulgare* L.) in Northwestern Himalaya

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Barley (*Hordeum vulgare* L.) is considered fourth largest cereal crop in the world with a share of 7% of the global cereal production (Pal *et al*., 2012). It also has immense potential as quality cereal especially for nutritional and medicinal point of view (Cavallero *et al.*, 2002). There are many problems such as high weed infestation, delayed sowing, poor nutrition and drought which lower barley yield and threaten food security due to weed infestation. The reduction in productivity depends upon the type of weed flora and weed density (Balyan *et al*., 1991). Grassy and broad leaved weeds usually pose greater problem in irrigated areas or in high rainfall areas. Generally, isoproturon and 2, 4-D are the herbicides recommended for weed control in barley in hills. Effective weed management with new herbicides proffer a substantial boost in crop productivity through efficient weed control, therefore the present investigation was carried out.

METHODOLOGY

A study was initiated during *Rabi* season of 2013-14 and continued for next twoconsecutive years (2014-15 and 2015-16) at the Research Farm of Hill Agricultural Research and Extension Centre, Bajaura, Kullu, Himachal Pradesh (1090 m amsl) to study the efficacy of new herbicides (pinoxaden, carfentrazone and metsulfuron) along with the standard Isoproturon and 2,4-D for the control of complex weed flora in barley crop under irrigated/high rainfall conditions with 11 treatments in a randomized block design (RBD) with 3 replications. The soil of the experimental site was silty-loam in texture with neutral pH (6.8), the available N (270 kg/ha) and medium in P(24.2 kg/ha) and K (188 kg/ha) with 0.54 % organic carbon. The normal annual rainfall of Bajaura is 943 mm and 56 % (≥525 mm) of which is received during *Rabi* season (October to May). Newly released high yielding barley variety VLB 118 was sown in the third week of November during all the years with 100 kg seed rate at 23 cm row spacing with recommended dose of N, P_2O_5 and K_2O at 60:40:30 kg/ha. The herbicides were sprayed with knapsack sprayer fitted with flat fan nozzle using a spray volume of 750 litre/ha in treatments 1 to 9 (Table 1.) whereas weed free treatment was kept clean by removing weeds at regular intervals manually. Plots were irrigated with ground water of good quality whenever required. The data on weed count and weed biomass were recorded at 90 DAS stage of the crop while that of yield and yield attributes were recorded at the time of harvesting. The crop was manually harvested in the third week of May. The data was subjected to statistical analysis where pooled analysis of 3 years data was done and comparisons were made at 5% level of significance.

RESULTS

The weed flora of the experimental site consisted of grassy and broadleaved weeds. The grassy weeds included *Avena ludoviciana* (Wild oat), *Poaannua* L. (Medow grass), *Cynodondactylon* L. (Burmuda grass), *Lolium temulentum*

Table 1. Effect of herbicides on weeds, yield and yield attributes of barley (pooled data of three years)

Dose (a.i. g/ha)	Panicles/ m^2	Grains/ ear	1000 grain weight (g)	Grain Yield (t/ha)	Weed density (No./m^2) 90 DAS			Weed biomass at 90 DAS (g/m^2)
					Grassy	Broad leaved	Total	
T_1: Pinoxaden 30	293	38.1	43.72	3.64	3.86 (17.33)	12.07 (145.78)	12.75 (163)	7.69 (58.79)
T_2: Pinoxaden 40	290	40.0	44.08	3.79	2.66 (9.78)	12.18 (148.89)	12.57 (159)	7.26 (51.98)
T_3: Pinoxaden 50	292	39.9	44.70	3.89	2.59 (8.89)	12.04 (146.22)	12.39 (155)	6.98 (48.25)
T_4: Pinoxaden 40 + Metsulfuron 4	305	41.8	45.75	4.38	2.41 (6.22)	1.71 (3.11)	2.78 (9.0)	2.15 (4.88)
T_5: Pinoxaden 40 *fb*Metsulfuron 4	305	41.1	46.45	4.32	1.62 (2.67)	1.71 (3.11)	2.08 (6.0)	1.91 (4.61)
T_6: Pinoxaden 40 + Carfentrazone 20	295	41.0	44.41	4.03	3.32 (17.11)	10.29 (105.33)	11.03 (122)	6.82 (46.00)
T_7: Isoproturon 1000	295	42.5	45.00	4.14	5.61 (31.11)	9.49 (90.67)	11.03 (122)	6.87 (48.32)
T_8: Isoproturon 750 + 2,4-D 500	305	41.8	44.86	4.23	5.84 (33.78)	7.49 (56.44)	9.52 (90.0)	5.68 (33.22)
T_9: Isoproturon 750 + Metsulfuron 4	311	42.8	46.42	4.59	1.00 (0.00)	1.00 (0.0)	1.00 (0.0)	1.00 (0.0)
T_{10}: Weedy Check	281	34.9	41.29	3.00	12.21 (149.78)	15.53 (245.78)	19.76 (396)	10.52 (111.26)
T_{11}: Weed Free	308	42.3	45.75	4.28	1.00 (0.0)	1.00 (0.0)	1.00 (0.0)	1.00 (0.0)
CD (P = 0.05)	NS	3.51	1.67	0.32	0.68	0.87	0.81	0.68

fb: followed by

*Analysis done after square root transformation, figures in parentheses are the means of original values

(Darnel Ryegrass) and *Phalaris minor* while prominent broad leaved weeds included *Veronica persica* (Persian Speedwell), *Coronopus didymus* L. (Wild carrot), *Medicago denticulate* Willd. (Burclover), *Stellaria media* (Chickweed), *Fumariaparviflora* (Pitta-papda), *Oxalis corniculata* L. (Creeping Wood Sorrel), *Spergulaarvensis* (Corn spury), *Convolvulus arvensis* (Field bindweed), *Lathyrusaphaca* (Yellow pea), *Vicia sativa*(garden vetch), *Viciahirsuta G.* (Tiny vetch) and *Anagallisarvensis* (Krishna Neel). The pooled data of three years observations reveal that the combined application of isoproturon (750g/ha) + metsulfuron (4g/ha) recorded the minimum dry matter and lowest weed count (grassy weeds, broad leaved weeds and total) followed by the combined application of pinoxaden (40g/ha) + metsulfuron (4g/ha) and pinoxaden (40g/ha) *fb* metsulfuron (4g/ha) (Table 1). These treatments resulted in a significant increase in grain yield to the tune of 52.95, 45.99 and 43.79% respectively over the weedy check.

CONCLUSION

It can be concluded from the above study that post emergence (3-4 leaf stage) application of either isoproturon 750g/ha+ metsulfuron 4g/ha or pinoxaden 40g/ha + metsulfuron 4g/ha can completely control all grassy and broad leaved weeds in barley in North- Western Himalayan region.

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Effect of re-use of salinity grown seed on yield potential of groundnut under saline irrigation condition

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Salinity is an increasing and consistent environmental threat throughout the world especially for agriculture. It is predicted that it could further aggravated during in the coming decades. In an estimate about 1-2% land become non-cultivable every year due to soil salinization. Excess salt in soils and water has not only injurious effect on crop yield but also results in generous losses of arable soils especially in arid and semiarid areas (Cayuela *et al.,* 2001). Besides, this other challenges like increasing demand for agricultural production for expanding population (Howell, 2001) and the availability of fresh water for agricultural production has been not only decreasing but also the quality of irrigation water has been deteriorated (Cai and Rosegrant, 2003). Productivity of groundnut in saline prone areas has sharply declined which is the major cause of concern to be addressed on priority. Hence, we hypothesized that whether the re-use of groundnut seeds harvested from those areas would be the probable reason for this abrupt decline in groundnut productivity.

METHODOLOGY

The field study was conducted at experimental farm of ICAR-Directorate of Groundnut Research, Junagadh situated at 70º36'E longitude and 21º31'N latitude at an altitude of 60 m above mean sea levelduringtwo years study (*i.e*. 2012 to 2014) at a permanent site having different levels of in-built soil salinity developed artificially by using NaCl irrigation water over one & half decade. The experiment, consisting of four salinity levels of NaCl irrigation water of {(0.5 (control, S_1), 2 (S_2), 4 (S_3) and 6 (S_4) dS/m} to main plots, two Spanish groundnut cultivars {(*i.e.* TG 37A (V_1) and GG 2 (V_2)} in sub-plots and two seed types {(*i.e.* fresh seed (FS) and salinity grown seed (SGS)} in sub-sub-plots. The experiment was laid out in a split-split plot design with three replications.For different seed types groundnut crop (*cv.* TG 37A and GG 2) were sown in the month of February in the same soils. After germination the crop was irrigated by using irrigation water of

Table 1. Germination and yield of groundnut cultivars as influenced by salinity and seed types.

ECiw (dS/m)	Germination (%)			Yield (kg/ha)		
	8th	9th	10th	13th	Pod	Haulm
Salinity level						
S_1	50.67[a]	68.08[a]	77.04[a]	82.08[a]	1512[a]	2910[a]
S_2	44.04[a]	67.00[a]	77.54[a]	81.50[a]	1455[a]	2198[b]
S_3	22.50[b]	46.75[b]	60.67[b]	72.54[b]	960[b]	1686[c]
S_4	7.63[c]	24.63[c]	41.29[c]	57.67[c]	260[c]	789[d]
SEm±	4.78	3.65	3.71	3.02	70.19	101.77
CD (P=0.05)	11.71	8.93	9.07	7.39	171.74	249.02
Groundnut cultivar						
V_1	26.73[b]	48.25[b]	61.65[b]	70.73[b]	963[b]	1499[b]
V_2	35.69[a]	54.98[a]	66.63[a]	76.17[a]	1130[a]	2293[a]
SEm±	1.77	1.73	1.45	1.55	26.28	79.50
CD (P=0.05)	4.07	3.98	3.34	3.57	60.61	183.32
Seed type						
FS	38.63[a]	60.17[a]	74.04[a]	82.46[a]	1205[a]	2151[a]
SGS	23.79[b]	43.06[b]	54.23[b]	64.44[b]	889[b]	1641[b]
SEm±	1.69	1.80	1.75	1.53	26.79	68.91
CD (P=0.05)	3.58	3.82	3.70	3.24	56.80	146.08

*FS= Fresh Seed, SGS=Salinity Grown Seed

4 dS/mNaCl salinity up to harvest. The seed harvested from normal and NaCl irrigation plots were treated as fresh and salinity grown seeds, respectively. The gross plot size was 20 m^2. Each salinity treated plot was separated from each other by putting a 250-micron polythene sheet up to 60 cm soil depth in different channels surrounding the various treated plots. About three to five irrigations were applied at a soil depth of 10-15 cm. depending upon the rainfall occurred during different year of experimentations. The simulated water salinity levels of 2, 4 and 6 dS/m were achieved by adding 1.3, 2.6 and 3.9 kg commercial sodium chloride salts per1000 L of water, respectively.

RESULTS

Germination was significantly (P=0.05) decreased beyond the 2 dS/m salinity level. The germination percentage at the level of 6 dS/msaline irrigation water was decreased by 85, 64, 46 and 30% on 8th, 9th, 10th and 13th days after sowing, respectively as compared to normal irrigation water (i.e. control). The germination percentages for both the cultivars as well as seed types were also significantly differed at all the four measurements (i.e. at 9 to 13th days). The germination performance was found better for GG 2 and use of fresh seed as compare to the TG 37A and salinity grown seeds, respectively. Further, fresh seed differed significantly over salinity grown seed with higher germination percentage by 38, 28, 27 and 22% at 8th, 9th, 10th and 13th days after sowing, respectively. The pod as well as haulm yield decreased as salinity increased. Although there was not a significant decrease in pod yield between 0.5 dS/m(i.e. control) and 2 dS/mbut as the level of saline irrigation increased further from 2 to 4 dS/mthere was drastic fall in pod yield from 1455 to 960 kg/ha. Moreover, the reduction in pod yield from 4 to 6 dS/mwas severe, as it reduced to almost one third from 960 to 260 kg/ha at respective level. Similar trend was also observed for haulm yield of groundnut, an important by-product of groundnut cultivation and used as fodder for animals. A significant difference in haulm yield was observed even at 0.5 and 2 dS/mwater salinity levels proved its vulnerability for salinity hazard. The GG 2 produced significantly higher pod yield by 167 kg/ha compared to TG 37A. Further, the fresh seed gave a significantly higher pod yield by 316 kg/hathan saline grown seed.

CONCLUSION

Based on the results it can be confirmed that as per our hypothesis there was great influence of seed types on pod yield of groundnut. Fresh seed have significantly higher yield potential than salinity grown seed both under saline and non-saline conditions.

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Bioefficacy of different herbicides for control of weed flora in soybean

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Yields from Unchecked weeds may cause 58-88% reduction in the grain yield of soybean. Moreover, hand weeding is tedious and time consuming and many a times damages surface feeding roots of the crop due to mechanical hand weeding. Therefore use of pre-emergence and pre plant incorporation herbicides have a very short persistence in soil and weed flora may appear again after a time span and compete with the crops at later stages. Whereas, post-emergence herbicide kill weeds and keep the hardy uncontrolled weeds under control by arresting there growth through various kinds of deformities in foliage and growing points. The medium to deep vertisol of malwa plateau in monsoon season at many times loose there workability due to rains and mechanical and hand weeding in standing crop becomes almost impossible. Under such situations, the chemical weed control seems to be the best option to overcome the weed competition.

METHDOLOGY

Field investigation was conducted at Research Farm of the AICRP on Dry Land College of Agriculture Indore (M.P) during *kharif* season of 2013-2014 a product testing trial to assess the effect of different herbicides to control weeds in soybean and their subsequent effect on growth, yield and yield attributing character of soybean. Ten treatments *viz.*, weedy check (T_1), Fluazifop-p-butyl 12.5% EC @ 125 g a.i./ha + Fomesafen 12.5% EC @ 125 g a.i./ha (T_2) imazethapyr 10%SL @ 100g a.i./ha(T_3),Propaquizofop @ 750 ml/ha(T_4) Propaquizofop @ 750 ml/ha + Imazethapyr 10% SL @100 g ai/ha(T_5),Chlorimuron Ethly 25% WP @9 g ai/ha.(T_6), imazamox 12 %SL @35G ai + imazethapyr10%SL @35g ai(T_7), Quizalofop ethyl 5% EC @ 50 g a.i./ha (T_8), weed free up to harvest (T_9) and Hand weeding at 15 and 30 DAS (T_{10}) were laid out in randomized design with 3 replications. The soybean variety JS-95-60 was shown on 19-06-2013 and harvested on 04-10-2013.

RESULTS

Application of post-emergence herbicides killed the majority of monocot weeds and the effect of Fluazifop -p-Butyl 12.5% EC + Fomesafen 12.5 % EC @ 1000 ml CP/ha was found to be relatively more effective than other herbicides (Table 1). Weed free treatment also recorded the lower population of monocot weeds. Post-emergence herbicides were applied at 21 DAS, the population of dicot weeds remained very much under control at all the stages, ahead. Population of weeds in untreated plots under weedy check up to 15 DAS

Table 1. Influences of different herbicides on weed intensity, weed dry weight, weed control efficiency, seed yield and economics of soybean

TREATMENTS	Monocot weed intensity m^2 at 45 DDA	Dicot weed intensity m^2 at 45 DDA	Weed control efficiency (%)	Seed yield (kg/ha)	Net monetary return (₹/ha)	B:C ratio
Control	152.3	196.0	0.0	841	17470	1:1.20
Fluazifop-p-Butyl 12.5% EC+ Fomesafen 12.5% EC@ 250g ai/ha.	32.0	49.2	75.6	1809	52741	1:3.30
Imazethapyr10% SL @100 g ai/ha.	53.5	115.1	49.1	1661	47161	1:2.96
Propaquizofop @ 750 ml/ha.	83.7	161.3	35.7	1450	39611	1:2.56
Propaquizofop @ 750 ml/ha + Imazethapyr10% SL @100 g ai/ha.	64.0	116.0	34.7	1617	45752	1:2.91
ChlorimuronEthly 25% WP @9 g ai/ha.	95.3	108.8	37.0	987	22701	1:1.53
Imazamox12 %SL @35G ai + Imazethapyr10%SL @35g ai/ha	89.3	74.7	33.4	1181	29089	1:1.84
Quizalofop Ethyl 5% EC @ 50 g ai/ha.	102.5	156.3	25.9	928	18959	1:1.16
Weed free	6.6	4.2	99.7	1919	55419	1:3.17
Hand weeding + Dora at 15 and 30 DAS	2.6	3.2	99.4	1716	49208	1:3.08
SEm ±	17.3	15.2	-	50.2	-	-
CD (P=0.05)	51.5	45.0	-	145.20	-	-

was almost similar but application of the post emergence herbicide Fluazifop-p-Butyl 12.5 % EC + Fomesafen 12.5 % EC @ 250g ai/ha that effectively control monocot and dicot both as compared to other herbicide and due to phytotoxic effects the growth of the weeds effectively up to 45 DAS making them inactive causing no competition with the crop plants. The post-emergence herbicide were found to provide good control over the weeds throughout the growing period after their application at 21 DAS and produced higher yields. The WCE observed was relatively higher in weed free plots in dicots Higher weed control efficiency was observed in Weed free plot (99.7) followed by Hand weeding + Dora at 15 and 30 DAS (99.4%) and Fluazifop-p-Butyl 12.5% EC + Fomesafen 12.5% EC@ 250g ai/ha (75.6%) and Imazethapyr 10% SL @100 g ai/ha (49.1%) Highest grain yield of 1919 kg/ha was recorded under treatment Weed free, followed byFluazifop -p- Butyl 12.5% EC + Fomesafen 12.5 % EC @1000 ml CP/ha1809 Kg/ha, Hand weeding + Dora at 15 and 30 DAS1716Kg/ha,Imazethapyr 10% SL @100 g ai/ ha.1661Kg/ha,Propaquizofop @ 750 ml/ha + Imazethapyr 10% SL @100 g ai/ha1617 Kg/ha, Propaquizofop @ 750 ml/ ha1450 Kg/ha, Imazamox 12 % SL @35G ai + Imazethapyr 10% SL @ 35g ai/ha. 1181 Kg/ha. The lowest grain yield of 841 kg/ha was obtained under treatment weedy check.Thus all the herbicidal treatments as well as treatment weeds free were recorded significantly superior to weedy check. Under the assessed herbicidal treatments from grain yield/ha point of view, application of Fluazifop -p- Butyl 12.5% EC + Fomesafen 12.5 % EC @ 1000 ml CP/ha at 21DAS appeared promising (1809 Kg/ha) followed by Imazethapyr 10% SL @1000 ml CP/ha (1661 Kg/ha), Propaquizofop @ 750 ml/ha + Imazethapyr 10% SL @100 g ai/ha)1617 Kg/ha and Propaquizofop @ 750 ml/ha) 1450 Kg/ha **.** The increase in soybean yield was to the tune of 69.34 and 56.7 % due to post emergence applied weedicide viz. Fluazifop-p-Butyl 12.5 % EC + Fomesafen 12.5 % EC @ 250g ai/ha and Imazethapyr 10% SL @ 1000 ml /ha, respectively. Highest cost benefit ratio 3.30 was recorded under treatment Fluazifop-p-Butyl 12.5 % EC + Fomesafen 12.5 % EC @ 250g ai/ha followed by weed free,Hand weeding + Dora at 15 and 30 DAS andImazethapyr 10 SL @ 1000 ml /ha 3.17, 3.08 and 2.96,By employing hand weeding at 15 and 30 DAS treatment the net profit of Rs. 49208 was obtained as compared to Rs. 17470 under treatment control.

CONCLUSION

Treatment weed free gave highest net profit Rs 55419/- followed byFluazifop -p- Butyl 12.5% EC +Fomesafen 12.5 %EC @ 250g ai/ha gave net profit of Rs.52741/- Thus, in case of non-availability of labour and unfavourable weather conditions at the time of weeding it is recommended to apply Fluazifop -p- Butyl 12.5% EC + Fomesafen 12.5 % EC @ 250g ai/ha as post emergence for controlling weeds and obtained higher net profit and benefit on the cost involved in the cultivation of soybean.

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Integrated weed management options in poplar (*Populus deltoides*) nursery

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Poplar based agro forestry system is widely adapted in Indo-Gangetic plains of India. Poplar nursery is raised by planting cuttings at a spacing of 50 x 50 cm. This wider row to row spacing and longer duration of plants in nursery make the nursery vulnerable to competition from weeds especially during early stage of nursery establishment. Weeds often lead to economic loss to poplar nursery. In order to control weeds in poplar nursery, the efficacy of pre-emergence herbicides was tested in poplar nursery established at the Punjab Agricultural University, Ludhiana and Regional Research Station, Bathinda. One year old cuttings of poplar were planted at spacing of 50 cm x 50 cm. Thirteen treatments viz. Pendimethalin @ 0.75 or 0.94 kg/ha alone and with 62.5q/ha paddy straw mulch; Alachlor @ 1.88 or 2.5kg/ha with or without 62.5q/ha paddy straw mulch, plastic mulch strips in between tree rows, plastic much strip with holes for plants, hand weeding and unweeded check. All the treatments were replicated three times in randomized block design. Population of different weeds was recorded at both the experimental sites. Prominent ones were *Cyperus rotundus, Cyanodon dactylon,* *Anagallis arvensis, Rumex dentatus, Spergula arvensis, Leptochloa chinensis, Coronopus didymus, Cannabis sativa, Mollugo nudicaulis, Euphorbia hirta*, *Argemone mexicana*, *Corchorus tridens*, *Digera arvensis* etc. The result indicated that uniform spreading of black plastic mulch (both in strips or by making holes) and an integrated use of pendimethalin 0.94 kg/ha or alachlor 2.5 kg/ha with paddy straw mulch effectively controlled weeds and significantly reduced the density and biomass of weeds as compared to unweeded check. These treatments recorded statistically similar density and weeds biomass to that of hand weeding. The height and diameter of poplar plants under these treatments were observed to be at par with hand weeding treatment at both the locations. The maximum height (cm) of poplar plants recorded was 513.75 and 530.51 in treatments such as full plastic mulch with holes and alachlor @ 2.5 kg/ha with paddy straw mulch at Ludhiana and Bathinda, respectively. The maximum total above and below ground biomass (607.49 g/ha and 218.52 g/ha) of poplar plant was observed with alachlor @ 2.5 kg/ha with paddy straw mulch and minimum (216.05 g/ha and 77.54 g/ha) in unweeded check at Ludhiana. Likewise at Bathinda, maximum above ground biomass (655.69 g/ha) was observed in full plastic mulch with holes which was at par with integrated weed control with pendimethalin @ 0.94 and alachlor @ 2.5 with paddy straw mulch. Whereas, total dry weight of poplar below ground biomass was highest (138.14 g/ha) in alachlor @ 2.5 kg/ha with paddy straw mulch. Uniform spreading of black plastic mulch (in strips or by making holes) after first irrigation provides effective control of weeds in poplar nursery. Alternatively, spray pendimethalin 0.94 kg/ha or alachlor 2.5 kg/ha within two days of poplar nursery plantations in moist soil, and spread uniformity paddy straw mulch 62.5q/ha immediately after spray of herbicides for controlling weeds effectively and higher tree biomass yield.

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Role of potassium nitrate in mitigating the effect of heat stress in spring maize (*Zea mays*) under different dates of planting

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Maize (*Zea mays* L.) is one of the most important cereal crops in world because of its high yield potential. Among cereals, it occupies third place after rice and wheat on basis of both area and production in the world. In India, Maize is cultivated on an area of 8.6 million hectare with production of 23.7 million tonnes and productivity of 2.75 t/ha (Anonymous, 2014). If the planting of the maize crop is delayed, its reproductive phase coincides with the period of high temperature and might face stress at the anthesis causing desiccation of pollens resulting in poor grain filling in ears and reduced grain yield. Recently, spray of osmo-protectants has been proposed to mitigate the effect of temperature and water stress. The nutritional role of potassium in tolerance and avoidance of abiotic stress is universal. Application of potassium nitrate (KNO_3) may be considered as an option through its effect on water uptake, root growth, transpiration and stomatal behavior. The present experiment was carried out with the objective to standardize the planting dates and mitigate the heat stress with the foliar application of potassium nitrate in spring maize.

METHODOLOGY

The experiment was conducted at Punjab Agricultural University, Ludhiana during spring season of 2014 and 2015 in split plot design with three dates of planting (February 10, February 20 and March 2) in main plot and seven foliar application treatments of potassium nitrate viz. control, water spray (WS), WS at Tassel Initiation (TI), WS at TI + another spray after one week, 1.0% KNO_3spray at TI, 1.0% KNO_3spray at TI +another spray after one week, 2.0% KNO_3spray at TI, 2.0% KNO_3spray at TI +another spray after one weekin sub plots with four replications. The yield parameters number of cobs per plant, cob length, cob girth, number of rows per cob, number of grains per row, number of grains per cob and 100-grain weight along with grain yield and stover yield were recorded and analysed. The maize variety PMH-1 was planted at spacing of 60 cm × 20 cm with a fixed dose of nitrogen (125 kg/ha) and phosphorus (60 kg/ha).

RESULTS

Pooled data of both the years (2014 and 2015) revealed

Table 1. Effect of dates of planting and foliar application on number of grains per cob, 100-grain weight and Grain and stover yield (t/ha) of springmaize. (Pooled data of two years)

Treatment	No. of grains/cob	100-Grain weight (g)	Grain yield (t/ha)	Stover yield (t/ha)
Dates of planting				
10 February	412.4	26.9	5.81	14.76
20 February	433.1	28.1	6.04	15.01
2 March	317.0	22.7	3.73	12.23
CD (P = 0.05)	39.1	1.9	4.	0.59
Foliar applications				
1.0% KNO_3 spray at tassel initiation (TI)	453.6	28.2	5.73	15.18
1.0% KNO_3 spray at TI +another spray after one week	431.8	27.3	5.54	14.59
2.0% KNO_3spray at TI	428.3	27.3	5.55	14.66
2.0% KNO_3spray at TI +another spray after one week	434.0	2f7.8	5.54	14.77
Water spray at TI	314.1	23.6	4.75	12.38
Water spray at TI + another spray after one week,	348.1	24.4	4.96	12.68
Control (No spray)	304.3	21.7	4.45	12.10
CD (P = 0.05)	27.4	1.6	.24	1.24

that February 20 planted crop recorded significantly higher number of cobs per plant than March 2 planted crop but was statistically at par with February 10 planted crop which was 30% more than March 2 and 10 % more than February 10 planted crop. Both cob length and cob girth were significantly higher in February 20 planted crop than March 2 planted crop which were 11% and 8.7% more than March 2 planted crop, respectively.In February 20 planted crop,thenumber of rows per cobwere highest and were 12.9% more than March 2 planted crop. Both number of grains per row and number of grains per cobin February 20 planted crop were significantly higher than March 2 planted crop which were 22% and 36% higher, respectively. 100-grain weight in February 20 planted crop was 23.7% more than March 2 planted crop. Pooled grain yield of 6.04 t/ha was recorded under February 20 planted crop which was highest among all the three planting dates. Although this was statistically at par with February 10 planting but it was 61.9% higher than March 2 planted crop. Stover yield of February 20 planted crop was also significantly higher than March 2 planted crop which was 22.7% higher than March 2 planted crop and statistically at par with February 10 planted crop. Singh and Singh (2000) obtained 49.3% higher grain yield during early summer (6 February) than late summer (April 25). With foliar application treatments,1% potassium nitrate at tassel initiation (TI) stage resulted in significantly higher all yield attributes except number of cobs per plant that was recorded as not significant but grain yield was significantly higher with foliar application of 1% potassium nitrate at tassel initiation (TI) (5.73 t/ha) which was 28.8%,20.6% and 15.5% higher than that obtained with control (no spray), water spray at TI and water spray at TI + another spray after one week. But it was statistically at par with foliar application of 1% potassium nitrate at TI + another spray after one week, 2% potassium nitrate at TI and 2% potassium nitrate at TI + another spray after one week with application of 1% potassium nitrate at TI. Results showed that only the potassium nitrate spray caused a statistically significant increase in grain yield of 47 per cent compared to the control. It had been found that foliar application of K has increased quality and yields of maize.

CONCLUSION

Both grain yield and yield attributes were significantly higher under February 20 planted crop among the other planting dates and with foliar application of either 1% or 2% potassium nitrate at tassel initiation stage as compared to control (no spray) and water spray treatments.

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Efficacy of post emergence herbicides in groundnut (*Arachis hypogaea*)

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Groundnut is grown mainly in kharif season in India, where in it encounters severe infestation of weed especially during the early stages of growth, because the seedling emerges 7 to 10 days after sowing coupled with the slow growth in the initial stages. The weeds emerge fast and grow rapidly competing with the crop severely for the resources *viz* .nutrients, light, and space and also transpire lot of valuable conserved water from the soil. On an average the loss of groundnut production in the country due to weeds has been estimated to the tune of 33 % (Suryawanshi *et al.* 2001) and 70 % (Gnanamarthy and Balsubramanian, 1998). Thus, weed control during initial stage is essential to get optimum crop yield. Though, physical methods of weed control are very effective, but they have certain limitations such as non-availability of labour during peak period, high labour cost and unfavourable environmental conditions, such as rainfall. Under such conditions, the chemical weed control plays an important role in groundnut and enhances the groundnut yield substantially. Looking to the above facts the experiment was planned to manage the weeds in groundnut with post emergence herbicides.

METHODOLOGY

A field investigation was carried out at the farm of Agronomy Department, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (MS) during the *Kharif* season of 2015. The experiment was laid out in randomized block design with eight treatments replicated thrice. The experimental site was low in nitrogen, medium in phosphorous and fairly rich in potash and slightly alkaline in reaction. Sowing of rainfed groundnut CV, TAG-24 was done at spacing of 30 X 10 cm on 19th June 2015, with RDF 25:50:30 NPK Kg/ha. Herbicides were applied as per the treatments and Phytotoxicity symptoms on crop was recorded by using a visual score scale of 0-10.

RESULTS

Weed management practices exerted significant influence

Table 1. Weed population, weed dry matter, weed control efficiency, grain yield, and B:C ratio as influenced by weed control treatments in Groundnut

Treatments	Weed count/m^2 at harvest	Weed dry matter g/m^2 at harvest	Weed control efficiency (%)	Dry Pod yield (t/ha)	B:C Ratio
T_1 : Pendimethalin 1kg /ha P.E.	7.62 (57.57)	7.70 (59.03)	68.62	1.91	2.87
T_2 : Propaquizofop 0.10 kg /ha POE 20 DAS	5.38 (28.50)	5.76 (32.67)	82.08	2.33	3.50
T_3 : Quizolofop ethyl 0.10 kg /ha POE 20 DAS	6.68 (44.23)	6.95 (47.83)	73.76	2.04	2.92
T_4 : Imazethapyr 0.10 kg / ha POE 20 DAS	6.44 (41.03)	6.88 (46.87)	74.29	2.06	3.09
T_5 :Imazethapyr+ Imazomox 0.10 kg /ha POE 20 DAS	5.72 (32.23)	5.97 (35.20)	80.69	2.26	3.34
T_6 :Imazethapyr 0.10 kg /ha POE fb Quizolofop ethyl 0.10 kg/ha 20 DAS	6.99 (48.43)	7.16 (50.77)	72.15	1.93	2.59
T_7 :Imazethapyr 0.10 kg /ha + Quizolofop ethyl 0.10 kg /ha POE 20 DAS	6.85 (46.47)	7.03 (48.93)	73.16	1.97	2.69
T_8 :Oxyflurofen 0.20 kg /ha POE 20 DAS	6.55 (42.50)	6.88 (46.80)	74.33	1.50	2.22
T_9 :Weed free	2.31 (4.87)	2.17 (4.25)	97.67	2.52	3.09
T_{10} :Weedy check	12.35 (152.23)	13.52 (182.30)	67.62	1.01	1.63
SEm±	0.16	0.14	-	0.06	0.16
CD (P= 0.05)	0.48	0.43	-	0.17	0.48

Data are subjected to square root transformation ($\sqrt{x+0.5}$)Data given in parentheses are original values on weed population, weed dry matter, yield and economics when compared with unweeded control (Table 1). Weed count and weed dry matter were recorded significantly lowest in treatment propaquizofop 0.10 kg/ha POE 20 DAS but found at par with imazethapyr+ imazomox 0.10kg/ha POE 20 DAS.this may be due to better control of weeds by combination of both post emergence herbicides. Highest weed control efficiency (%) was observed in weed free check. Among the herbicides maximum WCE was recorded propaquizofop 0.10 kg/ha POE 20 DAS followed by imazethapyr+ imazomox 0.10 kg/ha POE 20 DAS. Lowest WCE was noticed in weed check treatment. Data on yield (t/ha) of dry pods as influenced by various treatments (Table 1) showed that weed free check gave highest pod yield (2.52 t/ha) followed by post emergence application propaquizofop 0.10 kg/ha POE 20 DAS (2.33 t/ha) and imazethapyr+ imazomox 0.10 kg/ha POE 20 DAS (2.26 t/ha), both these treatments recorded significantly higher dry pod yield over rest of treatments. The lowest yield was recorded in weedy check. The pre emergence application of pendimethalin 1000 g/ha recorded lowest pod yield as compared to other herbicidal treatment but highest than unwedded control. Maximum B:C ratio (3.50) was recorded in post emergence herbicide treatment propaquizafop 100 g/ha followed by application of imazethapyr+ Imazomox 0.10kg /ha POE 20 DAS (3.34), than rest of treatments. The lowest B:C ratio was observed in unweeded control treatment. The additional amount of income obtained under weed free check appeared to be immaterial when compared to cost of weeding incurred to maintain weed free condition beyond eight weeks after sowing.

CONCLUSION

The post emergence herbicide treatment propaquizofop 0.10 kg/ha POE 20 DAS and imazethapyr+ imazomox 0.10 kg/ha PoE 20 DAS proved practically more convenient and economically best feasible herbicidal weed management practices for groundnut. Considering the present condition of scarcity and high cost of labour, quality of weed control, yield and B:C ratio of cultivation of groundnut.

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Herbigation studies in aerobic rice

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Rice (*Oryza sativa* L.) is the world's most important staple food crop and primary source of food for more than half of the world's population, occupying a prime place among the food crops after wheat. In India, it is grown in an area of 46.19 million hectare with a production of 106.29 million tonnes and productivity of 2462 kg/ha (Anon., 2014).The shrinking water resources and competition from other sectors, the share of water allocated to irrigation is likely to decrease by 10 to 15 per cent in the next two decades. Aerobic rice with drip irrigation can address the multifaceted problems of water scarcity, weed competition and environmental pollution. Herbigation is the improved method of application of herbicides through irrigation water and may be superior over conventional spraying mainly by reducing the herbicide loss through run-off and leaching(Kesthkar*et al.,* 2010). Hence, the herbigation is the solution to manage the weed problems in the aerobic rice system.

METHODOLOGY

A field experiment was conducted to study the "studies on weed management approaches for trickle irrigated aerobic rice" during *summer* 2014 at Zonal Agricultural Research Station, University of Agricultural Sciences, Bengaluru-560 065. Field experiment was designed using RCBD consisting of 10 weed management practice with three replications. The soil of the experimental plot was red sandy loam. The aerobic rice hybrid (KRH-4) was fertilized with 100:50:50 N, P_2O_5, K_2O kg/ha through urea, single super phosphate and murate of

Table 1. Grain yield, straw yield, Dry weight at harvest, WCF, WI, net return and B:C ratio of aerobic rice as influenced by weed management practices

Treatments	Grain yield (kg/ha)	Straw yield (kg/ha)	Weed dry weight (kg/ha) at harvest	Weed control efficiency (%)	Weed index (%)	Net returns (Rs/ha)	B:C
T_1: Weed free check	10615	20037	0	100.00	0.00	126613	3.09
T_2: Weedy check	1101	1865	12127	0.00	89.58	-33438	0.36
T3: Two hand weeding at 20 and 40 DAS	7563	14556	4088	66.30	28.31	74959	2.27
T_4: Hand hoeing at 15,30 and 45 DAS	8308	17124	2002	83.30	20.81	88830	2.49
T_5: One hand hoeing at 15 DAS and one HW at 20 DAS	5727	13390	5231	57.03	45.83	46687	1.81
T_6: One HW at 20 DAS and mulching with Glyricidia at 30 DAS	8009	16009	3572	70.53	24.83	85184	2.48
T_7: Pre-emergent application Pretilachlor + Bensulfuran methyl	5386	11759	5390	55.48	48.91	41929	1.76
T_8: Pre-emergentapplication of Pretilachlor + Bensulfuran methyl and Post emergent application of Bispyribac sodium at 20 DAS	7662	15279	4111	66.01	27.33	80357	2.44
T_9: T_7 through herbigation (Drip)	8194	16396	3502	71.13	22.45	90540	2.64
T_{10}: T_8 through herbigation (Drip)	9892	18063	570	95.27	6.99	117704	3.10
CD (P=0.05)	1238	1457	808	1.64	2.99	—	—

potash respectively. Data on weed growth, yield performance and economics were recorded.

RESULTS

At 20 DAS, Significantly higher total weed count (Table 1) was found in weedy check (37.67) followed by pre-emergent application of pretilachlor + bensulfuran methyl (T_7: 21.67). Significantly lower weed population was recorded in weed free check (T_1: 0.00) and followed by herbigation of pre-emergent pretilachlor + bensulfuran methyl + post emergent bispyribac sodium at 20 DAS (T_{10}: 4.67). Same trend is fallowed in 40 DAS, 60 DAS and 80 DAS. Weed dry weight (g/hill) was significantly higher pre-emergent application of pretilachlor + bensulfuran methyl (2.40 g) after weedy check (T_2: 4.36 g) at 20 DAS. Significantly lower total weed dry weight was found in weed free check (0.00) followed by herbigation of pre-emergent pretilachlor + bensulfuran methyl + post emergent bispyribac sodium at 20 DAS (T_{10}:0.52 g). T_{10} was on par with hand hoeng at 15, 30 and 45 DAS (T_4:0.58 g) and herbigation of pre-emergent pretilachlor + bensulfuran methyl (T_9: 0.96 g). Similar results are fallowed at 40 DAS, 60 DAS and 80 DAS. The dry matter of crop at harvest varied significantly due to weed management practices (Table 1). Weed free check (262.83 g) and herbigation of pre-emergent pretilachlor + bensulfuran methyl + post emergent bispyribac sodium at 20 DAS recorded significantly higher dry weight (254.97 g /ill) compared to weedy check. Similar observations were also noticed at all the stages of crop growth.Herbigation of pre-emergent application of pretilachlor + bensulfuran methyl and post emergent bispyribac sodium at 20 DAS (Table 1) significantly higher grain and straw yield ((9892 and 18063 kg/ha, respectively) after weed free check (10615 and 20037 kg/ha, respectively) which was on par with hand hoeing at 15, 30 and 45 DAS (8308 and 17124 kg/ha, respectively) and whereas in weedy check (1101 and 1865 kg/ha, respectively). These practices were also recorded total weed dry weight at harvest (570, 0.00, 2002 and 12127 kg/ha, respectively), weed index (6.69, 0.00, 20.81 and 89.58 %, respectively) and higher weed control efficiency (95.27, 100.00, 83.30 and 0.00 %, respectively).Though highest net return (Rs. 90540 /ha) was recorded in herbigation of pre-emergent application of pretilachlor + bensulfuran methyl and post emergent bispyribac sodium at 20 DAS after weed free check (Rs. 126613 / ha) where as in weedy check (Rs. -33438 /ha and B: C ratio (3.10, 3.09 and 0.36, respectively).

CONCLUSION

Herbigation of pre-emergent application of pretilachlor + bensulfuran methyl and post emergent bispyribac sodium at 20 DAS, hand hoeing at 15, 30 and 45 DAS and weed free check condition is best weed management practice for aerobic rice.

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Weed Stress alleviation in wheat (*Triticum aestivum*) through herbicides and their mixtures

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Wheat is one of the most important cereal crops of India not only in terms of meeting calorie requirement of sizable segment of the society, but also in terms of its versatility for adoption under wide range of agro- climatic conditions and crop growing situations. Wheat crop is prone to a variety of weeds which are classified as annual grassy and broadleaf (Chhokar *et al*., 2012). Appropriate weed management technology can help in increasing the productivity and production of this crop. Wide ranges of herbicides are under recommendation for weed control in wheat but most of them suffer from narrow spectrum control viz. either grassy or broadleaf ones. This has opened a new vista of applying herbicides of diverse selectivity together. One way is to apply 2 herbicides one after the other in sequence. However, mixtures have shown encouraging results to save time and cost, instead of sequential application of herbicides (Kumari *et al*., 2013). It is advantageous to tank mix broadleaf weed herbicide with grass controlling herbicide to combat broad spectrum weed flora

METHODOLOGY

An experiment was conducted at Instructional Farm of Agronomy, Department of Agronomy, Rajasthan College of Agriculture, Udaipur (Raj.). The fourteen treatments comprised of 4 single herbicides viz. metribuzin 210 g/ha, clodinafop 60 g/ha, pinoxaden 40 g /ha and sulfosulfuron 25 g/ha, 4 tank mixtures viz. clodinafop + metribuzin (60 + 210 g/ha). Pinoxaden + metribuzin (40 + 210 g/ha) sulfosulfuron + metribuzin (25 + 210 g/ha) and isoproturon + 2, 4-D (1,000 + 500 g/ha) and 4 premixes viz. accord plus (fenoxaprop + metriburin) 310 g/ha, total (sulfosulfuron + metsulfuron) 32 g/ha, atlantis (mesosulfuron + iodosulfuron) 12 + 2.4 g/ha and vesta (clodinafop + metsulfuron) 60 + 4 g/ha along with weed free and weedy check. The experiment was laid out in randomized block design with 3 replications. Wheat cultivar 'Raj 4037' was used and all the herbicides were applied as POE (32 days DAS) in both the years. Density and dry weight of weeds were recorded at 60 and 120 DAS using quadrate of 0.5 m × 0.5 m, placed at 2 random spots in each plot. Yield attributes and yield were recorded at maturity of the crop.

RESULTS

The lowest density of total weeds (0.5 m row length) was observed in weed free plots and it was statistically superior over rest of the treatments at 60 DAS. Amongst application of ready mix herbicides sulfosulfuron + metsulfuron @ 32 g *a.i/* ha recorded the minimum total weed density (6.65/m^2) which was at par with ready mix mesosulfuron + iodosulfuron @ 14.4 g *a.i*/ha tank mix, sulfosulfuron + metribuzin (25+210 g *a.i*/ha), clodinafop + metribuzin (60+210 g *a.i/*ha), sulfosulfuron 25 g *a.i/*ha, pinoxaden 40 g *a.i/*ha, clodinafop 60 g *a.i/*ha and metribuzin 210 g *a.i*ha, while gave significantly superior weed control over rest of the herbicide treatments and weedy check at 60 DAS. The maximum grain yield was recorded under application of ready mix sulfosulfuron + metsulfuron @ 32 g *a.i/*ha gave the highest grain yield (52.9 q/ha) which was at par with sulfosulfuron + meribuzin, mesosulfuron + iodosulfuron and clodinafop + metsulfuron while statistically superior over other herbicidal treatments. Higher yield was recorded in wheat might be due to low weed density and dry-atter which helped in better crop growth and production of more effective tillers. The lowest straw yield was found in metribuzin applied plots are due to burning or phototoxic effect of metribuzin on wheat crop.

CONCLUSION

Application of various herbicide combinations made significant reduction in density and biomass of complex weed flora. The application of herbicides increased the yield, harvest index and monetary income of wheat crop compared to weedy check, although maximum grain yield was recorded under weed free plots. In respect to herbicides, application of sulfosulfuron + metsulfuron @ 30 + 2 g *a.i*/ha recorded the maximum grain yield because this combination have superiority in reduction of weed density and weed biomass so ultimately lesser competition for light, space, nutrients and moisture which might be helped into increasing yield of crop.

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Bioefficacy of imazethapyr against weeds and growth yield of redgram

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Redgram is the second most important pulse crop of India after chickpea. Due to its initial slow growth, weeds pose a major problem to its growth and development which leads to yield reduction upto 80 % (Talnikar *et al.*, 2008). In redgram, many pre-emergence herbicides were in use such as alachlor, metolachlor and pendimethalin etc. for effective control of weeds but these herbicides were providing effective weed control during the initial growth period only (up to 30 days after sowing). But, it is essential to control the post emergence weeds at the later stages of crop growth also. Therefore, we have to go for other post emergence herbicides for controlling weeds during later stages of crop growth. Imazethapyr may play a pivotal role in controlling weeds during later stages of crop growth.

METHODOLOGY

A field experiment was conducted during *Kharif* seasons 2015-16 at Live stock Farm, JNKVV, Jabalpur. The ten treatments comprising of five doses of imazethapyr (60, 75, 90, 105, 120 and 150 g/ha), alone application of pendimethalin (1000 g/ha) as pre-emergence and propaquizafop (75 g/ha), hand weeding twice (20 and 40 DAS) including weedy check, were layout in randomized block design with three replications. Redgram variety ICPL-87-119 was grown in the experimental field with recommended package of practices. Fertilizers were applied uniformly through urea, single super phosphate and muriate of potash at the rate 20,60 and 20 kg N, P, and K/ha, respectively. The species-wise weed population was recorded by quadrate (0.25 m^2) method at 45 days after application. The economic analysis of each treatment was done on

Table 1. Influence of herbicides on yield and economics of redgram

Treatment	Seed yield (kg/ha)	Stick yield (kg/ha)	GMR (Rs ×10^3/ha)	NMR (Rs × 10^3/ha)	B:Cratio
T_1 Imazethapyr (60 g/ha)	1903.40	8351.59	119.69	96.78	5.23
T_2 Imazethapyr (75 g/ha)	2001.26	8450.87	126.25	103.08	5.45
T_3 Imazethapyr (90 g/ha)	2130.68	8535.79	133.46	110.04	5.70
T_4 Imazethapyr (105 g/ha)	2263.26	8724.28	141.02	117.35	5.96
T_5 Imazethapyr (120 g/ha)	2373.74	8750.93	147.38	123.45	6.16
T_6 Imazethapyr (150 g/ha)	2449.49	8751.35	152.22	127.78	6.23
T_7 Pendimethalin (1000 g/ha)	2026.52	8314.63	124.71	100.29	5.11
T_8 Propaquizafop (75 g/ha)	1960.23	8087.07	121.76	99.31	5.42
T_9 Hand weeding (20 and 40 DAS	2455.81	8759.66	152.94	120.85	4.77
T_{10} Unweeded control	1423.61	6583.19	91.26	69.681	4.23
SEm±	0.46	0.31	-	-	-
CD (P=0.05)	1.37	0.94	-	-	-

GMR = Gross monetary return, NMR = Net monetary returns, B:C ratio = Benefit cost ratio the basis of prevailing market price of inputs used and outputs obtained under each treatment.

RESULTS

Yield reduction due to presence of weeds in redgram was 42.03 %. The seed and stick yield of redgram was lower under weedy check plots (Table 1). These parameters were increased when weed control measures were adopted either chemically or manually. The seed and stick yields were minimum when imazethapyr was applied at lower rates (60 g/ha) but these were increased further with corresponding increase in application rates being higher at 120 and 150 g/ha. However, hand weeding plot recorded maximum seed and stick yields and proved significantly superior over other herbicidal treatments. Minimum net monetary returns (Rs 69681/ ha) was fetched under weedy check plots. However, post emergence application of imazethapyr a 120 and 150 g/ha was found more remunerative as they fetched higher net monetary returns (123432 and 127784) and B:C ratio (6.16 and 6.23).

CONCLUSION

It could be concluded that post-emergence application of imazethapyr at 120 and 150 g/ha was found more remunerative compared to its lower doses and application of pendimethalin (1000 g/ha) and propaquizafop (75 g/ha) and even to hand weeding twice (20 and 40 DAS).

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Chemical control of sedges and broadleaf weeds in dry seeded rice

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Rice (*Oryza sativa* L.) is an important cereal crop of Asia and other parts of the world and provides food security and livelihood for millions of farmers and workers. Dry-direct seeded rice (DSR) is one of the technologies that significantly reduce labour and water requirements. Heavy weed infestation comprising of grasses, broadleaf and sedges, one of the major constraints in DSR, causes severe yield losses (Rao *et al* 2015) and warrants use of herbicide depending upon weed flora present in the field. Sedges and broad leaf weeds become highly competitive with the crop when grasses are kept under control. Therefore, in the present study, efforts were made to find out suitable herbicides for managing sedges and broadleaf weeds at variable doses and its impact on DSR productivity.

METHODOLOGY

A field experiment was conducted at Department of Agronomy, Punjab Agricultural University, Ludhiana during *kharif* 2015. Sowing of rice cultivar PR 115 was done on 15 June in randomized complete block design (RCBD) with four replications comprising 12 treatments including metsulfuron 8, 12, 16 g, 2, 4-D amine salt 435, 580, 725 g, pre-mix of metsulfuron + chlorimuron 2, 4, 6 g, azimsulfuron 20 g/ha, weedy check and weed free check. All the herbicides were applied as post-emergence at 15 days after sowing by using 375 litres of water/ha with knap sack sprayer. Weed data was recorded at 30 days after herbicide application and B:C ratio was calculated using net returns and variable cost. The comparisons were made at 5 per cent level of significance with Tukey HSD (honest significant difference) test using functional analysis.

RESULTS

At 30 days after herbicide application, metsulfuron recorded effective control of broadleaf weeds only and was found ineffective against sedges. Application of azimsulfuron 20 g/ha recorded the lowest biomass of sedges which was statistically at par with metsulfuron + chlorimuron 4 g and 6 g and 2, 4-D amine salt 725 g/ha. The maximum weed dry matter of sedges was recorded in unweeded control which was statistically at par with metsulfuron 8 g and 12 g/ha. Metsulfuron + chlorimuron 6 g/ha was effective against broad leaf weeds and it recorded lowest biomass of broad leaf weeds as compared to other herbicidal treatments which was statistically at par with weedfree check. Amongst herbicidal treatments, application of azimsulfuron 20 g, metsulfuron + chlorimuron 4 g and 6 g, 2, 4-D amine salt 580 g and 725 g and metsulfuron 16 g/ha resulted in significantly lower biom-

Table 1. Effect of weed control treatments on weed biomass, effective tillers, yield and economics in DSR.

Treatment (g/ha)	Weed biomass* (g/m^2) at 30 DAA		Effective tillers/m^2	Grain yield (t/ha)	B:C
	Sedges	BLW			
Metsufuron 8	15.4 (239)	4.4 (19)	193.3	3.4	1.1
Metsulfuron 12	14.3 (207)	3.8 (13)	222.0	3.9	1.4
Metsulfuron 16	13.4 (180)	2.2 (4)	289.3	4.9	2.1
2, 4-D amine salt 435	12.2 (150)	5.4 (28)	246.3	4.3	1.8
2, 4-D amine salt 580	7.8 (63)	3.0 (8)	307.5	5.2	2.3
2, 4-D amine salt 725	5.4 (30)	1.9 (3)	361.0	6.2	2.9
Metsulfuron + chlorimuron 2	11.6 (133)	5.2 (27)	268.5	4.6	2.0
Metsulfuron + chlorimuron 4	6.1 (39)	2.6 (6)	355.0	6.1	2.9
Metsulfuron + chlorimuron 6	4.6 (21)	1.9(3)	336.0	5.7	2.6
Azimsulfuron 20	3.9 (14)	2.0 (3)	364.5	6.2	2.8
Weedy	16.9 (287)	7.3 (52)	145.3	2.2	0.5
Weedfree	1.0 (0)	1.0 (0)	365.5	6.3	1.2
HSD^a (P=0.05)	3.6	1.3	91.9	1.4	-
HSD^b (P=0.05)	2.7	1.0	69.4	1.0	-

*Data is subjected to square root transformation ($\sqrt{x+1}$). Figures in parenthesis are original means. DAA- days after application; HSD^a: Amongst Herbicide, and HSD^b: Herbicide v/s Control

ass of broad leaf weeds as compared with other herbicidal treatments. Weedfree treatment recorded significantly more number of effective tillers as compared with all herbicidal treatments which were also statistically at par with application of azimsulfuron 20 g, metsulfuron + chlorimuron 4 g and 6 g, 2, 4-D amine salt 580 g and 725 g/ha due to effective control of weeds (Table 1). Lower number of effective tiller was observed with metsulfuron 8 g/ha due to high weed pressure and effective tillers observed were similar to weedy check. In DSR, 64.25% yield reduction was caused by broadleaf weeds and sedges. The maximum grain yield was recorded in weed free which was statistically similar to yield obtained in azimsulfuron 20 g, 2, 4-D amine 725 g, metsulfuron + chlorimuron (pre-mix) 4 g and 6 g/ha and effectively controlled sedges and broad leaf weeds with more than 90 % WCE. Amongst herbicides, azimsulfuron 20 g, metsulfuron 16 g, 2, 4-D amine 580 g and 725 g, metsulfuron + chlorimuron (pre-mix) 4 g and 6 g/ha resulted in more yield and benefit:cost ratio as compared to other herbicidal treatments. The higher dose of metsulfuron + chlorimuron 6 g/ha was slightly phytotoxic to crop.

CONCLUSION

Post-emergence application of 2,4-D amine 725 g/ha, premix of metsulfuron +chlormiuron 4 g and 6 g/ha at 15 DAS controlled sedges and broadleaf weeds in dry seeded rice and increased rice grain yield however, higher dose of pre-mix of metsulfuron+chlormiuron was slightly phytotoxic to crop. Metsulfuron 16 g/ha controlled broadleaf weeds but failed to control sedges.

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Evaluation of cultivated wheat germplasm of different phenological groups under restricted irrigation

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Moisture stress is one of the most important factors limiting grain yield and quality of wheat crop. In India, about 20% of the area under wheat cultivation is rainfed. Even under irrigated conditions, 66 % areareceives only 1-2 irrigations subjecting the crop to water deficit(Joshi *et al*., 2007). It is well established fact that severe drought during anthesis decreases grain yield up to 50 %. Hence, apart from water conservation technologies, breeding varieties tolerant to low water conditions should become priority of the researchers. Although various groups of scientists are breeding drought tolerant varieties, the identification of new donors for various components traits of moisture stress tolerance in the wheat breeding programme will definitely hasten the process.But this requires large scale preliminaryevaluation of the largelyuntapped wheat gene pool conserved in the gene bank coupled with advanced screening of selected lines under controlled condition. Keeping this in view, the present study focussed towards phenotyping of diverse set of cultivated wheat germplasm under restricted irrigation condition, so that a smaller subset can be identified for advanced screening and important traits contributing towards grain yield under restricted irrigation condition can be determined.

METHODOLOGY

A set of1483 cultivated wheat accessions (1235 indigenous and 248 exotic collections) belonging to twenty states across India were evaluated under restricted irrigation condition during *rabi*season 2014-15 at NBPGR, Issapur farm. The experiment waslaid out in augmented block design with the block size of 148 and 4 checks C306 and WR544 (drought tolerant), Raj3765, HD2967(agronomic) were randomized in each block. The crop was raised with one irrigation after sowing at CRI stage for field establishment. The volumetric soil moisture content was recorded at monthly intervalsfrom sowing to harvest. The data on these germplasm lines were collected for 12 morpho-physiological traits including canopy temperature and chlorophyll concentration index (CCI).Statistical analysis was performed using Statistical Analysis Software (SAS) version 9.3.

RESULTS

The results revealed that there was sufficient variability for all the traits studiedin the wheat germplasm. Based on days to spike emergence, the accessions were classified into three phenological classes: early(d" 90), medium (91-100) and late (>100 days).Consequently, 107 early, 1058 medium and 318 late heading types were identified.The average monthly rainfall recorded during the *rabi* season (November to April) at Issapur farm was 37.5 mm. The distribution of total rainfall recorded during the month of November, December, January, February, March and April were 0 mm, 0mm, 0mm, 3 mm, 156 mm and 70 mm respectively. The seasonal mean value of minimum and maximum temperature was 16.1 and 28.3°C. The maximum temperature during the grain filling period remained more than 34°C for thirteen days. The mean volumetric soil moisture content at 30 cm depth during the month of November, December, January, February, March and April were 26.36, 19.21, 10.56 3.26, 15.46, 10.24 % respectively. Based on these predictor variables, a set of 150 wheat accessions were selected. Out of these accessions, EC178071-454, IC558801, IC498438, IC546936, IC393877, EC609554, EC178071-631, EC178071-210, were identified superior accessions based on grain yield per meter, biomass and grain weight in comparison to the best check C306. These selected accessions will be further evaluated under replicated trial and will be validated under controlled conditionfor different moisture regime also.

CONCLUSION

There was wide variability in this set of germplasm for the phenological, agronomical and physiological traits. This experiment identified correlated traits responsible for high grain yield under restricted moisture condition and different phenological classes. Grain yield was negatively correlated with canopy temperature and positively with chlorophyll content in medium and late maturing classes. Biomass, grain weight, spikelets per spike and chlorophyll content remained in the final model for prediction of grain yield. Based on predictor variables, accessions were selected for further validation under controlled condition. These accessions can be used for introgression of moisture stress tolerant genes in the background of elite varieties to enhance yield under moisture stress environments.

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Efficacy of post-emergence herbicides and their combination on composite weed flora of wet season transplanted rice

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Rice is generally cultivated in eastern India by transplanting. Among the several factors responsible for low rice productivity, weeds are considered to be the major one due to their manifold harmful effects. Transplanted rice is infested by heterogeneous types of weed flora which cause yield reduction by about 33-45% (Manhas *et al.,* 2012). Herbicides appear to hold a great promise in dealing with effective, timely and economic weed suppression in *kharif* transplanted rice. New generation herbicides like azimsulfuron and bispyribac-sodium have been launched recently which are effective against broad spectrum of weeds with very low dose ((Duary *et al.,* 2015; Sreelakshmi *et al*., 2016). But sole application of one herbicide has seldom been found ineffective against complex weed flora throughout the critical period of competition. Combined application of herbicides is emerging out as very effective tool to tackle the problem of complex weeds in transplanted rice.Therefore, the present investigation was undertaken to evaluate the efficacy of post-emergence herbicides either applied alone or in combination on complex weed flora and productivity of transplanted rice.

METHODOLOGY

Field experiments were carried out during *Kharif*season of 2014 and 2015 at Agriculture Farm, Institute of Agriculture, Visva-BharatiUniversity, Sriniketan, West Bengal.Eight treatments comprisingof azimsulfuron at 35g/ha at 20 DAT, bispyribac-sodium at 25g/ha at 20 DAT, 2,4-D (Na salt) at 400 g/ha at 35 DAT,fenoxaprop-p-ethyl at 60 g/ha at 20 DAT, azimsulfuron+ bispyribac-sodium at 35+25 g/ha at 25 DAT, fenoxaprop-p-ethyl at 60 g/ha at 20 DAT + 2,4-D (Na salt) at 400 g/ha at 35 DAT, hand weeding twice at 20 and 40 DAT anduntreated controlwere replicated thrice in a randomized block design.Ricevariety *'Swarna'*(MTU 7029) was used in the study.The crop was fertilized with 80 kg N, 40 kg each of P_2O_5 and K_2O per hectare. All other recommended agronomic practices and plant protection measures were adopted to raise the crop. The data on weed density and dry weight of weeds per m^2 were recorded at different growth stages of rice crop. These were subjected to square root transformation to normalize their distribution. Weed control efficiency (%) was computed using the dry weight of weeds. Grain yield of rice along with yield componentswere recorded at harvest.

RESULTS

The total number of weed species in the experimental field was 7 out of which *Echinochloacolona,* among the grasses; *Cyperus iria* among the sedges and *Ludwigia parviflora*among the broadleaved weeds were present as major weeds throughout the cropping period.Weed control treatments brought about significant variation in the density and dry matter production of weeds at 45 DAT (Table 1). The lowest density and dry weight of total weeds was registered under hand weeding twice at 20 and 40 DAT which was statistically at par with azimsulfuron+ bispyribac-sodium at 35+25 g/ha.Among the herbicidal treatments combined application of azimsulfuron+ bispyribac-sodium at 35+25 g/ha at 25

Table 1. Effect of treatments on density and dry weight of weeds, weed control efficiency, number of panicles and grain yield of transplanted rice (pooled data)

Treatments	Weed density (no. /m^2) at 45 DAT	Weed dry weight (g/m^2) at 45 DAT	Weed control efficiency (%) at 45 DAT	No of panicles/ m^2	Grain yield (kg/ha)
Azimsulfuron at 35 g/ha at 20 DAT	4.18 (17.00)	2.74 (6.99)	90.4	231	4732
Bispyribac-sodium at 25 g/ha at 20 DAT	4.02 (15.67)	2.57 (6.08)	91.6	231	4817
2,4-D (Na salt) at 400 g/ha at 35 DAT	5.31 (27.67)	6.19 (37.78)	48.1	196	4198
Fenoxaprop–ethyl at 60 g/ha at 20 DAT	5.55 (30.33)	5.16 (26.13)	64.1	202	4214
Azimsulfuron+bispyribac- sodium at 35+25 g/ha at 25 DAT	1.35 (1.33)	0.82 (0.17)	99.8	277	5363
Fenoxaprop–ethyl + 2,4-D (Na salt) at 60 + 400g/ha at 25 DAT	3.14 (9.33)	1.87 (3.01)	95.9	249	4966
Hand weeding twice at 20 and 40 DAT	1.08 (0.67)	0.76 (0.08)	99.9	280	5390
Unweeded control	7.58 (57.00)	8.56 (72.74)	0	152	3802
CD (P=0.5)	0.43	0.37	-	20.3	331

Figures in parentheses are the original values. The data was transformed to SQRT (x + 0.5) before analysis.

DATcontrolled complex weed flora effectively in transplanted rice and registered the highest weed control efficiency at 45 DAT. There was about 29.48% yield reduction due to weed competition in transplanted rice.The highest number of panicles per $m^2$and grain yield (5390 kg/ha) was recorded with hand weeding at 20 and 40 DAT which was statistically at par with azimsulfuron+ bispyribac-Na at 35+25 g/ha at 25 DAT(5363 kg/ha). Effective and timely weed management under these treatments reduced the density as well as dry weight of weeds which facilitated the crop plants to have sufficient space, light, nutrient and moisture and thus the number of panicles per m^2 and finally the grain yield was increased. The lowest grain yield (3802kg/ha) was recorded under unweeded control.

CONCLUSION

It may be concluded that combined application of azimsulfuron+ bispyribac-sodium at 35+25 g/ha at 25 DAT appeared to be the most effective for management of composite weed flora and obtaining higher grain yield of transplanted rice.

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Nutrient uptake by rice and weeds as influenced by weed management practices under semidry system of cultivation

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A field experiment was conducted during *kharif*, 2014 in sandy loam soils of Agricultural College Farm, Naira, AP to find out the effect of weed management practices on uptake of rice and weeds under semidry system of cultivation. The experiment was laid out in randomized block design with ten treatments, each replicated thrice. Nitrogen, phosphorus and potassium uptake by rice crop was found to be maximum with pre-emergence application of pendimethalin @ 0.75 kg a.i./ha at 3-5 DAS *fb* post-emergence application of metsulfuron methyl + chlorimuron ethyl @ 4 g a.i./ha at 20-25 DAS which was comparable with weed free check. Significantly lower values for the uptake of N, P and K by weeds was registered with application of pendimethalin @ 0.75 kg a.i./ha *fb* metsulfuron methyl + chlorimuron ethyl @ 4 g a.i./ha as post-emergence. Weedy check treatment registered the highest nitrogen, phosphorus and potassium uptake by weeds.

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Broad spectrum weed management in drum seeded rice

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Direct seeding of rice will only be successful provided good crop establishment as well as adequate weed control methods are available to keep crop free from weeds (Rao*et al*., 2007). The chemical weed control in direct seeded rice has gained importance because of the intensity of weed problems, coupled with the lack of labour for weeding and high cost. Timely weed control is crucial to increase rice productivity. Many of the rice herbicides presently used are mainly pre emergence and weeds coming at later stages of crop growth are not effectively controlled. Sometimes continuous use of a single herbicide may lead to build up of herbicide resistance in weeds (Kalaiselvi*et al*., 2009). In such situations, post emergence herbicides are needed for use in combination with pre emergence herbicides to control the late emerging weeds in direct seeded rice. Therefore, to manage the weeds in rice in a better way this study was conducted to evaluate the effect of herbicide combinations for control of complex weed flora in drum seeded rice.

METHODOLOGY

Field experiments were conducted during *rabi* 2014-15 at Tamil Nadu Agricultural University, Coimbatore (11ˆ N latitude with 77ˆ E longitude, 426.7 m mean sea level) to find out appropriate combination of herbicides in drum seeded rice. The experiment field was clay loam in texture with 36.7% clay, 20.4% silt and 41.7% sand. It was low in available nitrogen (238 kg/ha), medium in available P (17 kg/ha) and high in K (727 kg/ha). The pH of the soil was 8.8 with organic carbon and available soil moisture content of 0.24 and 27.83 per cent respectively.The treatments are pre-emergence application of either pretilachlor (S) 450 g/ha on 5 DAS or pyrazosulfuron ethyl 20 g/ha on 0 DAS or oxadiargyl 80 g/ha on 10 DAS *fb* HW on 40 DAS or POE azimsulfuron 35 g/ha on 30 DAS, either PE bensulfuron methyl + pretilachlor (RM) 660 g/ha on 5 DAS or POE bispyribac sodium 25 g/ha 20 DAS *fb* HW on 40 DAS, POE azimsulfuron 35 g/ha on 30 DAS, either mechanical or hand weeding on 20 and 40 DAS and unweeded check.Observations on weed flora, weed density and weed dry weight were recorded with a quadrate (0.25x0.25 m^2) placed randomly in each plot at 60 DASand data presented as per m^2. The data on weed density and weed dry weight were subjected to square root transformation (“X+0.5). Weed control efficiency (WCE) was computed by using weed dry weight. The grain yield and benefit cost ratio were calculated. The data were analyzed using ANOVA and the least significant difference (LSD) values at 5% level of significance were calculated.

RESULTS

Distinct reduction of total weed density by PE oxadiargyl 80 g/ha *fb* POE azimsulfuron 35 g/ha and PE pretilachlor (S) 450 g/ha *fb* POE azimsulfuron 35 g/ha and significant reduction at later stages as late germinating weeds were controlled by post emergence herbicide application of azimsulfuron 35 g/ha (Table.1).Considerable reduction in weed dry weight recorded with PE either oxadiargyl 80 g/ha or pretilachlor (S) 450 g/ha *fb* POE azimsulfuron 35 g/ha at all the stages of observation might be attributed to the minimum number of total weedswith lesser biomass in the cropping period. Weed dry weight reduced due to the efficient weed control and lesser weed density compared to other treatments.Higher WCE registered in PE either oxadiargyl 80 g/ha or pretilachlor (S) 450 g/ha *fb* POE azimsulfuron 35 g/ha at 40 and 60 DAS and PE oxadiargyl 80 g/ha *fb* either POE azimsulfuron 35 g/ha or HW at 20 DAS might be due to con-

Table 1. Effect of weed management on total weed density, total weed dry weightand weed control efficiency at 60 DAS in drum seeded rice

Treatment	Weed density (No./m²)	Weed dry weight (g/m²)	WCE (%)
PE pretilachlor (S) 450 g/ha *fb*HW on 40 DAS	8.13 (65.54)	4.53 (20.07)	84.75
PE pretilachlor (S) 450 g/ha *fb*POE azimsulfuron 35 g/ha on 30 DAS	6.35 (39.88)	4.17 (16.85)	87.19
PE pyrazosulfuron ethyl 20 g/ha *fb*HW on 40 DAS	9.16 (83.47)	5.38 (28.43)	78.39
PE pyrazosulfuron ethyl 20 g/ha *fb*POE azimsulfuron 35 g/ha on 30 DAS	7.89 (61.73)	5.62 (31.09)	76.37
PE oxadiargyl 80 g/ha *fb*HW on 40 DAS	7.32 (53.06)	4.18 (16.94)	87.12
PE oxadiargyl 80 g/ha *fb*POE *a*zimsulfuron 35 g/ha on 30 DAS	5.69 (31.91)	4.05 (15.87)	88.04
PE bensulfuron methyl + pretilachlor (RM) 660 g/ha *fb* HW on 40 DAS	8.47 (71.21)	4.76 (22.15)	83.16
POE bispyribac sodium 25 g/ha *fb*HW on 40 DAS	6.78 (45.50)	4.54 (20.14)	84.69
POE azimsulfuron 35 g/ha on 30 DAS	10.08 (101.12)	6.84 (46.23)	64.86
Mechanical weeding on 20 & 40 DAS	10.97 (71.94)	5.84 (33.57)	74.48
Hand weeding on 20 & 40 DAS	6.20 (37.98)	4.29 (17.91)	86.39
Un-weeded check	17.58 (308.65)	11.49 (131.56)	-
CD (P = 0.05)	0.86	0.56	-

Table 2. Effect of weed management on grain yield and benefit cost ratio in drum seeded rice

Treatment	Grain yield (kg/ha)	B:C
PE pretilachlor (S) 450 g/ha *fb*HW on 40 DAS	5339	2.28
PE pretilachlor (S) 450 g/ha *fb*POE azimsulfuron 35 g/ha on 30 DAS	6043	2.54
PE pyrazosulfuron ethyl 20 g/ha *fb*HW on 40 DAS	4789	2.13
PE pyrazosulfuron ethyl 20 g/ha *fb*POE azimsulfuron 35 g/ha on 30 DAS	4139	1.88
PE oxadiargyl 80 g/ha *fb*HW on 40 DAS	5875	2.56
PE oxadiargyl 80 g/ha *fb*POE *a*zimsulfuron 35 g/ha on 30 DAS	6286	2.80
PE bensulfuron methyl + pretilachlor (RM) 660 g/ha *fb* HW on 40 DAS	4872	2.07
POE bispyribac sodium 25 g/ha *fb*HW on 40 DAS	5072	2.35
POE azimsulfuron 35 g/ha on 30 DAS	3397	1.59
Mechanical weeding on 20 & 40 DAS	3955	1.96
Hand weeding on 20 & 40 DAS	5542	2.38
Un-weeded check	2765	1.49
CD (P = 0.05)	877	-

siderable reduction in weed density and weed dry weight. Significantly higher grain yield (6286 kg/ha) was recorded with the PE oxadiargyl80 g/ha *fb* POE azimsulfuron 35 g/ha which was on par with PE pretilachlor (S) 450 g/ha *fb* POE azimsulfuron 35 g/ha (Table 2). The favourable conditions created through the efficient weed management resulted in lesser weed competition between crop and weeds during the critical period of crop growth. The BC ratio was higher in PE oxadiargyl 80 g/ha *fb* POE azimsulfuron 35 g/ha (2.80) and was followed by PE oxadiargyl 80 g/ha *fb* HW (T_5) and PE pretilachlor (S) 450 g/ha *fb* POE azimsulfuron 35 g/ha (T_2). POE azimsulfuron 35 g/ha (T_9) recorded lower BC ratio of 1.59 barring unweeded check (T_{12}).

CONCLUSION

Pre-emergence application of either oxadiargyl 80 g/ha on 10 DAS or pretilachlor (S) 450 g/ha on 5 DAS followed by post emergence application of azimsulfuron 35 g/ha on 30 DAS was very effective for the control of wide spectrum of weed flora, increased productivity and profitability in drum seeded rice.

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Effect of herbicides on seed yield, economics and oil content of linseed

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Globally, linseed is an important oilseed crop grown widely in Asia, America and Europe for both seed and fibre with its production of 22.39 lakh tonnes from 22.70 lakh ha with productivity of 986 kg/ha, while our national production is 1.47 lakh tonnes from an area of 3.38 lakh ha with productivity of 435 kg/ha only. India is the third largest (14.88%) linseed growing countries in the world and production wise it ranks fourth (6.57%) in the world after Canada (31.80%), China (14.74%) and Kazakhistan (13.18%). Linseed is a major *rabi* oilseed crop of the country next to rapeseed and mustard. The major impediments for the lower national productivity are its cultivation under starved input and poor management conditions. The present productivity of 502 kg/ha is still very low as compared to the production potential realised at experimental (1800-2000 kg/ha) and frontline demonstration (965 kg/ha) level. Due to slow initial growth and small leaves size of the crop, linseed is highly infested with weeds causing 30-40% loss in seed yield (Mahere *et al*., 2000). Though, hand weeding is most common method of weed control but it is labour intensive and costly too in comparison to herbicides. Under such conditions, weed management through use of herbicides may be a viable option .To find out suitable herbicides and their doses for effective weed management in linseed is an important task to control weeds effectively and minimize the cost. It is also important to know the effects of herbicides on oil content of linseed. To address these challenges a field experiment was carried out to evaluate the effect of herbicides on seed yield, economics and oil content under irrigated conditions in central plain zone of Uttar Pradesh during the *rabi* seasons of 2012-13, 2013-14 and 2014-15.

METHODOLOGY

A field experiment was laid out in completely randomized block design with three replications at C.S. Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh during three consecutive *rabi* seasons of 2012-13, 2013-14 and 2014-15.The experiment comprised of9treatments *viz*. hand weeding twice at20 -25 and 35 - 45 DAS,pendimethalin30 EC1.0 kg/ha pre emergence, pendimethalin 30 EC+ imazethapyr 2 EC 0.75 kg/ha pre emergence,pendimethalin30 EC+ imazethapyr 2EC1.0 kg/ha pre emergence, isoproturon 1.0 kg/ha post emergence, clodinafop 60g/ha post emergence, imazethapyr 10EC 75g/ha post emergence,imazethapyr10 EC 100g/ha post emergence and weedy check. Soil of the experimental field was sandy loam in texture, slightly alkaline in reaction, low in organic carbon and available N, medium in available P and available K. The experimental site was infested with *Phalaris minor,Chenopodium album, Cyperus rotundus ,Convolvulus arvensis and Anagalis arvensis*. Linseed variety 'shekhar' was sown in lines 25cm, apart using seed rate of 25 kg/ha and fertilized with 80 kg N+ 40 kg P_2O_5 +30 kgK_2O /ha through urea, diammonium phosphate and muriate of potash, respectively. The experiment was irrigated twice besides pre sowing irrigation. The oil content from dried seeds (<10% moisture) were analyzed with the help of Nuclear Magnetic Resonance Oxford Model MQA 7005.Economic analysis was done on the basis of prevailing market price of inputs used and output obtained from each treatment. The data were subjected to pooled analysis.

RESULTS

The research findings revealed that twice hand weeding recorded significantly higher seed yield (1.60t/ha), but it was at par to clodinafop 60g per ha (1.40 t/ha). Among the tested herbicides clodinafop 60 g/ha recorded significantly superior seed yield (1.44 t/ha) of linseed compared to others except pendimethalin30 EC + imazethapyr 2 EC 1.0 kg/ha (1.15 t/ha). It is also clear from table 1 that twice hand weeding had significantly lowest weed dry weight (0.19 t/ha) in comparison to other treatments. There were no significant difference noted with regards to dry weight of weeds among herbicidal treatments except to imazethapyr10 EC 75 g/ha which recorded maximum weed dry weight (0.60 t/ha). The maximum oil content was recorded with the treatment twice hand weeding followed byimazethapyr 10 EC 75 g/ha applied as post emergence. Whereas pendimethalin 30 EC + imazethapyr 2 EC 1.0kg/ha recorded least oil content. The treatment clodinafop 60 g/ha recoded least weed competition index (10.11%), whereas weedy check recorded highest weed competition index (63.96%). This indicates that lower weed index resulted into higher seed yield of linseed. This also indicates a negative association between weed biomass and seed yield. The herbicide 'clodinafop 60g/ha' recorded significantly higher net monetary return (Rs 46.67 x10^3/ha) followed by

Table 1. Seed yield, oil content and economics of irrigated linseed as affected by herbicides

Treatment	Seed yield (t/ha)	Weed dry weight (t/ha)	Oil content (%)	Weed Index (%)	Net monetary returns (x10^3 Rs/ha)
Hand weeding at 20-25 and 35-45 DAS	1.60	0.19	36.16	-	44.27
Pendimethalin 30 EC 1 kg/ha preemergence	0.96	0.44	34.97	40.03	21.07
Pendimethalin 30 EC + imazethapyr 2 EC 0.75 kg/ha pre emergence	1.05	0.43	33.28	34.16	24.50
Pendimethalin 30 EC + imazethapyr 2 EC 1kg/ha pre emergence	1.15	0.41	33.02	28.16	29.33
Isoproturon 1 kg/ha post emergence	0.96	0.47	34.19	40.84	21.07
Clodinafop 60 g/ha post emergence	1.44	0.46	33.06	10.11	46.68
Imazethapyr 10 EC 75 g/ha post emergence	0.84	0.60	35.75	27.28	16.35
Imazethapyr 10 EC 100 g/ha post emergence	0.98	0.34	34.67	48.72	21.66
Weedy check	0.58	1.27	34.4	63.96	8.67
CD (P=0.05)	0.35	0.46	0.39	-	14.50

twice hand weeding (Rs 44.27 x10^3/ha). Though, both treatments were at par in terms of net monetary return. The weedy check recorded least monetary return (Rs. 8.67 x10^3/ha). This is due to highest weed index and poor seed yield. This also indicates that net monetary return is directly related with seed yield. In spite of having highest seed yield with treatment 'twice hand weeding', it could not gain maximum net monetary return because of higher investment on labour.

CONCLUSION

Based on the study it can be concluded that clodinafop 60 g/ha could be an alternative of twice hand weeding for effective management of weeds in irrigated linseed. This treatment not only controlled the weeds effectively but also recorded at par seed yield to twice hand weeding along with maximum net monetary return.

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Weed management in *kharif* maize in the plateau of Odisha

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Maize is predominantly grown in rainy (*kharif*) season in India. Nearly half of the total cultivable area in the Tribal dominated Plateau Region of Mayurbhanj District is considered moisture-limited 'upland', which is not suitable for growing *kharif* rice. Furthermore, the frequent rainfall deficit in monsoon and suppression in rice yield is a common scenario over the years. To build resilience to low rainfall years, focus has been given on increasing maize cultivation in Mayurbhanj as means of stabilizing and increasing agricultural productivity. But maize suffers from heavy weed infestation during *kharif* season. Weed infestation may cause maize yield losses ranging from 28-100% dependingupon the intensity, nature and duration(Das *et al.,* 2016). Considering the limitations of manual weeding, chemical weed control is an important alternative. There are a few herbicides options available for weed management in maize in India. Sole application of atrazine does not provide effective and desirable level of control of many weeds. Mix application of herbicides could be an effective tool to tackle the problem of complex weed flora in many crops including maize. Tembotrione, topramezone and halosulfuronare new selective post emergence herbicides introduced recently against weeds in maize either alone or as tank mixed with atrazine. But it is essential to study the efficacy of these herbicides against weed species in maize in combination with atrazine. With this background the present experiment was conducted to study the effect of sole application of new herbicides and their combinations with atrazine on weed growth and productivity of *kharif* maize.

METHODOLOGY

The field experiment was conducted during *kharif* season of 2015 at Farmer's field of Kashipal village of Mayurbhanj district of Odisha. Twelve treatments comprising of atrazine at 625 g /ha as pre-emergence, atrazine at 500 g/ha at 20 days after sowing (DAS), tembotrione at 100 g /ha + surfactant (1000 ml/ ha) at 20 DAS, tembotrione at 90 g /ha + surfactant (1000 ml/ ha)+ atrazine at 500 g/ ha at 20 DAS, topramezone at 90 g/ha + surfactant (1000 ml/ ha) at 20 DAS, topramezone at 80 g/ ha + surfactant (1000 ml/ ha) + atrazine 500 g /ha at 20 DAS, halosulfuron at 67.5 g/ ha + atrazine 500 g/ ha at 20 DAS, atrazine at 625 g/ ha as pre-emergence + one manual weeding at 25 DAS, current farmers' practice (one spading followed by earthing up at 25 DAS), manual weeding twice at 20 and 40 DAS, weed free check and unweeded control were assigned in a randomized block design with three replications. The maize hybrid '*P 3441*' used in the present experiment was fertilized with N: P_2O_5: K_2O at 160:100:80 kg/ha. All other agronomic practices were followed as per recommendations. Weed density and dry weight were recorded at 45 DAS and the data were subjected to square root transformation wherever required. Weed control efficiency (WCE) was worked out using the dry weight of weeds at 45 DAS. Yield components and yield of maize were recorded at harvest.

RESULTS

The total number of weeds species was 12 out of which *Linderniaciliata*among broadleaved, *Echinochloacolona* among grasses and *Cyperusiria* among sedges were predominant throughout the cropping period. The lowest density and dry weight of total weeds and higher weed control efficiency at 45 DAS were recorded in topramezone at 80 g/ ha+ surfactant + atrazine at 500 g/ha at 20 DAS and it was at par with tembotrione at 90 g/ha+ surfactant + atrazine at 500 g/ha at 20 DAS and halosulfuron at 67.5 g/ha+ atrazine 500 g/ha at 20 DAS and closely followed by atrazine at 625 g/hapre-emergence + one manual weeding at 25 DAS. Combined application of tembotrione at 90 g/ha+ surfactant + atrazine at 500 g/ ha at 20 DAS also registered the highest number of kernels/ cob and grain yield which was statistically at par with topramezone at 80 g/ha+ surfactant + atrazine at 500 g/ha at 20 DAS, halosulfuron at 67.5 g/ ha+ atrazine 500 g/ha at 20 DAS and atrazine at 625 g/hapre-emergence + one manual weeding at 25 DAS (Table 1). These treatments effectively reduced the density and dry weight of complex weed flora in maize which facilitated better growth in maize resulting in higher values of yield attributes and yield.

CONCLUSION

Tank mix application of tembotrione at 90 g/ha+ atrazine at 500 g/ha, topramezone at 80 g/ha+ atrazine at 500g/ha, halosulfuron at 67.5 g/ha + atrazine 500 g/ha or integrated use

Table 1. Effect of treatments on weed density and dry weight, weed control efficiency, kernels per cob and grain yield of maize

Treatment	Weed density (no./m^2) at 45 DAS	Weed dry weight (g/m^2) at 45 DAS	WCE (%) at 45 DAS	No. of kernels /cob	Grain yield (t/ha)
Atrazine at 625 g/ha-pre-emergence	5.22 (26.74)	3.42 (11.21)	89.41	384	5.65
Atrazine at 500 g /haat 20 DAS	5.44 (29.06)	5.32 (27.82)	73.72	382	5.36
Tembotrione at 100g/ ha+surfactant at 20 DAS	3.63 (12.68)	3.26 (10.15)	90.41	408	5.73
Tembotrione at 90g/ha+ surfactant + atrazine at 500g /ha at 20 DAS	0.96 (0.43)	0.81 (0.15)	99.86	447	7.15
Topramezone at 90 g/ha+ surfactant at 20 DAS	3.70 (13.19)	2.95 (8.18)	92.27	402	5.68
Topramezone at 80 g /ha+ surfactant + atrazine at 500g/ha at 20 DAS	0.95 (0.39)	0.72 (0.02)	99.98	446	7.10
Halosulfuron at 67.5 g/ha+ atrazine 500 g/ha at 20 DAS	1.02 (0.53)	0.73 (0.03)	99.97	441	7.06
Atrazine at 625 g/hapre-emergence + one manual weeding at 25 DAS	2.65 (6.50)	1.59 (2.03)	98.08	426	7.04
Current farmers' practice	6.76 (45.21)	5.16 (26.11)	75.33	377	5.35
Manual weeding twice at 20 and 40 DAS	1.40 (1.46)	0.80 (0.14)	99.87	424	6.93
Weed free check	0.71 (0.00)	0.71 (0.00)	100	457	7.35
Unweeded control	9.37 (87.26)	10.31(105.83)	0	323	4.76
CD (P=0.05)	0.37	0.31	-	36.44	0.67

* Figures in parentheses are the original values. The data was transformed to SQRT (x+0.5) before analysis

of atrazine at 625 g/ha + one manual weedingat 25 DAS showed promising results in managing complex weed flora and registering higher grain yield of maize in the Plateau of Odisha.

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Effect of weed control methods and phosphorus fertilization on growth, yield attributes and yield of clusterbean

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During *kharif* seasonlong competition with weeds in clusterbean causes severe yield reduction ranging from 29-48%. Fertility management also offers a great scope for increasing the productivity of crop. Phosphorus supply to legumes is more important than N because later is being fixed symbiotically due to *Rhizobium*. The P status of Rajasthan soils particularly the light textured ones where most of the clusterbean cultivation is confined is low and crop responses to its application are encouraging (Patel *et al*. 2004). Phosphorus has beneficial effect on nodulation, growth and yield. It is an essential element participating in the skeleton of plasma membrane nucleic acids, many co enzymes and organic molecules such as ATP and other phosphorylated products.

METHODOLOGY

The experiment consisted weed control (Weedy check, one HW at 25 DAS, two HW at 20 and 40 DAS, pendimethalin @ 0.75 kg/ha, imazethapyr @ 100 g/ha, fenoxoprop-p-ethyl @ 70 g/ha at 15-20 DAS and four levels of phosphorus (0, 20, 40 and 60 kg/ha), thereby, making twenty four treatment combinations. Fertilizers were applied through DAP and urea the time of sowing as basal dose. The clusterbean cv. 'RGC-1003 was sown on 6th July, 2013 using seed rate of 16 kg/ha with a row spacing of 30 cm. The average number of pods and seeds per plants was worked out. After threshing and winnowing the weight of seeds for each net plot area was recorded in kg per plot and then converted to kg/ha.

RESULTS

Results revealed that weed control treatments in two HW at 20 and 40 DAS significantly increases plant stand per meter row length, plant height, number of branches per plant and dry matter accumulation per meter row length and remained at par with the application of imazethapyr-p-ethyl @ 100 g/ha over the rest of treatments. However, two HW at 20 and 40 DAS significantly increases plant stand per meter row length and it remained at par with of one HW at 20 DAS and application pendimethalin @ 0.75 kg/ha over other treatments.The application of phosphorus @ 60 kg/ha significantly increase plant height, number of branches per plant and dry matter accumulation per meter row length and remained at par with the application of phosphorus @ 40 kg/ha over control. However, plant stand per meter row length remained materially unchanged under different treatments of phosphorus.The weed control treatments in two HW at 20 and 40 DAS significantly higher number of pods per plant, seed, stover and biological yield in clusterbean over rest of treatments. However, two HW at 20 and 40 DAS significantly increase number of seeds per pod and test weight of clusterbean and remained at par with one HW at 20 DAS and application of imazethapyr @ 100 g/ha over control. The increasing levels of phosphorus upto 60 kg/ha significantly higher number of pods per plant, number of grains per pod, test weight, seed, stover and biological yield and remained at par with the application of phosphorus @ 40 kg/ha over control.

CONCLUSION

On the basis of one year experimentation, it may be concluded that two hand weeding done at 20 and 40 DAS in conjunction with phosphorus fertilization at 40 kg/ha was found the most superior treatment combination for obtaining higher grain yield from clusterbean. Hence, it can be advocated for the areas where labour is easily available. Producing the grain yield, application of imazethapyr @ 100 g/ha as pre emergence combined with phosphorus was found the most effective and remunerative herbicidal combination.

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Water utilization and its economy in *kharif* maize

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Maize (*Zea mays* L.) is the third most important cereal crop in India after rice and wheat. Its grains are used for human consumption, feed for poultry and livestock, extraction of edible oil and also for starch and glucose industry. It has the highest genetic yield potential and wide adaptability, making it as the miracle crop. Currently, it is cultivated on 9.3 million ha with a production of 24.2 million tonnes and productivity of 2.6 t/ha (Economic survey, 2013-2014). Maize contributes Rs.100 billion to the agriculture GDP apart from the providing employment of nearly 100 million man-days (Economic survey, 2013-2014). In India, maize is grown under diverse agro climatic zones extending from subtropical to cooler temperate regions. Therefore, inevitably the crop remains open to varied types of biotic as well as abiotic stresses. Among various abiotic stresses, drought stress, excess soil moisture stress, cold stress and terminal heat stress are the major constraints in maize production. In general, water deficits in the vegetative phase slow the overall crop growth rate and result in shorter plants with a smaller leaf area (Musick and Dusek, 1980; Bradford and Hsiao, 1982; Hsiao and Xu, 2000). A mild water stress for longer duration leads to smaller canopy cover during the vegetative stage. If stress is more severe, stomatal conductance also reduces which leads to senescence of older leaves that reduces the activity (radiation use efficiency) of the crop canopy (English and Raja, 1996; Stone *et al*., 2001). Water is crucial input for augmenting agricultural production towards sustainability in agriculture. Therefore, knowledge of plant responses to soil water availability is essential for the development of efficient irrigation strategies. But, it is the fact that a close relationship exists between the rate of consumptive use of crop and the rate of evaporation and hence, a more practicable and understandable approach based on the ratio of fixed amount of irrigation water (IW) to cumulative pan evaporation (CPE) is much desired. Moreover, the combined studies involving IW/CPE based irrigation scheduling and crop establishment techniques together are rarely investigated in India. Therefore, the present study was undertaken to ascertain the combined effects of land configuration techniques and IW/CPE based irrigation scheduling on productivity, profitability and water-use efficiency of *rabi* and *kharif* maize.

METHODOLOGY

A field experiment titled "water utilization and its economy in *kharif* maize" was conducted during the *kharif* 2012 at IARI to assess the effect of planting and irrigation methods, irrigation regimes and fertility levels on productivity, water use and economics of maize. The experiment was conducted on the sandy loam soil of MB3C field of IARI farm. PEHM-2 variety of maize was sown. Two planting and irrigation methods (ridge and furrow and FIRBS), two irrigation regimes (rainfed and 60 mm CPE) and four fertility levels (control, RDF, 75 % RDF + 25 % N by FYM and 75 % RDF + 25 % N by live mulch of sesbania) comprising sixteen treatments were replicated thrice in a randomized block design.

RESULTS

Planting and irrigation methods significantly affected the grain yield (Table 1). Ridge and furrow recorded significantly higher grain yield (41.7 t/ha). Consumptive use of water (38.2 cm), water use efficiency (109 kg/ha cm), net return (Rs. 30,764 /-) and B:C (1.6) ratio were also higher under this treatment. Consumptive use of water was 36.8 cm in FIRBS, which was lower by 3.7 per cent. Irrigation regimes also significantly affected the grain yield. Irrigation at 60 mm CPE recorded significantly higher grain yield (41.43 t/ha). Consumptive use of water (38.0 cm), water use efficiency (109 kg/ ha cm), net return (Rs. 30,716 /-) and B:C ratio (1.7) were higher under this treatment. Fertility levels as well affected the grain yield significantly. The grain yield was significantly the highest (48.45 t/ha) with 75 % RDF + 25 % N by FYM. Consumptive use of water (38.0 cm), water use efficiency (128 kg/ha cm), net return (Rs. 42,240 /-) and B:C ratio (2.7) were also the highest under this treatment.

CONCLUSION

Planting on ridges and irrigation in furrows at 60 mm CPE with fertility level of 75% RDF + 25 % N by FYM proved the best.

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Efficacy of mechanical planting interventions and weed management practices in rice-wheat cropping system under temperate conditions of Kashmir

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Being staple food, rice is one of the most important cereal crops in temperate Kashmir.Conventional crop establishment practice in rice-wheat involves manual transplanting of rice in puddle soil and seeding of wheat in well prepared fine seed bed. These practices involve excessive tillage, manpower and hence involve high energy consumption and deterioration of soil structure (Jha *et al*., 2011). Tillage affects weed seed distribution in soil profile and the differential distribution of the seed in soil profile has the potential to change weed population dynamics. To reduce drudgery, cost of cultivation, time of operation and safeguarding soil structure against churning effect of conventional tillageinterventions like zero tillage, rotary tilling, transplanting rice by mechanical transplanter or direct seeding by drum seeder after puddling may prove beneficial. Weed control requires time and investment of manpower and money in rice-wheat cropping system. If left uncontrolled, the weeds in many fields are capable of reducing yields severely. Manual weeding is common in Kashmiri farmers in rice crop requiring heavy man power, drudgery and time, which can be altered by use of mechanical and chemical weeding.

METHODOLOGY

Field experiments were conducted during *rabi* and *kharif* seasons of 2005 to 2007 on clay loam soils of experimental fields of Sher-e-Kashmir University of Agricultural Sciences and Technology-Kashmir, Shalimar, Srinagar, J&K (India)with a geo-location of 34°08 North latitude ,74°52 East longitude and altitude of 1587m. The experiment was laid out in split plot design with 3 replications, comprised of 3 planting interventions in mail plot (viz.direct seeding through drum seeder, mechanical transplanting and manual transplanting in rice; zero tillage, rotary tilling once and seed drilling, conventional tillage followed by seed drill sowing in wheat) and 4 weed control treatments in subplot (viz. butachlor @1.5kg a.i./ha+ one hand weeding, butachlor @1.5kg a.i./ha + one mechanical weeding (cross moving of cono weeder) at 40 DAT, mechanical weeding at 20 and 40 DAT, mechanical weeding at 10,20,30 and 40 DAT in rice; weedy check, sulfosulfuron @ 30g a.i./ha, hoeing at 20 and 40 DAS and metribuzin @ 250 g a.i./ha in wheat crop). The experimental soil was silty clay loam in texture having pH value of 6.8, high in organic carbon, low in available nitrogen, and medium in phosphorus and potassium. Recommended dose of fertilizers have been applied in all the treatments of individual crop and a line spacing of 20 cm in rice and 22 cm in wheat. Weed samples were collected at 3 random places from each plot using square meter quadrant and dried at before weighing for weed biomass.

RESULTS

Mechanical planting interventions and weed management practices produced significant effect on seed and straw yields (t/ha) of rice and wheat both across the years of study. Significantly superior seed and straw yield of paddy was recorded under drum seeded followed by manual transplanting (Table 1). Weed biomass (g/m^2) was recorded significantly lower under manual transplanting compared with rest of the two planting methods. Drum seeding might reduced the transplanting shock thereby resulted in to higher yields. Mechanical weeding at 10,20,30 and 40 DAT was found significantly superior in terms of seed and straw yield of rice over mechanical weeding at 20 and 40 DAT whereas, butachlor @1.5kg/ha+ one hand weeding, butachlor + one mechanical weeding (cross moving of cono weeder) at 40 DAT, remained statistically at par with each other. Sangeetha *et al*. (2015) reported significant superiority of 3 times mechanical weeding over weedicides and hand weeding treatments.Rotary tilling and sowing of wheat through seed drill produced significantly higher seed and straw yields over zero till drill sowing. Statistically reduced weed density (nos/m^2) and weed biomass (g/m^2) were recorded under the same treatment over zero tillage and remained at par with conventional sowing (Table 2). In the weed management treatments, both weedicides,

Table 1. Seed and straw yields (t/ha), weed density and weed biomass (g/m) in rice crop as affected by planting methods and weed control (pooled data of 2 years)

Treatment	Seed yield (t/ha)	Straw yield (t/ha)	Weed density (Nos./m^2)	Weed biomass (g/m^2)
Planting intervention				
Drum Seeded	6.60	9.8	8.38	12.165
Mechanically Transplanted	5.12	8.80	8.83	12.745
Manually Transplanted	5.54	9.38	7.88	11.500
CD (P=0.05)	0.47	0.89	NS	0.895
Weed management				
Butachlor+ 1 HW*	6.00	9.62	6.93	10.060
Butachlor+1 MW** at 40DAT	5.93	9.54	7.38	10.700
2 MW at 20 and 40 DAT	5.39	8.88	10.39	15.040
4 MW at10,20,30 & 40 DAT	5.67	9.27	8.78	12.730
CD (P=0.05)	0.37	0.71	0.53	0.680

HW=Hand weeding, MW+ Mechanical weeding, DAT= Days after transplanting

Table 2. Seed and straw yields (t/ha), weed density and weed biomass (g/m) in wheat crop as affected by planting methods and weed control (pooled data of 2 years)

Treatments	Seed yield (t/ ha)	Straw yield (t /ha)	Weed density (Nos./m^2)	Weed biomass (g/m^2)
Planting intervention				
Zero till drill sowing	4.76	7.81	13.92	11.54
Rotary till drill sowing	5.46	8.54	9.275	8.16
Conventional sowing	5.17	8.19	10.33	9.31
CD (P=0.05)	0.37	0.65	1.29	0.905
Weed management			0	0
Weedy Check	4.18	7.45	16.73	13.255
Sulfosulfuron @ 30g	5.93	8.77	7.21	7.345
MW at 20 and 40 DAS	4.75	7.87	11.54	9.86
Metribugine @ 250g	5.66	8.64	9.2	8.22
CD (P=0.05)	0.34	0.56	0.98	0.685

MW + Mechanical weeding , DAS= Days after sowing sulfosulfuron @30g a.i./ha and metribuzine @ 250g a.i./ha recorded significantly higher seed and straw yield (t/ha) over weedy check and mechanical weeding at 20 and 40 days after sowing and remained at par with each other. Statistically lower weed density and weed biomass (g/ha) recorded due to application of sulfosulfuron @ 30g a.i./ha over rest of the weed control treatments in study (Table2).

CONCLUSION

Drum seeding of pre-sprouted seeds of rice with application of butachlor @ 1.5kg a.i./ha followed by one mechanical weeding at 40 days after transplanting in rice; one rotary tilling and drilling of wheat seeds and application of sulfosulfuron @30g/ha in wheat on clay loam soils of temperate Kashmir proved superior in terms of productivity and weed control in rice-wheat cropping system.

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Effect of tillage and weed management on productivity of maize-wheat cropping system under irrigated sub-tropical conditions of J&K

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Maize and wheat are the two important staple food crops of India which provide food security to the country's population. Intensive tillage has a negative impact on environment quality by accelerating soil carbon loss and green house gas emissions. Further, tillage operations account for more than 25 per cent of agricultural production costs and with increasing in fuel prices, tillage now accounts for a higher proportion of production costs than harvesting does. The low productivity of maize-wheat cropping system by and large can be attributed to several limiting factors and all but most important among these has been the poor weed management which poses a major threat to crop productivity. Therefore, it is need to evaluated impact of tillage and weed management practices on productivity of maize-wheat cropping system.

METHODOLOGY

A field experiment was conducted to study the effect of tillage and weed management on productivity of maize-wheat cropping system in sub-tropical foot hills plain of Jammu at research farm of division of agronomy, Chatha, SKUAST-J during the *kharif* and *rabi* season of 2013-14. The soil of the experimental site was sandy clay loam in texture, low in nitrogen, medium in organic carbon, available phosphorous and potassium. The experiment was laid out in split-plot design with four tillage treatments in main plots and three weed management treatments in sub-plots with three replications each. In maize and wheat, the main plot treatments consisted of four tillage practices viz ZT pb (preceded by) ZT (zero tillage), ZT pb CT (conventional tillage), CT pb ZT and CT pb CT and sub plots comprised of hand weeding (two), recommended herbicides (atrazine 1 kg/ha in maize and metribuzin 200 g/ha in wheat) and weedy check. The *Kanchan*-517 and RSP-561 varieties of maize and wheat were taken during *kharif* and *rabi* season, respectively.

RESULTS

In maize, among the different tillage treatments, CT pb CT maize had significant suppressing effect on weed density and dry weight over ZT pb ZT and ZT pb CT. The CT pb CT maize was recorded highest grain yield which was statistically at par with CT pb ZT, whereas in different weed management significant highest grain yield was recorded with two hand weedings which was statistically at par with the application of attrazine 1 kg/ha (Table 1). The higher yield in CT pb CT

Table 1. Weed density, weed biomass and grain yield of maize as influence by different tillage and weed control treatments

Treatment	Weed density/m^2 at 90 DAS	Weed biomass at 90 DAS (g/m^2)	Grain yield (kg/ha)	Weed control efficiency (%)
Tillage				
ZT pb ZT	9.77 (99.78)	12.58 (170.78)	3145	44.45
ZT pb CT	9.47 (94.67)	12.39 (166.89)	3267	45.71
CT pb ZT	8.81 (83.44)	11.87 (155.11)	3640	49.54
CT pb CT	8.63 (80.89)	11.67 (151.56)	3851	50.670
LSD (P=0.05)	0.30	0.20	212	-
Weed management				
Hand weedings (two)	7.24 (52.00)	9.28 (85.33)	4010	72.24
Atrazine at 1 kg/ha	7.58 (56.75)	9.55 (90.50)	3899	70.56
Weedy check	12.70 (160.33)	17.56 (307.42)	2519	-
LSD (P=0.05)	0.34	0.30	281	

Table 2. Weed density, weed biomass and grain yield wheat as influence by different tillage and weed control treatments

Treatment	Weed density/m^2 at 90 DAS	Weed biomass at 90 DAS (g/m^2)	Grain yield (kg/ha)	Weed control efficiency (%)
Tillage				
ZT pb ZT	9.41 (95.22)	12.19 (156.78)	3147	40.16
CT pb ZT	9.21 (92.56)	12.00 (151.67)	3325	42.11
ZT pb CT	9.42 (95.78)	12.12 (154.56)	3157	41.01
CT pb CT	9.18 (91.78)	11.87 (149.00)	3336	43.13
LSD (P=0.05)	NS	NS	NS	
Weed management				
Hand weedings (two)	7.38 (53.75)	10.14 (102.25)	3850	60.97
Metribuzin 200 g/ha	7.19 (50.75)	9.78 (94.75)	3958	63.83
Weedy check	13.34 (177.00)	16.22 (262.00)	1916	-
LSD (P=0.05)	0.21	0.51	204.67	

might be happened due to favourable soil physical conditions for growth and development as well as lesser crop-weed competition. These results are in close conformity with results of Sarma *et al.* (2010). In wheat, different tillage treatments did not-significant effect on weed density, biomass and grain yield. Significantly highest grain yield of wheat was recorded with metribuzin 200 g/ha which was statistically at par with two hand weedings (Table 2). The higher grain yield might have been achieved due to better weed control by metribuzin which finally resulted in increase in grain yields of wheat. These results are in close conformity with results of Ashrafi *et al.* (2009).

CONCLUSION

It was concluded that among the different tillage in maize and wheat crop conventional tillage preceded by conventional tillage was best followed by conventional tillage preceded by zero tillage. However, two hand weeding and attrazine 1 kg/ha in maize and metribuzin @ 200 g/ha in wheat found to be most suitable for weed management.

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Evaluation of herbicides in direct sown ragi

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Finger millet is one of the important millet crops grown in North Coastal Andhra Pradesh. It is cultivated during *Kharif, Rabi* and Summer seasons and also as a relay crop in rice fallows. Direct seeding is gaining importance as a cost reduction practice either in *Kharif* or in *Rabi* over transplanting. Weeds are greatest menace under direct seeding especially at initial stages of crop growth. Uncontrolled weed growth during crop period reduce the grain yield ranging from 34 to 61 % (Ramachandra Prasad 1991). Non – availability of labour coupled with poor efficiency is necessitating herbicide application. Information on pre and post emergence herbicides suitable for effective weed control in direct sown ragi is meager. There is also demand from the farmers for selective pre and post emergence herbicides which become cheaper when compared to manual weeding for timely control of weeds in direct sown ragi. Hence the present study was proposed to recommend an effective and selective pre and post emergence weedicides in direct sown ragi.

METHODOLOGY

A field investigation was carried out at Regional Agricultural Research Station, Anakapalle during *kharif*, 2015. The experimental site was red sandy loam, neutral in p^H normal in E.C, low in available nitrogen medium in available phosphorus and potassium. The experiment was laid out in a Randomized Block Design with 12 treatments consisting of four pre - emergence weedicides, 6 post emergence weedicides along with hand weeding at 20 and 40 DAS and weedy check and replicated thrice. A medium duration ragi was used as test variety and sown on 23rd July, 2015 at a row spacing of 30 cm in solid sows. Excess plants were thinned out at 15 days after sowing by maintaining a hill to hill spacing of 10 cm. A basal dose of 30 kg N, 40 kg P2O5 and 30 kg K2O/ha was applied at the time of sowing and 30 kg N/ha was topdressed at 30-35 days after sowing at optimum soil moisture. Pre-emergence weedicieds were applied on second day after sowing and post-emergnece weedicieds were applied at 20 days after sowing as per treatments. The data on weed density and weed biomass were recorded at 20 and 40 days after sowing and the data on number of fingers/ear head, ear head weight, grain and straw yields were recorded at harvest. Based on weed density and grain yield in different treatments the Weed Control Efficiency and Weed Index were calculated.

RESULTS

The predominant weed flora in the experimental site was *Cyperus rotundus*, *dactyloctenium aegyptium, digitaria sanguinalis*, *Cenchrus celiaris* among monocots, *Mollugo pentaphylla, Phyllanthus niruri*, *Cynotis cucutella* among dicots.

Among the pre-emergence herbicides, Bensulfuran methyl+pretilachlor @ 5.0 kg/ha recorded lowest weed density (180/m2) and fresh weed biomass (133.2 g/m2) at 20 days after sowing and resulted in higher WCE (41.4 %) over other pre-emergence weedicides. Post emergence spraying of 2, 4-D amine or cyhalofop butyl @ 1.0 kg/ha at 20 DAS controlled the weeds effectively and resulted in less weed population of 71 and 63/m^2 respectively. The Weed Control Efficiency at 40 DAS was also higher with post emergence spraying of 2, 4-D amine (82.5 %) and cyhalofop butyl (80.3 %). Fresh weed biomass was lowest with hand weeding twice at 20 and 40 DAS (173.2 g/m^2) and highest with weedy check (400 g/m^2) at 40 DAS. Among the post emergence weedicides, weed biomass was lower with 2, 4-D amine (233.3 g/m2) and almix (240.0 g/m2) at 40 DAS. Prithvi *et al.,* 2015 reported higher weed control efficiency with pre emergence application of oxadiargyl @ 100 g/ha followed by inter cultivation with weeder at 20 DAT in transplanted ragi. Weed index which indicate the magnitude of yield reduction in treatment plot compared to weed free plot was lowest with 2, 4-D amine @ 1.0 kg/ha(12.4) followed by almix @ 20 g/ha (15.1) and bensufuran methyl + pretilachlor (16.20) while it was maximum with weedy check (41.3).

No. of ears/fingers/ear head was not influenced by weed control treatments significantly, whereas, weight of ear head differed significantly. Ear head weight was higher with pre-emergence application of Oxadiargyl (6.6 g) follwed by bensulfuran methyl + pretilachlor (6.47 g). Hand weeding twice at 20 and 40 DAS recorded higher ear head weight over weedy check (4.2 g). Post emergence spraying of almix (4.87 g) or 2, 4-D amine (4.67 g) at 20 DAS recorded higher ear head weight (Table 2). Grain and straw yields were significantly influenced by different weed control treatments. Main-

Table 1. Weed density and weed biomass as influenced by different weed control treatments in finger millet

Treatment	Weed density at 20 DAS (No/m^2)	Weed density at 40 DAS (No/m^2)	WCE at 20 DAS	WCE at 40 DAS (%)	Weed biomass at 20 DAS (g/m^2)	Weed biomass at 40 DAS (g/m^2)
T_1, weedy check	307	360	-	-	293.2	400.0
T_2, HW at 20 and 40 DAS	265	109	-	69.7	286.8	173.2
T_3, Pendimethalin 30% EC	204	185	33.6	48.6	166.8	306.8
T_4, Pendimethalin 37.5% EC	221	145	28.0	59.7	186.8	253.2
T_5, Pretilachlor 50% EC	217	184	29.3	48.9	220.0	240.0
T_6, Bensulf+pretilachlor	180	208	41.4	42.2	133.2	280.0
T_7, Oxadiargyl 80%WP	212	223	30.9	38.1	180.0	293.2
T_8, Bispyribac sodium 10% EC	267	187	-	48.1	266.8	301.2
T_9, 2,4-D sodium salt 80% WP	272	205	-	43.1	306.8	386.8
T_{10}, Cyhalofop butyl 10% EC	249	71	-	80.3	253.2	273.2
T_{11}, 2, 4-D Amine 58%EC	243	63	-	82.5	266.8	233.3
T_{12}, Almix 20% WP	271	85	-	76.4	300.0	240.0

Table 2. Yield attributes and yield of finger millet as influenced by different weed control treatments

Treatment	Number of ears/fingers/ ear head	Weight of ear head at harvest	Grain yield (kg/ha)	Straw yield (kg/ha)	Weed index
T_1, weedy check	5.73	4.20	654	5695	41.3
T_2, HW at 20 and 40 DAS	5.67	5.47	1114	6806	-
T_3, Pendimethalin 30% EC	6.53	5.20	876	5417	21.4
T_4, Pendimethalin 37.5% EC	6.03	5.00	904	6667	18.9
T_5, Pretilachlor 50% EC	6.07	4.87	785	6806	29.5
T_6, Bensulf+pretilachlor	6.50	6.47	933	6529	16.2
T_7, Oxadiargyl 80%WP	5.73	6.60	732	5973	34.2
T_8, Bispyribac sodium 10% EC	5.53	4.73	866	6806	22.3
T_9, 2,4-D sodium salt 80% WP	5.83	4.87	903	5695	18.9
T_{10}, Cyhalofop butyl 10% EC	5.80	4.33	712	5417	40.1
T_{11}, 2, 4-D Amine 58%EC	5.77	4.67	976	6956	12.4
T_{12}, Almix 20% WP	6.30	4.87	946	6945	15.1
SEm±	0.24	0.41	68	433	
CD (P=0.05)	NS	1.21	199	1270	
CV%	7.11	14.0	14.0	11.9	

tenance of weed free environment by hand weeding twice at 20 and 40 DAS controlled the weeds effectively, favoured good crop growth and resulted in significantly higher grain yield (1114 kg/ha) over un-weeded control (654 kg/ha) which was higher by 70.3%. Among the herbicides, pre- emergence application of bensufuran methyl + pretilachlor (933 kg/ha) or post emergnce application of 2,4—D amine (976 kg/ha) were proved effective and recorded grain yields on par with traditional hand weeding (Table. 2). Cyhalofop butyl though recorded higher weed control efficency it was not reflected in yield as such registered lower yield (712 kg/ha) and higher Weed Index (40.1). Higher grain and straw yield of drill sown ragi with pre emergence application of bensufuran methyl + pretilachlor @ 7.5 kg/ha compared to unweeded check was reported by Prashanth Kumar *et al*. 2015.

CONCLUSION

The study indicated that, weeds reduce the grain yield by 41.3% in direct sown ragi. Maintenance of weed free condition up to 40-45 days after sowing by hand weeding twice at 20 and 40 DAS was proved more effective in controlling weeds and improving grain yield of direct sown ragi. However, when labour is scarce to take up weeding pre emergence application of bensufuran methyl + pretilachlor @ 5.0 kg/ha or post emergence application of 2,4-D amine @ 1.0 kg/ha can be followed for effective control of weeds and realizing higher grain and straw yields from direct sown ragi.

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Impact of non-chemical weed management on weed control efficiency and weed index in organic brinjal [s*olanum melongena* (L.)]

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Brinjal (*Solanum melongena* L.) is one of the common vegetable used for human consumption and has medicinal value. This crop is grown for vegetable purpose in several parts of the world and consumes more amounts of plant protection chemicals leading to more toxic residues in the environment as well as in the plant parts (Sharma *et al*., 2010). Hence, organically grown brinjal fetches important role in the human food chain. As the weeds are important biotic factor, which influences greatly to the yield of the organic brinjal, the non-chemical weed management is one of the options to produce herbicide residue free organic brinjal. The present study is focused on identification of suitable non chemical weed management practices for organic brinjal and to study the post-harvest nutrient status of soil due to addition of organic amendments.

METHODOLOGY

A field experiment was conducted at organiccertified field Annur, Coimbatore district, Tamil Nadu, during *kharif* 2015. The experiment was laid out in randomized block design with three replications. Treatments comprised of pre emergence application of corn flour @ 1t/ha, pre emergence application of corn flour @ 1t/ha along with one hand weeding on 60 DAT, pre emergence application of sunflower dried stalk solution @ 1:10 w/v basis, Pre emergence application of sunflower dried stalk solution @ 1:10 w/v basis along with one hand weeding on 60 DAT, Live mulching with Multi Varietal Crops and Sunnhemp, mechanical weeding, hand weeding twice on 30 and 60 DAT, Weed free check and Control. Recommended organic management and plant protections were followed.

RESULTS

The observations revealed that the application of corn flour @ 1 t/ha to soil enabled weed control without reducing yield of organic brinjal. The reason was that the PE corn flour application prevented the germination of broad leaved and sedge weeds seeds effectively. This method might be useful in organic agriculture especially for the control of the weeds in any transplanted crops. PE application of corn flour at 1 t/ha *fb* HW on 60 DAT was the best treatment as it resulted with weed index of 2.70 per cent. It was followed by PE application of dried sunflower stalk solution *fb* HW on 60 DAT (16.00 per cent) might probably due to reduced weed competition (Table 1). Obviously, higher weed index registered under unweeded check (T_{10}) due to higher weed competition at all the stages. Thepost-harvest nutrient status was found to be higher in live mulching with Multi Varietal Crops (Navathaniyam) (T_4) and Live mulching with sunnhemp (T_1). This might be due to residual effect of added sunnhemp and Multi Varietal Crops (Navathaniyam) and it also was due to added biomass to the soil.

CONCLUSION

Hence, it is concluded that trenching of corn flour at 1t/ha or spraying of sunflower dried stalk solution at 1:10 w/v basis along with one hand weeding recorded higher weed control efficiency with lower weed index and it will be a viable

Table 1. Influence of different non chemical weed management practices on weed density and weed dry weight in organic brinjal

Treatment	Weed Control Efficiency (%)	Weed Index (%)
T_1 : Livemulching with sunnhemp after 30 days of growth	83.1	40.81
T_2 : PE application of Corn flour @ 1 ton/ha	84.7	23.74
T_3 : T_2+ Hand Weeding at 60 DAT	94.1	2.70
T_4 : Livemulching with Multi Varietal crops after 30 days of growth	82.1	46.77
T_5 : PE application of dried sunflower stalk solution on w/v basis @ 1:10 lit/ha^{-1}	84.1	29.90
T_6: T_5+ Hand Weeding at 60 DAT	93.5	16.00
T_7: Mechanical weeding twice using twin hoe weeder on 30 & 60 DAT	89.3	20.71
T_8: Hand weeding twice on 30 & 60 DAT	90.3	17.26
T_9:Weed free check	100.0	0.00
T_{10}: Unweeded check	0.0	65.40

Data statistically not analysed; PE-Pre Emergence ; DAT- Days aftertransplanting

Table 2. Influence of different non chemical weed management practices on soil post-harvest nutrient status in organic brinjal

Treatment	Post-harvest soil nutrients (kg/ha)		
	N	P	K
T_1 : Livemulching with sunnhempafter 30 days of growth	144.8	19.5	326.0
T_2 : PE application of Corn flour @ 1 ton/ha	126.6	15.4	316.3
T_3 : T_2+ Hand Weeding at 60 DAT	109.2	10.4	240.0
T_4 : Livemulching with Multi Varietal crops after 30 days of growth	146.2	25.0	371.3
T_5 : PE application of dried sunflower stalk solution on w/v basis @ 1:10 lit/ha	127.2	16.3	320.3
T_6: T_5+ Hand Weeding at 60 DAT	116.4	11.1	253.0
T_7: Mechanical weeding twice using twin hoe weeder on 30 & 60 DAT	124.4	14.7	308.1
T_8: Hand weeding twice on 30 & 60 DAT	118.0	12.0	296.7
T_9:Weed free check	100.7	8.3	231.0
T_{10}: Unweeded check	52.9	5.7	184.7
CD (P=0.05)	22.5	2.6	54.1

and ecologically sustainable options to maintain less weed competition in organic brinjal. Live mulching with sunnhemp and Multi Varietal Crops recorded higher post-harvest nutrients in soil which will be useful for successive crops in organic production systems.

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Herbicide combinations to manage mixed weed flora in wheat

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Isoproturon is nationwide recommended herbicide to control complex weed flora in wheat. However, continuous reliance on isoproturon resulted in a heavy build-up of *P. minor*. However, for effective weed control double knock is essential to tackle the survivors (Chhokar *et al*., 2008a and 2008b; Kumar *et al*., 2010). Herbicides with differential selectivity can be applied sequentially, but it results in enhancing the cost. Therefore, mixing two different herbicides and applying them simultaneously widens the spectrum of weed-control, saves time and application cost. Keeping this in view, the present investigation was carried out.

METHODOLOGY

Sixteen weed control treatments *viz.* pinoxaden (40 g /ha), isoproturon (1250 g /ha) alone, isoproturon + pinoxaden (1000 + 40 g /ha), isoproturon + pinoxaden (750 + 30 g /ha), isoproturon + 2,4-D (1000 + 500 g /ha), isoproturon + metsulfuron-methyl (1000 + 4 g /ha), pinoxaden + 2,4-D (40 + 1000 g /ha), pinoxaden + metsulfuron-methyl (40 + 4 g /ha), isoproturon *fb* pinoxaden (1000 *fb* 40 g /ha), isoproturon *fb* pinoxaden (750 *fb* 30 g /ha), pinoxaden *fb* isoproturon (40 *fb* 1000 g /ha), pinoxaden *fb* isoproturon (30 *fb* 750 g /ha), pinoxaden *fb* 2,4-D (40 *fb* 1000 g /ha), pinoxaden *fb* metsulfuron-methyl (40 *fb* 4 g /ha), hand weeding (30 & 60 DAS) and weedy check were tested in a Randomized Block Design with three replications at Palampur on a silty clay loam. Wheat variety HPW- 155 was sown on 20 November 2010 in plough furrows 22.5 cm apart using 100 kg seed /ha. Herbicides as per treatments were applied with knapsack power sprayer using 600 liters water per hectare. The crop was harvested on May 21 2011. The species-wise weed count was recorded at 60, 90, 120, 150 DAS and at harvest.

RESULTS

Avena ludoviciana and *Phalaris minor* were the major weeds constituting 35% and 25.1%, respectively, of the total weed population at 90 DAS. *Lolium temulentum, Anagallis arvensis, Vicia sativa* and *Coronopus didymus* constituted 11.3%, 11.3%, 10.7% and 6.6%, respectively of the total weed population. All weed control treatments except isoproturon (1.25 kg /ha), isoproturon + 2,4-D (1000 + 500 g /ha) and isoproturon + metsulfuron methyl (MSM) (1000 + 4 g /ha) significantly reduced the population of *A. ludoviciana* over weedy check. The rest of the treatments (including pinoxaden) were comparable to each other in reducing the population of *A. ludoviciana*. Similar observations with respect to pinoxaden alone and in combination with other herbicides on count of *A. ludoviciana* have been reported (Chhokar *et al*., 2008a and 2008b; Kumar *et al*., 2010). All treatments involving isoproturon and pinoxaden were equally good in reducing the count of *P. minor* and *L temulentum*. Pinoxaden *fb* MSM (40 *fb* 4 g /ha) resulted in significantly lower population of *C. didymus* over isoproturon (1250 g /ha), isoproturon + 2, 4-D (1000 + 500 g /ha) and isoproturon + MSM (1000 + 4 g /ha. Pinoxaden (40 g /ha) was less effective in reducing population of *V. sativa.* The main flushes of *A. arvensis* i.e. the broad-leaf species appeared around 60-90 DAS and 90-120 DAS *i.e.* after the application of post-emergence herbicides, 2, 4-D and MSM still adjudged to be effective against the weed. Owing to reduction in species-wise weed count, all the weed control treatments resulted in significant reduction in total weed count as compared to weedy check. Application of pinoxaden *fb* MSM (40 *fb* 4g /ha) resulted in lowest total weed count. Weed control treatments resulted in significantly higher grain yield over weedy check. Pinoxaden *fb* MSM (40 *fb* 4 g /ha) remaining at par with pinoxaden + MSM (40 + 4 g /ha) gave significantly higher grain yield over rest of the treatments. Because of higher grain and straw yield, pinoxaden *fb* MSM (40 *fb* 4 g /ha (‘ 47489 / ha) being at par with pinoxaden + MSM (40 + 4 g /ha) resulted in resulted in 160.1% higher net returns over weedy check. Application of pinoxaden *fb* MSM (40 *fb* 4 g /ha) resulted in highest net returns per rupee invested (1.97) followed by pinoxaden + MSM [(40 + 4 g /ha) (1.93)].

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Competitiveness of wheat (*Triticum aestivum*) genotypes against weed infestation under different row spacing in Eastern India

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Wheat is the second most important cereal crop after rice, grown under diverse agro climatic conditions on 28 M ha area in India with a production of about 84 M tonnes. Jharkhand share to national production is less than 1%. Productivity of 2.8 t/ha is also far below the national average of 3.14 t/ha (DES, 2013). Since wheat is a major cereal crop and population is gradually increasing with time, increasing its production and acreage should be given top priority in order to achieve food and nutritional security in the state. However, success of any crop production depends on the use of appropriate and location-specific genotype along with improved cultural practices to achieve high yield potential. Among the agronomic practices spacing plays a significant role in maximizing the crop yield as well as productivity. Inter row spacing is very important for maximizing light interception, penetration, light distribution in crop canopy and average light utilization efficiency of the leaves in the canopy, proper distribution of plants over cultivated area and for better utilization of available soil and natural resources (Mali and Choudhury, 2013) and the feasibility and effortlessness of using inter tillage devices for sufficient weed control. Therefore, keeping the above facts in view, a field experiment was conducted to evaluate the effect of different row spacing on yield and economics of wheat genotypes in eastern India.

METHODOLOGY

A field experiment was carried out at the Agronomy research farm, Birsa Agricultural University, Ranchi, Jharkhand located at 23º17’ N latitude and 85º19’E longitude at an altitude of 625 m above the mean sea level during *rabi*season of 2011-12. The soil was sandy loam in texture, with pH 5.6, organic carbon 0.49%, available nitrogen 262.6 kg/ha, phosphorus 15.3 kg/ha and potassium 172.5 kg/ha. The experiment was laid out in split plot design with three wheat genotypes (K0307, HD2773 and DBW 39) and four row spacing (15cm weed free, 15 cm weed check, 20cm weed free and 20 cm weed check) replicated thrice. The crop was sown on 2nd fortnight of November during both years of experimentation, with a fertilizer dose of 120 kg N/ha, 60 kg P_2O_5/ha and 60 kg K_2O/ha. One third of N along with full dose of P and K was applied as basal and remaining two- third N was top dressed in two equal splits, at crown root initiation and at active tillering stage.

RESULTS

Results revealed that 20 cm weed free registered higher grain yield (4.51 t/ha) against weedy check and yield reduction was found to the tune of 35.52% in weedy plots (Table 1).

Table 1. Yield and economics of wheat genotypes as influenced by different row spacing and weed management practices

Treatment	Grain yield (t/ha)	Straw yield (t/ha)	Net return (Rs./ha)	B:C ratio
Spacing				
15.0 cm, W Free	3.73	4.79	29620	1.24
15.0 cm, W Check	3.22	4.35	27159	1.14
20.0 cm, W Free	4.51	5.41	35222	1.39
20.0 cm, W Check	3.69	4.30	19424	0.77
SEm ±	0.06	0.17	1718	0.07
CD (P=0.05)	0.19	0.58	5930	0.25
Genotypes				
K 0307	4.05	6.59	40804	1.66
HD 2733	3.81	6.22	33503	1.37
DBW 39	3.49	6.04	37119	1.51
SEm ±	0.13	0.15	1768	0.07
CD (P=0.05)	0.39	0.46	5303	0.21

Weed free plots also registered higher net return (Rs. 35222) and B:C ratio (1.39) in comparison to non remunerative weedy check due to low weed pressure which might have resulted in increased nutrient, water, space and light supply to the crop due to absence of strong crop weed completion (Pandey *et al.* 2005). Among the wheat genotypes, K0307 recorded significantly higher grain yield (4.05 t/ha) and straw yield (6.59 t/ha) which ultimately led to maximum net return (Rs.40804) and B:C ratio (1.66) as compared to other wheat varieties.

CONCLUSION

On the basis of results it was concluded that 20 cm weed free along with genotype K 0307 gave significantly higher values as compared to rest of row spacing.

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Weed dynamics, growth and yield of baby corn influence with agri-horti system and weed management practices in eastern Uttar Pradesh

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In Vindyan region of eastern Uttar Pradesh, agri-horti system like, custard apple (*Annona squamosa* L.) and guava (*Psidium guajava* L.) are very promising agri-horticulture enterprise in Vindhyan region as both these crops are very hardy, withstand heat and prolonged droughts. In fact, during the initial 6"7 years of plantation, interspaces can be effectively utilized for growing short duration cereals, pulses and fodder crops (Gill and Gangwar 1992). Under this situation, introduction of baby corn (*Zea mays* L.) in agri-horti systems has potential to provide quality green fodder for livestock, chances for diversification, revenue generation and value addition to the industries. However, being a rainy season crop, it suffers from heavy weed infestation which resulted in severe yield loss. Indeed, information on effective weed management practices for baby corn production, especially under agri-horti system is still lacking. Therefore, keeping these facts in view, present study was undertaken.

METHODOLOGY

The field experiment was conducted at Research Farm of Rajiv Gandhi South Campus (Banaras Hindu University), Barkacha, Mirzapur, Uttar Pradesh, India (25^{0}10'N, 82^{0}37'E, 365 m amsl) during rainy season of 2012. Baby corn *cv.* Hybrid-4212 (Bayer) was sown manually with single row drill, using seed rate of 40 kg/ha at a spacing of 40x15 cm, in alleys of agri-horti system and open field following standard agronomic practices. The predominant soil in the experimental field was sandy clay loam, slightly acidic in reaction (pH 6.2), low in organic carbon content (0.29 kg/ha) and medium in available P and K contents. The experiment was laid out in a split plot design, where three agri-horticultural systems, i.e. custard apple (S_1), guava (S_2) and open field (S_3) were assigned as main-plot factors, whereas, five weed management practices [atrazine 1.0 kg/ha (PE) (W_1), atrazine 0.5 kg + wheat straw mulch 5 t/ha (W_2), mungbean as living mulch *fb* 2,4-D 1.0 kg/ha (20 DAS) (W_3), atrazine 0.5 kg/ha + 1-hand hoeing (20 DAS) (W_4) and weedy check (W_5)] were kept in sub-plots and replicated thrice. The gross plot size under guava, custard apple agri-horti system and open field was 18.4, 9.0, and 9.0 m^2, respectively. The distance between tree under guava and custard apple agri-horti system is 7x7m and 5x5m, respectively.

RESULTS

Guava based agri-horti system showed highest density (grasses, broad-leaved) of weeds, simultaneously lowest yield

Table 1. Effect of agri-horti system and weed management practices on weeds, plant height, LAI and dehusked cobs yield of baby corn

Particular	Weed Density[A] (number/m^2)			Weed biomass (g/m^2)[A]	Baby corn		
	Grasses	Sedges	Broadleaved		Plant height (cm)[a]	Leaf area index[A]	Dehusked cobs (kg/ha)[B]
Agri-horti system							
S_1	7.01b	0.96	3.36b	7.60a	79.6a	0.83a	1703.85a
S_2	9.12a	1.60	4.70a	9.39a	65.2b	0.83a	1497.40c
S_3	7.97a	0.71	3.30b	9.11a	53.1c	0.81a	1610.85b
SEm±	0.41	0.29	0.31	0.46	1.53	0.01	74.91
CD (P=0.05)	1.59	NS	1.20	NS	6.00	NS	294.12
Weed Management Practices							
W_1	7.51b	0.71b	1.41b	9.17b	68.8a	0.89a	1901.91a
W_2	4.64c	0.71b	1.41b	6.87c	64.9a	0.86b	1779.58a
W_3	6.26b	0.71b	1.41b	6.77c	66.1a	0.78c	1357.67c
W_4	2.83c	0.71b	1.41b	4.95c	63.6a	0.85b	1611.73b
W_5	18.93a	2.61a	13.27a	15.74a	66.4a	0.76c	1369.27c
SEm ±	0.73	0.39	0.64	0.71	3.41	0.01	82.04
CD (P=0.05)	2.14	1.14	1.88	2.06	NS	0.02	239.45

Observation recorded at — [A]30 DAS, [B] at harvest. Weeds data are subjected to square root transformation.

of dehusked cob over other agri-horti systems. The mechanism of weed control through trees in agricultural systems is through competition for light, water and nutrients (Impala 2001), availability of less space for their growth, shifts in species composition, and altered environmental conditions (Sileshi *et al.* 2006), allelopathic interaction associated with some fallow trees. However, weed biomass and LAI of baby corn differed non-significantly with agri-horti system. Custard apple agri-horti system showed consistently lower density of grasses and BLWs, thus associated with highest plant height and dehusked cobs. Application of different weed management practices showed non-significant difference in density of sedges, BLWs as well as plant height of baby corn. Although, statistically similar lowest density of grasses and biomass of total weed was recorded under atrazine 0.5 kg + wheat straw mulch 5 t/ha (W_2) and atrazine 0.5 kg/ha + 1-hand hoeing (20 DAS) (W_4), however, statistically similar higher yield of dehusked cob produced under atrazine 1.0 kg/ha (PE) (W_1) and atrazine 0.5 kg + wheat straw mulch 5 t/ha (W_2).

CONCLUSION

From the data, it was evident that baby corn grown under custard apple agri-horti has lower infestation of weeds (grasses and BLWs) and produced higher plant height and dehusked cobs as compared to guava agri-horti system and open field. Application of atrazine 0.5 kg+wheat straw mulch 5 t/ha effectively reduced weed growth and produced comparable higher yield to that of atrazine 1.0 kg/ha.

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Efficacy of propaquizafop against weeds, growth and yield of sesame [*Sesamum indicum* (L.)]

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Sesame is most important oilseed crop of India including Madhya Pradesh. Competitional stress of weeds on crop for nutrients, water, light and space is responsible for poor yields of sesame. Though the conventional methods of weed control viz., hand weeding, hand hoeing etc. are very much effective but due to high wages and non-availability of labourers these practices are presently not economically viable. Therefore, use of herbicides could be more, economical and efficient to check early crop-weed competition. Henceforth, the efficacy of propaquizafop was adjudged against weeds in sesame.

METHODOLOGY

The present experiment was conducted at the Product Testing Unit, Department of Agronomy, College of Agriculture, JNKVV, Jabalpur (M.P.) during *kharif* 2015. Nine weed control treatments comprising of 5 doses of propaquizafop (50, 62.5, 75, 100 and 125 g/ha), fenoxaprop-p-ethyl 100 g/ha, propaquizafop + imazethapyr mixture (50+50 g/ha) as post emergence including hand weeding twice (20 and 40 DAS) and weedy check plots, were laid out in Randomized Block Design with three replications. The sesame crop variety Phule til-1 was sown with seed rate of 5 kg/ha. The crop was fertilized with 60 kg N, 30 kg P_2O_5 and 20 kg K_2O/ha through urea, single superphosphate and muriate of potash, respectively. Efficacy of weed control treatments was judge through weed index, as suggested by Mani et.al. (1968). Yield attributing traits and yield parameters of sesame under particular treatments were taken in to account to adjust the superiority of weed control treatments. The economic analysis of these treatments was done on the basis of prevailing market price of agro-inputs and output obtained under each treatment

RESULTS

Density of monocots was higher (80.89%) than dicot weeds (19.11%) in weedy check plot in sesame at Jabalpur (M.P.). Among the monocot weeds, *Echinochloa colona*, *Cyperus rotundus* and *Dinebra retroflexa* were rampant as they contributed 38.74, 23.64, and 14.56 per cent to the relative density of weeds respectively. However, other monocot weed (*Cynodon dactylon* 3.95%) and dicot weeds like *Eclipta*

Table 1. Influenced of herbicidal treatments on yield attributing traits, yield, weed index and economics of sesame

Treatment	Weed index (%)	Seed yield (kg/ha)	Stalk yield (kg/ha)	NMR (Rs/ha)	B:C Ratio
T_1 Propaquizafop 50 g/ha	46.09	357.10	1567.59	7261	1.37
T_2 Propaquizafop 62.5 g/ha	42.36	381.79	1610.19	9018	1.46
T_3 Propaquizafop 75 g/ha	33.74	438.89	1697.22	13207	1.67
T_4 Propaquizafop 100 g/ha	31.36	454.63	1763.89	14200	1.71
T_5 Propaquizafop 125 g/ha	28.66	472.53	1850.00	15355	1.76
T_6 Fenoxaprop-p-ethyl 100 g/ha	43.85	371.91	1732.10	6898	1.33
T_7 Imazethapyr + Propaquizafop 50+50 g/ ha	68.69	207.41	1593.83	-4666	0.77
T_8 Hand weeding (20 & 40 DAS)	0.00	662.35	1872.84	21829	1.78
T_9 Weedy check	74.28	170.37	1270.99	-6069	0.68
SEm±	-	1.66	26.27		
CD (P=0.05)	-	4.99	78.76		

• GMR = Gross monetary return, NMR = Net monetary return, B:C ratio =Benefit cost ratio
• WCE= Weed Control efficiency

alba, *Alternanthera philoxeroides* and *Mollugo pentaphylla* also marked their presence in less numbers (8.12, 6.03 and 4.96, per cent, respectively) in sesame. Yield reduction due to presence of weeds in sesame was 74.28 per cent. Alone application of propaquizafop (50 g/ha) as post-emergence, scaled down the yield reduction to the tune of 46.09 per cent. But yield reduction was further checked when propaquizafop was applied at 100 g/ha (31.36%) or higher rate 125 g/ha (28.66 %) and proved significantly superior over check herbicide fenexaprop - p-ethyl (100g/ha), imazethapyr + propaquizafop (50+50g/ha) mixture and lower doses of propaquizafop (50 to 75g/ha) including weedy check plots. The seed and stalk yields were comparatively low when propaquizafop was applied at the lowest rate (50 g/ha) but value of these parameter were improved further with corresponding increase in application rates being higher when it was applied at 100 and 125 g/ha. However, hand weeded plots recorded the maximum seed and stalk yields and proved significantly superior to herbicidal treatments. Post-emergence application of propaquizafop at 100 g/ha or higher rate (125 g/ha) was found more remunerative, as both fetched higher net monetary returns (Rs 14200 and 15355/ha) and benefit-cost ratio (1.71 and 1.76) nearly similar to hand weeded plots (Rs 21829/ha and 1.78) respectively.

CONCLUSION

Post-emergence application of propaquizafop between 100-125 g/ha was found more remunerative to that of hand weeding twice.

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Efficacy of different herbicides on weed control and yield of cluster bean (*Cyamopsis tetragonoloba*)

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Cluster bean, vernacularly known as 'Guar', is a drought hardy leguminous, rainy season crop of semi-arid and arid regions of India. Presence of 30-35% galactomann (gum) in its endosperm has changed it from a conventional arid legume to industrial crop. This crop is mainly cultivated in the marginal and rainfed areas where inadequate weed management is a major constraint in harnessing its production potential. Being a rainy season crop, it suffers badly due to severe competition by mixed weed flora. Yield reduction to the tune of 53.7% has been observed due to weed infestation (Saxena *et al.,* 2004). Although weeds pose problems during entire crop growth period, initial one month of the crop is especially critical. Therefore, weed control needs to be ensured to exploit the yield potential of this crop. Hand weeding is a traditional and effective method but untimely rains, unavailability of labour at peak time and increasing labour cost are the main limitations. Under such situations, the only alternative that needs to be explored is the use of suitable herbicides which may be effective and economical.

METHODOLOGY

A field experiment was conducted at ARS, Mandor, Jodhpur during the rainy (*kharif*) season of 2014 and 2015 to study the efficacy of different herbicides on weeds control and yield of cluster bean. The rainfall was very scanty and erratic in nature throughout crop season both the years. The soil of experimental plot was sandy loam with low in organic carbon (0.13%) and available N (170.6 kg/ha), medium in P_2O_5 (26.08 kg/ha) and high in K_2O (391.0 kg/ha). The pH and EC (dS/m) of the soil were 7.98 and 0.39, respectively. Ten treatment combinations comprising pre-emergence application of pendimethalin (30 EC) at 1000 g/ha, pendimethalin (38.7 CS) at 400, 500 & 600 g/ha, post-emergence application (20 DAS) of imazethapyr at 40 & 60 g/ha, imazethapyr + imazamox (pre-mix) at 40 & 60 g/ha, weed free (hand weeding at 20 and 40 DAS) and weedy check (control) were tested in Random-

Table 1. Efficacy of different herbicides on weed control and seed yield of cluster bean (Pooled data of two years)

Treatment	Weed dry weight (g/m^2)	WCE (%)	Seed yield (kg/ha)
Pendimethalin @ 1000 g/ha at pre-em.	54.3	63.4	545
Pendimethalin (38.7 CS) @400 g/ha at pre-em.	71.4	51.9	674
Pendimethalin (38.7 CS) @500 g/ha at pre-em.	66.2	55.4	703
Pendimethalin (38.7 CS) @600 g/ha at pre-em.	51.4	65.3	676
Imazethapyr@ 40g/ha at post-em.	56.2	62.1	705
Imazethapyr@ 60g/ha at post-em.	62.7	57.7	623
Imazethapyr+Imazamox (Pre-mix) @ 40g/ha at post-em.	34.7	76.6	733
Imazethapyr+Imazamox (Pre-mix) @ 60g/ha at post-em.	29.8	79.9	624
Weedy check	148.3	0.0	437
Weed free (hand weeding at 20 and 40 DAS)	14.7	90.1	805
SEm±	3.1	-	35
CD (P=0.05)	9.3	-	105

ized Block Design and replicated thrice. The test crop used cluster bean variety was RGM-112 grown with reccommended package of practices for the crop.

RESULTS

The data on seed yield and weeds biomass revealed that there was significant reduction in weed dry matter accumulation due to herbicidal treatments at post-emergence application (40 DAS) than pre-emergence one. Post-emergence application of imazethapyr + imazamox at 40 g/ha recorded maximum weed control efficiency (76.6%) compared to pre-emergence application of pendimethalin 38.7 CS at 600 g/ha (65.3%). This treatment also enhanced seed yield to the tune of 67.7% over weedy check and 8.4% over pre-emergence application of pendimethalin 38.7 CS at 600g/ha. The post-emergence application of Imazethapyr at 40 g/ha also increased seed yield of cluster bean by 61.3% over weedy check with weed control efficiency of 62.1%.

CONCLUSION

Based on two years investigation, it is concluded that post emergence application (20 DAS) of imazethapyr + imazamox (pre mix) at 40 g/ha or imazethapyr alone at the same dose effectively controlled weeds in cluster bean. Amongst pre-emergence herbicides, pendimethalin (38.7 CS) at 600 g/ha was found effective for controlling weeds in this crop with enhanced seed yield.

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Integrated weed control measure under different sowing method in Isabgol (*Plantago ovata*)

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Isabgol is the annual species that have originated from arid and semi-arid zones used widely in traditional and industrial pharmacology (D. Antuno *et al.,* 2002). Plant population may affect the maximum accessibility and consumption of these factors. Therefore, it is necessary to determine the optimum density of plant population per unit area for obtaining maximum yields (Baloch *et al.*, 2002). Yield losses depending on the competitive ability of weed and crop density and duration of competition varies from 10 to 100 percent. During recent past, fast development in industries and infrastructure sectors which reduced labour availability in agriculture and also increased labour wages. Integrated weed management approach

Table 1. Effect of sowing methods and weed control on yield attributes, yield and net return of isabgol (pooled data of 2 years)

Treatment	Plant population/ m^2	Effective tillers per plant	1000 seed weight (g)	Seed yield (kg/ ha)	Net return (Rs/ha)
Sowing method					
Broadcasting	358.39	21.12	1.70	758.99	26535
Line sowing at 30 cm	263.18	31.48	1.74	1042.06	46134
Line sowing at 22.5 cm	372.39	28.66	1.72	1131.53	51550
CD (p=0.05)	26.25	1.76	0.04	82.91	5389
Weed control					
Control	210.95	19.25	1.60	695.29	25460
Hand weeding at 30 DAS	392.55	29.83	1.76	1072.64	46788
Isoproturon 600 g/ha at 20 DAS + Hand weeding at 30 DAS	390.47	32.17	1.81	1164.66	51970
CD (P=0.05) ±	19.45	1.37	0.03	54.93	3570

* Selling price of Isabgol Rs. 65000/t

involving the physical and chemical weed control techniques, achieve complete, long and effective control of weeds during crop season. Keeping this in view, the present experiment was planned as different methods of sowing and herbicidal control with hand weeding was tried to find solutions for the above said problems.

METHODOLOGY

Study was conducted at farmers field Jalore during *Rabi* 2011-12 and 2012-13 having silty loam soil with pH 8.2. The experiment was laid out in a split-plot design with five replications. The treatments consisted of three main plots (sowing methods– broadcasting, sowing in line at 30 cm and sowing in line at 22.5 cm) and three sub plots (unwed control, hand weeding at 30 DAS and post emergence application of isoproturon 600 g *a i* per ha at 20 DAS +hand weeding at 30 DAS) . Sowing of isabgol RI- 89 was done at first week of November in both the year as per the sowing method treatment at broadcasting and line at different spacing. Besides sowing method and weed control measures, the crop was raised with recommended package of practices.

RESULTS

It is evident from pooled data of the year 2011-12 and 2012-13 (Table 1) explicit that sowing in rows at 30 cm as well as 22.5 cm. increased significantly effective tillers per plant, test weight, seed yield, and net returns over broadcasting sowing in isabgol. Further, seed yield and net returns was higher with sowing in narrow rows at 22.5 cm as compared to sowing in rows at 30 cm and broadcast method. These increases in yield could be ascribed higher plant population increase production per unit area. This might have enabled the crop to maintain optimum plant stand. Given the small plant size, higher husk, leaf and seed yield at higher densities was probably due to the quick formation of canopy, the increase in leaf area index and better utilization of solar radiation and other resources. An appraisal of pooled data of the year 2011-12 and 2012-13 reveled that integrated weed control measures with post emergence isoproturon at 20 DAS and hand weeding at 30 DAS observed significantly higher effective tillers per plant, test weight, seed yield, and net returns compared to single hand weeding at 30 DAS and unweeded control in isabgol (Table 1). This might be due to effective destruction of weeds at their critical growth stages that created favorable conditions for crop growth and ultimately resulted in lowest density of later emerged weeds and their lowest biomass with higher weed control efficiency. Effective removal of weeds throughout the crop growth period by physical and integrated weed control practices provided better space and resources i.e., moisture, nutrients, solar radiation etc., for crop plant which led to higher yields.

CONCLUSION

Seed yield and net returns was higher with sowing in narrow rows at 22.5 cm as compared to sowing in rows at 30 cm and broadcast method. Further, integrated weed control measures with post emergence isoproturon at 20 DAS and hand weeding at 30 DAS observed significantly higher effective tillers per plant, test weight, seed yield, and net returns compared to single hand weeding at 30 DAS and unweeded control in isabgol.

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Impact of new generation HPPD inhibiting herbicides on growth and yield of maize (*Zea mays* L.)

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Maize is among the world's three most important cereal crops. India ranks 5th and 3rd in the world in terms of area and production of maize, + respectively. Maize is being cultivated in 6.29 mha area in the country, with a production of 10.30 Mt and average productivity of 1.64 t/ha. In Telangana total cropped area was 7.52 lakh ha with production and productivity of 35.25 lakh tonnes and 4.69 t/harespectively. (DMR, 2013).Maize crop gets infested with variety of weeds and subjected to heavy weed competition, which often inflicts huge losses ranging from 28 to 100 % (Patel *et al*., 2006). Currently herbicides available for post-emergenceweed control in maize have relatively short time of action and effective against broad leaf weeds, but control of grasses and sedges remain a problem for the farmers, especially when the too high or too low soil moisture hinders the intercultural operation. It is also well documented that persistence of atrazine in soil resulting in residual effects (Singh *et al*., 2012). Hence present investigation was undertaken to study the tank mix efficacy of new herbicides like topramezone and tembotrione for broad spectrum of weed control in maize.

METHODOLOGY

Field experiment was carried out at College Farm, College of Agriculture, Professor Jayashankar Telangana State Agricultural University (PJTSAU), Rajendranagar, Hyderabad. The soil of the experimental field was sandy loam in texture with pH of 7.6 low in available nitrogen (255 kg/ha), medium in available phosphorus (25kg/ha) and potassium (263 kg/ha). The experiment was laid out in randomized block design (RBD) with ten treatments and three replications comprising of new hydroxy-phenyl pyruvate dioxygenase (4-HPPD) inhibiting herbicides topramezone and tembotrione tank mixed with and without atrazine. Maize hybrid DHM-117 were dibbled manually at 60 cm between and 20 cm within the line @ 25 kg seed/haduring the first week of July.

RESULTS

Predominant weed species observed were *Cynodon dactylon* L., *Dactyloctenium aegyptium* L., *Echinocloa spp* and *Rottboellia exaltata* L among grasses, *Parthenium hysterophorus* L., *Commelina benghalensis* L., *Amaranthus*

Table 1. Weed growth, yield and economics of maize as influenced by different weed control measures

Treatments	Relative density (%) at 40 DAS			Grain yield (t/ha)	Weed Index (%)	Net returns (₹/ha)	B:C ratio
	Grasses	Sedges	BLW				
Atrazine @1.0 kg/ha as PE fb inter- cultivation at 30 DAS	43.2	32.5	24.3	5.72	13.00	55337	3.11
Topramezone @25.2 g/ha + MSO (adjuvant) as PoE	29.2	43.4	27.4	4.99	24.13	43133	2.50
Tembotrione @105 g /ha + adjuvant as PoE	28.8	41.8	29.5	4.83	26.53	40972	2.43
Topramezone + atrazine @ 25.2 + 250 g/ ha + adjuvant as PoE	22.9	60.6	16.5	6.44	2.18	62608	3.17
Tembotrione + atrazine @105 + 250 g /ha + adjuvant as PoE.	23.6	56.2	20.2	6.28	4.52	60181	3.10
Tembotrione @ 105 g/ha as PoE	25.0	43.0	32.0	4.53	31.20	37028	2.30
Intercropping of maize with cowpea and PE application of pendimethalin @1.0 kg/ha.	30.7	45.7	23.6	4.71 (MEY)	28.40	41175	2.55
Hand weeding at 20 and 40 DAS.	31.7	42.0	26.3	6.58	-	59368	2.72
Intercultivation at 20 and 40 DAS	33.5	41.8	24.7	5.49	16.60	52355	3.01
Unweeded control	36.7	27.6	35.8	2.59	69.2	14728	1.60
CD (P=0.05)				0.360		4773.8	

viridis L., *Euphorbia geniculata* L.,and *Trianthema portulacastrum* L among the broadleaved weeds and sedge *Cyperus rotundus* L.*Cyperus rotundus* was found to be most predominant weed with relative density varying from 32.5% to 60.6% in different weed control treatments at 40 DAS. Relative density of *Cynodon dactylon* and *Cyperus rotundus* in topramezone + atrazine @ 25.2 + 250 g/ha+ MSO was 15.9% and 60.6% whereas in tembotrione + atrazine @ 105 + 250 g/ha + stefesmero as PoE the densities were 17.5% and 56.2%. *Digitaria sanguinalis, Dactyloctenium aegyptium, Echinocloa spp,Amaranthus viridis, Euphorbia geniculata, Digera arvensis* were totally controlled in these treatments indicating relative predominance of perennial weeds compared to annual grasses and BLW. Lowest weed index was recorded with topramezone + atrazine @ 25.2 + 250 g/ha + MSO as PoE (2.18%), tembotrione + atrazine @ 105 + 250 g *a.i*/ha as PoE (4.52%). Highest grain was recorded with hand weeding at 20 and 40 DAS which was at par with topramezone + atrazine @ 25.2 +250 g/ha + MSO and tembotrione + atrazine @ 105 + 250 g/ha + stefes mero. Herbicidal treatments resulted in considerably lower cost of cultivation compared to hand weeding. The B:C ratio was found maximum (3.17) with topramezone + atrazine @ 25.2 + 250 g/ha + MSO and atrazine @ 1.0 kg/ha as PE fb intercultivation at 30 DAS (3.11).

CONCLUSION

Tank mix application of post-emergence herbicides topramezone and tembotrione @ 25.2 and 105 g/ha with atrazine @ 250 g/ha along with adjuvants resulted in efficient control of grasses and broad leaf weeds with higher net returns. Hence these can be recommended for weed control in maize.

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Weed management in soybean [*Glycine max* (L.) Merrill] under dryland condition of Vertisol in Malwa Plateau of Madhya Pradesh

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Soybean [*Glycine max* (L.) Merrill] has established its recognition both as a pulse and an oilseed crop and ranks third among oilseed crops grown in India. One of the major reasons for this poor performance of soybean is inadequate weed control. Unchecked weeds may cause 58-88% reduction in the grain yield of soybean (Singh *et al.,* 2004). Severe weed competition is one of the major constraints responsible for low productivity of soybean in Madhya Pradesh. Moreover, hand weeding is tedious and time consuming and many a times damages surface feeding roots of the crop due to mechanical hand weeding. Inter-culture by hoe is another common practice locally called as *Dora* and is effective in inter row spaces and exerts severe stress on crop. Therefore, it is necessary to suggest alternative methods of reducing the weed load during early crop growth period of soybean to sustain yield. Thus herbicidal weed control remains the only choice under such situations. However, herbicides are costly and their availability in desired quality is also problematic, but this can be managed, by quality control measures and judicious use of herbicides, as per the recommendations.

METHODOLOGY

Field investigation was conducted at Research Farm of the Dryland Agricultural Research Project, College of Agriculture Indore (M.P) during *kharif* season of 2010 to assess the effect of different weed management practices for controlling weeds and their subsequent effect on growth, yield and yield attributing character of soybean. Ten treatments *viz.*, pendimethalin

30EC @ 1000g a.i./ha (PE) (T_1), imazethapyr 10%SL @ 100g a.i./ha (20 DAS) (E-PoE) (T_2), Odyssey 70%WG @ 87.5g/ha (E-PoE) [imazethapyr @ 30.62g a.i./ha+ imazamox @ 30.62g a.i./ha] (T_3), chlorimuron ethyl 25% WP @ 37.5g/ha (E-PoE) (T_4), imazethapyr 10%SL @ 100g /ha (45 DAS) (PoE) (T_5), pendimethalin 30EC @ 1000g a.i./ha (PE) + imazethapyr 10%SL @ 100g a.i./ha (20 DAS) (E-PoE) (T_6), interculture by small harrow/Dora (20 & 30 DAS) (T_7), interculture at 15 DAS + imazethapyr 10%SL @ 100g a.i./ha (20 DAS) (E-PoE) (T_8), weed free up to 60 DAS (T_9) and weedy check (control) (T_{10}) were laid out in randomized design with 3 replications. The soybean variety JS-93-05 was sown on 27-06-10 and harvested on 03-10-10. Data pertaining to weed count recorded at 20, 40, 60 days growth stages and harvest were subjected to Log (n) transformation for statistical analysis.

RESULTS

The population of monocot weeds was significantly reduced by pre-emergence application of pendimethalin 30EC @ 1000g a.i./ha (T_1), application of pendimethalin 30EC @ 1000g a.i./ha as PE + Imazethapyr 10%SL @ 100g a.i./ha as E-PoE (T_6), interculture at 15 DAS + imazethapyr 10%SL @ 100g a.i./ha as E-PoE (T_8) and weed free (T_9) at early growth stage of the crop. In case of broad leaf weeds interculture at 15 DAS + imazethapyr 10%SL @ 100g a.i./ha as E-PoE (T_8) and weed free (T_9) was found effective in controlling their population at early stage of the crop. At later stage of the crop, most of the weed management practices significantly reduced the weed population compared to unweeded control. Weed free (T_9) recorded significantly lower population and dry matter of both types of weeds compared to rest of the weed management practices. Among the herbicidal treatments, application of pendimethalin 30EC @ 1000g a.i./ha as PE + Imazethapyr 10%SL @ 100g a.i./ha as E-PoE (T_6) resulted in significantly lower population of monocot and dicot weeds followed by early post-emergence application of imazethapyr 10%SL @ 100g a.i./ha (T_2) and interculture at 15 DAS + imazethapyr 10%SL @ 100g a.i./ha as E-PoE (T_8) over other treatments. The trend of different weed control treatments for increased weed control efficiency was in order of in weed biomass production. The application of Pendimethalin 30EC @ 1000g a.i./ha (PE) had the lower value of weed control efficiency (39.99%) because of poor control of all weeds but it was identical when imazethapyr was applied at Imazethapyr 10%SL @ 100g a.i./ha (20 DAS) or when combined application of imazethapyr 100 g/ha was done with interculture by Dora (20DAS) because of control of nearly all weeds. Weed free (T_9) resulted in the maximum seed yield of soybean, which were significantly higher over rest of the weed management treatments. However, it was found at par with early post-emergence application of imazethapyr 10%SL @ 100g a.i./ha (T_2), application of pendimethalin 30EC @ 1000g a.i./ha as PE + Imazethapyr 10%SL @ 100g a.i./ha as E-PoE (T_6) and interculture at 15 DAS + imazethapyr 10%SL @ 100g a.i./ha as E-PoE (T_8) in respect of seed yield. Net return and B;C ratio was highest under application of pendimethalin 30EC @ 1000g a.i./ha as PE + Imazethapyr 10%SL @ 100g a.i./ha as E-PoE (T_6) followed by early post-emergence application of imazethapyr 10%SL @ 100g a.i./ha (T_2).

Table 1. Influence of different herbicides on weed intensity, weed dry weight, weed control efficiency, yield attributes, seed yield and economics of soybean

S. No.	Treatment	Monocot Weed intensity m^2	Dicot Weed intensity m^2	Weed control efficiency (%)	Seed yield (kg/ha)	Net monetary Return (/ha)	B:C Ratio
T_1	Pendimethalin 30EC @ 1000g a.i./ha (PE)	1.52(32.75)	1.85(70.57)	39.99	657.41	1888	1.15
T_2	Imazethapyr 10%SL @ 100g a.i./ha (20 DAS) (E-PoE)	1.38(23.97)	1.40(24.85)	81.82	731.48	3643	1.29
T_3	Odyssey 70% WG @ 87.5 g/ha (E-PoE) [Imazethapyr @ 30.62g a.i./ha+ Imazamox @ 30.62g a.i./ha]	1.45(28.36)	1.55(35.28)	77.04	691.36	3425	1.29
T_4	Chlorimuron ethyl 25% WP @ 37.5g/ha (E-PoE)	1.91(82.05)	1.58(38.15)	41.91	670.99	3350	1.29
T_5	Imazethapyr 10%SL @ 100g /ha (45 DAS) (PoE)	1.73(53.69)	1.56(35.99)	66.15	662.04	2115	1.17
T_6	Pendimethalin 30EC @ 1000g a.i./ha (PE) + Imazethapyr 10%SL @ 100g a.i./ha (20 DAS) (E-PoE)	1.22(16.54)	1.28(18.90)	83.03	796.30	4019	1.30
T_7	Interculture by small harrow/Dora (20 & 30 DAS)	1.48(30.05)	1.58(37.82)	71.51	716.05	2503	1.19
T_8	Interculture at 15 DAS + Imazethapyr 10%SL @	1.44(27.69)	1.40(25.33)	79.40	729.94	3459	1.27
	100g a.i./ha (20 DAS) (E-PoE)	0.85(7.09)	0.64(4.39)	93.58	842.59	3487	1.23
T_9	Weed free up to 60 DAS	2.18(149.75)	2.22(167.62)	0.00	592.59	2037	1.19
T_{10}	Weedy check (Control)						
	SEm ±	0.09	0.08	39.99	38.99	-	-
	CD (P=0.05)	0.26	0.23	81.82	115.86	-	-

DAS – Days after sowing; PE – Pre emergence; PoE – Post emergence; E-PoE– Early Post emergence Figures in parentheses refers original data

CONCLUSION

Weed free (T_9) proved highly effective for attaining higher weed suppression and yield simultaneously. Among herbicidal treatments, application of pendimethalin 30EC @ 1000g a.i./ ha as PE + Imazethapyr 10%SL @ 100g a.i./ha as E-PoE (T_6) observed most effective in controlling both monocot and dicot weeds, resulting in production of higher growth and yield attributes and yield than other herbicidal treatments and was found comparable to weed free treatment in most of the cases.

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Role of sulphydryl bioregulator thiourea in mitigating abiotic stress in crops

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Crops are continually exposed to environmental fluctuations and stresses, and have to co-ordinate their growth and development throughout their life cycle to ultimately give harvestable products. Environmental stresses of drought,heat, frost and salinity are of major concern as they cause large yield losses According to world estimates, an average of 50% yield losses in agricultural crops are caused by abiotic stresses (Wang *etal*., 2003). In the present context of agriculture faced with the twin problemsof declining total factor productivity and the mounting problems of environmental stresses due to climate change, it is absolutely necessary to develop crop genotypes with enhanced photosynthetic efficiency coupled with tolerance to abiotic stresses. While this may be a long term research challenge, on the short term scale it should be possible to devise crop management techniques that would trigger plant's intrinsic metabolism to adapt to abiotic stresses and at the same time enhance the plant efficiency in the utilization of production resources like water and nutrients. It is felt that molecular biology-based plant breeding or molecular agronomy can alone break the yield barrier of crops in stress environments. The allocation and partitioning of assimilated carbon provides resources for acclimation to environmental stress. Mobilization of reserves that were previously allocated to storage can also supply carbon needed for stress responses.

METHODOLOGY

The research work carried out in India and elsewhere in the world on the role of sulphydryl bioregulator thiourea in mitigating abiotic stress in crops was reviewed and summarized in this paper.

RESULTS

During the past one decade, a number of publications have appeared on the role of thiourea in mitigating abiotic stress, and the effects have been ascribed to the bioregulatory role of its sulphydryl group configuration. Drought amelioration studies showed that foliar spray of 0.1% thiourea spray at tillering and flowering significantly increased the grain yield, registering 26.6% increase as compared to control (Sahu e*tal*., 2006). A similar experiment conducted to find out agro-techniques to overcome drought stress in pearl millet under rainfed conditions showed that foliar spray of 0.1% thiourea increased the grain yield by 10.7% over control (Siddiqui *etal*., 2014). Effectiveness of foliar spray of thiourea was tested in wheat under salinity and heat stresses at University of Agriculture, Faisalabad, Pakistan (Anjum*et al.,* 2008). Foliar application of thiourea (10 mM) induced both salinity and heat tolerance by improving net photosynthesis and grain yield in wheat. In another study, Anjum *et al*. (2011) investigated the possible role of foliar spray of thiourea in improving the salinity tolerance threshold (ECe) and high temperature tolerance of five wheat varieties. Foliar applied thiourea (10mM) improved ECe (6-11%) and high temperature tolerance (4-10%) in wheatvarieties at different stages. Recently, thiourea was evaluated by All India Coordinated Research Project for Dryland Agriculture (AICRPDA) network centres to mitigare dry spells during crop growing season across diverse rainfed agroecologies (DARE/ICAR Annual Report 2015-16). Foliar spray of thiourea at 250 g/ha improved the yields of fingermillet (10%) at Bengaluru, maize (9.5%) at Ballowal Saunkhri and soybean (30%) at Indore, resulting in higher net returns and rainwater-use efficiency (RWUE) compared to water spray.

CONCLUSION

The introduction in nature of genetically engineered plants is still controversial. Thus, the continued study of the intricatesignaling pathways involved in plant response to environmental stress is a promising area of research, which may ultimately lead to improvements in yield potential through plant treatment with exogenous compounds, therefore without resorting to genetic manipulation. Restoring cellular homeostasis in crop plants underenvironmental stresses, viz. drought, salinity or high temperature, with the use of external bioregulatory compounds becomes necessary for improving growth and yield of crops. In this regard, sulphydryl bioregulatror thiourea can prove a catalyst for bringing about a quantum jump in crop productivity in stress agriculture.

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Chemical composition and nematicidal activity of vetiver root oil against *Meloidogyne incognita* as affected by its commercial grading and extraction methods

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Nematicidal activity of oil obtained from different commercial grades of north Indian vetiver (*Vetiveria zizanioides* L.) root and extracted by different extraction methods has been evaluated against root-knot nematode *Meloidogyne incognita*. The highest oil yield was obtained from lachha followed by nakhuni and munjhar, irrespective of distillation methods. Similarly, in case of effectiveness of extraction methods, the highest oil yield was obtained from solvent extraction (SE) method followed by steam distillation (SD) and deg bhapka (DB) method in all grades of root materials. The oil yield ranged from 0.076% to 0.45%. Physico-chemical properties viz., appearance, colour, odour, specific gravity, refractive index, optical rotation, acid value, ester value, free, combined and total alcohols, carbonyl value and solubility varied with source of oils obtained from three different commercial grades. The nematicidal activity of four concentrations (500, 250, 125 and 62.5ppm) of vetiver root oils extracted from three grades by three different extraction methods, were tested against *M. incognita* at different time intervals after 24, 48 and 72 hours. Irrespective of their commercial grades or extraction methods, the oils exhibited 100% mortality at the concentration of 500 ppm at 24 hrs. However, the rate of mortality decreased from 69 to 3% in other combinations of concentrations, commercial grades and extraction methods over a period of 72 hrs. The effect of commercial grades was seen distinct as the oil extracted from lachha showed 64, 42 and 12% mortality at 250, 125 and 62.5 ppm concentration, respectively as compared to 54, 37 and 10% in case of nakhuni and 52, 37 and 8% in case of munjhar at 250, 125 and 62.5 ppm concentration, respectively. The oil extracted by SE method showed 60, 43 and 13% mortality at 250, 125 and 62.5 ppm concentration, respectively as compared to 57, 38 and 10% in case of SD and 52, 34 and 8% in case of DB method at 250, 125 and 62.5 ppm concentration, respectively. Thus, the oil obtained by DB method showed lowest toxicity. The higher nematicidal activity of oil obtained from lachha over all other grades of roots, nakhuni over munjhar, oil obtained by SE method over all other methods and SD method over DB may be due to higher concentration of á-vetivone and bicyclovetivenol in these oils as indicated from their respective chemical compositions. Alpha-vetivone and bicyclovetivenol are known for their pesticidal activities.

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Herbicide resistance in littleseed canarygrass populations from Haryana

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Littleseed canary grass has been an importunate trouble in the North-Western Indo-Gangetic Plains of India. The infestation of *P. minor* is mostly contained in the states of Punjab and Haryana where rice-wheat is the predominant crop rotation and this weed has been a long-standing management problem for farmers in these states. Presently, its control has become even more difficult after it evolved multiple herbicide resistance to recommended herbicides: isoproturon (PSII); diclofop-methyl, fenoxaprop-P-ethyl, clodinafop-propargyl, pinoxaden (ACCase); sulfosulfuron and premix of mesosulfuron + iodosulfuron (ALS inhibitors); mediated by enhanced metabolism and target site mutations (Singh, 2015a). Multiple herbicide resistant populations of *P. minor* in wheat in these states is again threatening wheat productivity and profitability as it did in the early 1990s when resistance to isoproturon first occurred. Increase in GR_{50} (50% growth reduction) values of clodinafop, fenoxaprop, sulfosulfuron, and pinoxaden have been observed for resistant *P. minor* populations particularly under continuous use of these herbicides (Singh, 2015b). Thus, evolution of multiple herbicide resistance in *P. minor* populations has unfolded as a demanding problem daunting wheat production of the grain bowl states of India. Therefore, the present study was planned under pot conditions to evaluate the impact of ACCase and ALS inhibitors in *P. minor* populations from wheat growing fields of Haryana.

METHODOLOGY

Spatial investigation of *P. minor* was made through systematic seed collection. Seeds of fourteen populations of *P. minor* were collected randomly from cropped fields at different locations of Haryana (with uncontrolled history with different herbicides) for a herbicide resistance profile study. Fifty seeds of each population were sown by November end in sandy loam soil in earthen pots (93 dia) during the *rabi* season of 2014-15 and 2015-16. Thinning was done to maintain ten plants in each pot. CDF 0-120 g, PDN 0-100 g, SSN 0-50 g and mesosulfuron + iodosulfuron (M+I) 0-28.8 g/ha were sprayed at the 3-4 leaf stage by using a battery operated back-pack sprayer fitted with flat fan nozzle delivering 375 L/ha spray volume at 40 psi pressure. There were 4 replicated pots for each population and herbicide treatments along with control, arranged in completely randomized design. Observations were recorded 30 days after spray on percent control and biomass accumulation.

RESULTS

The quantification of herbicide resistance revealed that out of the 14 populations, 3 were susceptible (S), 1 was moderately susceptible/resistant (MS/MR) while the remaining were highly resistant (R) to clodinafop (60 g/ha). Similarly, 9 populations were R to pinoxaden (50 g/ha), 2 were MS/MR and 3 were S. When tested against sulfosulfuron (25 g/ha), only 1 population was found to be S, 7 were MS/MR and 6 were R. Nine populations were MS/MR to 14.4 g/ha mesosulfuron + iodosulfuron and 4 R and 1 S. The data revealed that the selection pressure exerted by ACCase and ALS inhibiting herbicides has led to the development of multiple resistance to these herbicides in *P. minor* populations at most of the locations in Haryana. Indiscriminate use of available herbicides without integration with other weed control strategies resulted in evolution of herbicide resistance in India. Swift evolution of herbicide resistance was also cautioned in earlier findings (Dhawan *et al*., 2012; Singh, 2015a). The over-reliance of farmers on the alternate herbicides after their recommendation to manage isoproturon resistant *P. minor* has led to the evolution of multiple herbicide resistance in *P. minor*. Therefore, the future weed management strategies must consider use of all cultural, mechanical, and herbicidal options available and suitable for a particular cropping system for effective weed control; and for avoidance of herbicide resistance.

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Suppress weeds through different rows orientation, cutting management and increase crop yield of dual purpose barley

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Barley (*Hordeum vulgare* L.) is the fourth most important cereal crop of the world after wheat, rice and maize. Its grains contain 8 to 10% protein and 74% carbohydrates besides the minerals and vitamin B-complex, it thus forms a staple food, cattle feed, malt for manufacturing of beer and other liquor products (Singh *et al*., 2009). One possible way to reduce light interception by weeds and to increase light interception by the crop canopy is to manipulate the crop row spacing and orientation (Holt, 1995). Crop rows oriented to sunlight direction (i.e. uni-direction, bi-direction within the winter cropping system in Punjab) may suppress weed growth through greater shading of weeds in the inter row spaces. Light is a significant determinant of crop productivity and crops can be manipulated to increase shading of weeds by the crop canopy, to suppress weed growth, and to maximize crop yield (Catherine *et al*., 2010). The objective of this study was to examine whether crop row orientation and cutting could change the light availability to crops and weeds and, consequently, affect weed growth and crop yield.

METHODOLOGY

A field experiment was conducted during *rabi* 2014-15 at Department of Agronomy, Punjab Agricultural University, Ludhiana, India. The crop using variety PL 807 was sown at 22.5 cm row spacing using 87.5 kg seed/ha of barley. The experiment was laid out in factorial randomized block design (RBD) with 9 treatments have three planting techniques viz. unidirectional (UD), bidirectional (BD), broadcast (BC) and three cutting practices viz. uncut (UN_C), cut at 50 DAS ($C_{50\ DAS}$) and cut at 60 DAS ($C_{60\ DAS}$) with four replications and statistically analysed by using STAR software (Statistical Tool For Agricultural Research), IRRI (International Rice Research Institute), Manila, Phillipines. The weed population (Grass: *Avena fatua* and *Phalaris minar* and Broad leaves: *Chenopodium album, Rumex dentatus, Anagallis arvensis, Fumaria parviflora, Medicago denticuta, Malva parviflori*) in the marked spots of one meter square area each plot were count and after dry biomass of weed.

RESULTS

The data (Table 1) showed that the weed density (Grass and broad leaves) at 30 DAS and 60 DAS reduced significantly under bidirectional (22.5 × 22.5 cm) orientation than other planting, but unidirectional and broadcast rows orientation were statistically at par. Low weed density under bidirectional (22.5×22.5 cm) orientation was due to less availability of space, light and nutrients for proper establishment of weed and more smothering effect by the barley. The weed density in

Table 1. Effect of different rows orientation and cutting management on weed density (no./m), weed biomass (g/m) and grain yield (t/ha)

Treatment	Weed density (/m) at 30 DAS		Weed density (/m) at 60 DAS		Weed biomass (g/m) at 30 DAS		Weed biomass (g/m) at 60 DAS		Grain yield (t/ha)
	Grasses	Broad leaves	Grasses	Broad leaves	Grasses	Broad leaves	Grasses	Broad leaves	
Planting method									
Unidirectional	25.49 (5.14)*	43.61 (6.67)	22.82 (4.87)	38.89 (6.31)	4.16 (2.26)	9.19 (3.18)	8.78 (3.05)	20.89 (4.54)	4.10
Bidirectional	20.85 (4.65)	38.59 (6.28)	18.79 (4.43)	34.63 (5.96)	2.44 (1.84)	6.46 (2.72)	6.12 (2.59)	14.79 (3.77)	4.46
Broadcast	24.06 (4.99)	43.60 (6.67)	21.55 (4.74)	38.86 (6.31)	3.49 (2.11)	8.26 (3.04)	8.16 (2.96)	18.82 (4.29)	4.65
CD (P=0.05)	0.30	0.21	0.24	0.19	0.09	0.16	0.29	0.14	0.21
Cutting management									
Un-cut	23.89 (4.97)	41.81 (6.53)	21.29 (4.71)	37.48 (6.19)	3.47 (2.09)	8.00 (2.99)	9.95 (3.29)	24.45 (5.03)	4.45
Cut at 50 DAS	22.90 (4.86)	41.96 (6.54)	20.85 (4.65)	37.24 (6.17)	3.19 (2.03)	7.93 (2.97)	3.27 (2.02)	5.64 (2.54)	4.6
Cut at 60 DAS	23.60 (4.95)	42.02 (6.55)	21.02 (4.68)	37.66 (6.21)	3.42 (2.09)	7.98 (2.98)	9.84 (3.28)	24.40 (5.02)	3.8
CD (P=0.05)	NS	NS	NS	NS	NS	NS	0.29	0.14	0.21

***** The figures within parenthesis are square root transformations.

different cutting practices at uncut, cut at 50 DAS and cut at 60 DAS were non-significant effect on weed density. The weed dry biomass at 30 DAS and 60 DAS reduced significantly under bidirectional (22.5×22.5 cm) orientation than other treatments. The cutting management 30 DAS was non-significant effect on weed dry biomass and 60 DAS reduced dry biomass significantly under cut at 50 DAS than other treatments, but uncut and cut at 50 DAS of cutting management were statistically at par. The grain yield were significantly higher in BD planting method compared to BC and UD row orientation and UN_C treatment were significantly higher than C_{50DAS} and C_{60DAS} treatments.

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Residual effect of herbicides applied in clusterbean on succeeding mustard crop in two texturally different soils

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Herbicide may also have carryover effect to sensitive crops in the next cropping season.For providing season long weed control persistence of herbicide is very important but this advantage can become disadvantage when the carryover effect of herbicide is injurious to the growth of succeeding crop. Persistence of the herbicides applied in cluster bean may affect the yield of mustard crop in the next cropping season and persistence of imazethapyr at higher rate has been reported by farmers in sandy loam soil. But in the present experiment, there was no effect of the used herbicides at various rates on mustard growth.

METHODOLOGY

Keeping these points in view, field experiments in two texturally different soils were conducted to assess the weed control efficacy and residual effect of herbicides applied in cluster bean on succeeding mustard crop atfarmer's field in village Kheri Batter (loamy sand), district Bhiwani and Weed Control

Table 1. Residual effect of different herbicides applied in cluster bean on plant height of mustard crop

Treatments	Rate(g/ha)	Time of application	Plant height (cm)			
			Kheri Batter		Hisar	
			30 DAS	60 DAS	30 DAS	60 DAS
Pendimethalin	1000	PRE	19.1	122.3	9.3	110.0
Imazethapyr+imazamox (RM)	43.75	3 WAS	20.0	121.7	9.3	111.5
Imazethapyr+imazamox (RM)	52.5	3 WAS	19.4	120.8	9.4	110.5
Imazethapyr+imazamox (RM)	61.5	3 WAS	19.5	121.6	9.5	109.4
Imazethapyr+imazamox (RM)	70	3 WAS	20.1	122.2	9.2	109.4
Imazethapyr+imazamox (RM) fb propaquizafop	43.75 fb 62.5	3 WAS *fb* 6 WAS	19.2	121.6	9.7	109.6
Imazethapyr+imazamox (RM) fb propaquizafop	52.5 fb 62.5	3 WAS *fb* 6 WAS	21.5	122.9	9.3	109.3
Imazethapyr+imazamox (RM) fb propaquizafop	61.5 fb 62.5	3 WAS *fb* 6 WAS	21.7	124.3	9.7	110.0
Imazethapyr+imazamox (RM) fb propaquizafop	70 fb 62.5	3 WAS *fb* 6 WAS	21.1	122.9	9.4	109.6
Imazethapyr fb propaquazafop	50 fb 62.5	3 WAS *fb* 6 WAS	21.7	121.7	9.3	110.1
Imazethapyr fb propaquazafop	75 fb 62.5	3 WAS *fb* 6 WAS	20.6	124.7	9.6	111.4
Imazethapyr fb propaquazafop	100 fb 62.5	3 WAS *fb* 6 WAS	20.8	124.6	9.6	109.8
Pendimethalin+imazethapyr (TM)	500 fb 50	PRE	19.2	123.2	9.6	109.9
Pendimethalin+imazethapyr (RM)	1000	PRE	19.8	124.1	9.3	110.2
Weed free	-	-	21.2	122.0	9.7	111.8
Weedy check	-	-	19.7	121.6	9.7	109.8
CD (P=0.05)	-	-	NS	NS	NS	NS

Research area of Department of Agronomy, CCS HAU Hisar (sandy loam) during the *Kharif* and *rabi* seasons of 2013-14. The Crop received 500.5 and 655.8 mm of rainfall in the crop growing season at both the locations (Kheri Batter and Hisar), respectively. Treatments used in cluster bean consisted of pendimethalin (1.0 kg/ha, PRE), imazethapyr + imazamox (Odyssey) POE at 43.75, 52.5, 61.5 and 70 g/ha 3 WAS (weeks after sowing) alone and followed by (*fb*) propaquizafop 62.5 g/ha (6 WAS), imazethapyr (50, 75 and 100 g/ha *fb* propaquizafop 62.5 g/ha applied at 3 fb 6 WAS), weed free and weedy check.

RESULTS

There was no effect of different herbicides at various rates on mustard growth though some visual crop injury on mustard plants was recorded under imazethapyr + imazamox 61.5 and 70 g/ha at 3 WAS alone &*fb* propaquizafop 62.5 g/ha at 6 WAS, imazethapyr 50, 75 & 100 g/ha 3 WAS *fb* propaquizafop 62.5 g/ha at 6 WAS, pendimethalin 0.5 kg + imazethapyr 50 g/ha (tank mixture) PRE and pendimethalin + imazethapyr (RM) 1.0 kg/ha PRE at Kheri Batter location only, but that was non-significant and transient (fig.2 & table 1). No injury was visible at 4 WAS and later stages, probably due to microbial degradation mediated by higher temperature (36.5^{O}C observed during the *kharif season* 2013-14) or leaching of these herbicides because of heavy rainfall (500-580 mm) occurred between time of herbicide application and planting of mustard in 2013-14.As rainfall amount increased from low to high (75 to 300 mm/month equivalent) imazethapyr bioactivity declined significantly in loamy sand and sandy loam soil.

CONCLUSION

Residual effect of herbicides (used in cluster bean) on mustard was not recorded even at the highest use rates which could be due to high rainfall and temperature during the season.

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Imidazolinone herbicides efficacy in green gram (*Vigna radiata*) and their residual effect on succeeding mustard crop

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Weeds in green gram have been reported to offer serious competition and cause yield reduction to the extent of 20-45 per cent. Weed emergence in green gram begins almost with the crop emergence leading to severe crop-weed competition from initial stages. Pre-emergence use of pendimethalin at 1.0 kg/ha has been found effective to control weeds in green gram but a residual herbicide is needed to control second flush of weeds emerging after rains. Keeping it in view, herbicides imazethapyr alone or in combination with imazamox and pendimethalin as pre-mixture with imazethapyr were tested under PPI, PRE and POE conditions and compared with pendimethalin alone.

METHODOLOGY

The present studies were conducted during *kharif* and *Rabi* seasons of 2014-15 at Department of Agronomy, CCS Haryana Agricultural University Hisar under irrigated conditions. The soil of the experimental field was sandy loam in texture, having pH 8.1, low in organic carbon (0.3%) and nitrogen (182 kg/ha), medium in available phosphorus (18.5 kg/ha) and high in potassium (372 kg/ha) content. Fifteen treatments were applied in a randomized block design replicated thrice. The treatments were imazethapyr at 70 and 80 g/ha as pre-plant incorporation (PPI), pre-emergence (PRE) and post-emergence (POE), imazethapyr + imazamox (RM) at 70 and 80 g/ha as PRE and POE, pendimethalin at 1.0 kg/ha and pendimethalin+ imazethapyr (RM) at 1000 g/ha as PRE and compared with weed free and weedy checks. POE herbicides were applied at 20 DAS (2-3 leaf stage of weeds) by knapsack sprayer fitted with flat fan nozzle using 300 L/ha water. Mus-

Table 1. Effect of different treatments on visual weed control, phytotoxicity and seed yield of green gram and their residual effect on emergence and seed yield of succeeding mustard crop

Treatments	Dose g/ha	Application time	Green gram: Visual weed control (%) 15 DAS	Visual weed control (%) 30 DAS	Phytotoxicity (%) 30 DAS	Phytotoxicity (%) 45 DAS	Seed yield kg/ha	Mustard: Emergence/ m.r.l.	Seed yield Kg/ha
Imazethapyr	70	PPI	90	77	0	0	980	1.73	1298
Imazethapyr	80	PPI	94	82	0	0	967	1.26	1168
Imazethapyr	70	PRE	87	71	0	0	919	5.7	2569
Imazethapyr	80	PRE	88	75	0	0	922	5.46	2340
Imazethapyr	70	POE	0	56	23	11	603	3	2551
Imazethapyr	80	POE	0	61	29	18	657	2.78	2180
Imazethapyr + Imazamox (RM)	70	PRE	55	41	0	0	798	5	2687
Imazethapyr + imazamox (RM)	80	PRE	74	45	0	0	800	4.66	2366
Imazethapyr + imazamox (RM)	70	POE	0	53	22	14	492	5.16	2573
Imazethapyr + imazamox (RM)	80	POE	0	57	26	18	500	4.83	2488
Pendimethalin	1000	PRE	88	56	0	0	946	7.13	2636
Imazethapyr + pendimethalin(RM)	1000	PRE	92	71	0	0	983	6.3	2499
Weedy check	-	-	0	0	0	0	519	7.8	2575
Two hoeings	-	20 & 40 DAS	0	88	0	0	971	8.93	2589
Weed free	-	-	100	100	0	0	1161	7.01	2664
SEm±							97	0.64	141
LSD (P= 0.05)							285	1.88	411

DAS= Days after sowing

tard crop cultivar RH 749 was planted on 21 October 2014 after harvest of green gram with shallow disking and planking in the same layout as in *kharif* 2014.

RESULTS

Weed flora of the field was dominated by *Trianthema portulacastrum* constituting 82% of total weeds intensity followed by C*yperus spp.* and effectively managed by all PPI and PRE herbicides treatments (Table 1). POE application of imazethapyr and imazethapyr + imazamox (RM) at 70 & 80 g/ha proved less effective in minimizing weed density, both of these herbicides caused suppression in *T. portulacastrum* growth but it recovered after few days. Imazethapyr as POE and its combination with imazamox at 70 & 80 g/ha caused slightly toxicity to green gram and toxicity was higher at 30 DAS, which mitigated within 15 DAT but with significant reduction in plant height and seed yield. Punia *et al*., (2011) reported similar findings in clusterbean. Although, PRE use of pendimethalin 30 % EC+ imazethapyr 2% (RM) at 1000 g/ha was very effective with 92 to 71% visual controls of weeds at 15 and 30 DAS without any crop suppression. At 15 DAS, visual weed control was more than 90% and 85% in all PPI and PRE treatments of imazethapyr but in POE application it was only 50-61% at 30 DAS. Visual weed control decreased in all PRE as well as PPI treatments due to second flush of weeds appeared due to rains. Maximum seed yield (1161 kg/ha) was obtained in weed free treatment which was significantly at par with all PPI and PRE treatments, but higher than all POE treatments. PPI treatments of imazethapyr showed visual toxicity (90-95%) on mustard but less in PRE and POE applications of imazethapyr & imazethapyr + imazamox. Mustard crop in these treatments showed significant reduction in germination and seed yield as compared to two hoeing, weedy check and weed free. Seed yield in imazethapyr at 70 and 80 g/ha as PPI was also significantly reducedas compared to other treatments (Table-1). PRE use of pendimethalin and its ready mix combination with imazethapyr at 1000 g/ha did not show any residual carry over effect on mustard crop on germination and seed yield in these treatments.

CONCLUSION

POE use of imazethapyr and its combination with imazamox at 70 & 80 g/ha caused slight toxicity to green gram in terms of yellowing; bud necrosis and crinkling of leaves which mitigated within 15 days after application caused significant reduction in seed yield. Application of imazethapyr as PPI at 70 and 80 g/ha reduced germination and seed yield of mustard. PRE use of pendimethalin 30 % EC+ imazethapyr 2% (RM) at 1000 g/ha was very effective without any crop suppression and no residual effect on succeeding mustard crop.

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Phenology and yield of sweet corn (*Zea mays* var. *saccharata*) cultivars as influenced by planting time under irrigated subtropic foothills of J&K

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Planting date and cultivar selection are the major factors affecting sweet corn production in addition to soil fertility, temperature regimes and irrigation .For optimization of yield, planting at the appropriate time is very critical. Photoperiod and temperature influence the time from sowing to tassel initiation with appreciable genetic differences in relative sensitivity to these factors. Earlier planting of corn is preferable because of utilization of the entire growing season, achieving physiological maturity and proper drying; thereby increasing profit through reduced drying costs while delays in sowing date reduced individual kernel weight .High yielding varieties are of primary importance for potential yield. Yield can be increased to a greater extent provided high yielding varieties are identified and planted at proper time .As no information available on sweet corn in J&K state, therefore, it becomes imperative with the objective to find out suitable cultivar and planting date of sweet corn under sub-tropical Jammu conditions.

METHODOLOGY

A field trail was conducted during spring 2013 at Research Farm of Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, on sandy clay loam soil (62.52% sand,11.73% silt and 25.75% clay), slightly alkaline in reaction (pH 7.31), low in organic carbon (0.37%) and available nitrogen (245.78 kg/ha) but medium in available phosphorus (13.26 kg/ha) and potassium (144.26 kg/ha).The treatments consisted of three sweet corn cultivars 'Misthi' , 'Sugar-75' and 'Goldstar' in main plots and six planting times *viz.,* 29th March, 15thApril, 30thApril, 15thMay, 30thMay and 19thJune in sub-plot .The treatment were replicated thrice in split plot design in gross plot size 4.8 m × 3.0 m. Fertilizer dose of 120 kg N, 60 kg P_2O_5 and 40 kg K_20/ha was applied to all the plots. Half of the total dose of recommended nitrogen, whole phosphorus and potash were applied at the time of sowing and the remaining half dose of nitrogen was applied in two equal splits at knee high and pre-tasseling stages The crop was sown with liner by kera method by maintaining row to row distance of 60 cm as per treatment scheduled. All recommended agronomic practices were followed throughout the crop period.

RESULTS

Cultivar 'Misthi' took significantly maximum days followed by 'Sugar -75' to attain 50 % tasseling which were statistically at par but significantly higher than cultivar 'Gold star' which took minimum days to attain this stage. This variation in the number of days taken to tasseling with in cultivars was might be proabably due to genetic variation of the different sweet corn cultivars. Planting times 29th March sown crop took maximum days to acquire 50 % tasseling and silking which was statistically at par in days taken by the crop with April 15th and April 30th sown crops whereas June 19th sown crop recorded significantly less days from all the sowing dates to manage these stages might be due to the reason that the highest rainfall of 309.4 mm (30.45 per cent of the total rainfall) was received during the silking stage of the sixth planting date, which have resulted in the shedding of pollens before appearance of silks and thus effects the fertilization process (Nielsen *et al*., 2002).Cultivar 'Gold star' took minimum days to reach harvest maturity stage. This might be due to the reason that different crop cultivars take their normal time to develop different vegetative and reproductive structure and attain maturity. March 29th sown crop was statistically at par with April 15th and April 30th sown crops in days taken to maturity. Cultivar 'Misthi' recorded not only maximum but statistically higher fresh cob yield as compared to 'Sugar -75'and 'Gold star' cultivars .These yield differences were attributed to differences in the growth cycles of the sweet corn cultivars. Highest fresh cob yield of cultivar 'Misthi' was probably due to cumulative effect of superior attributing characters .Genetically different varieties significantly differed in their yield performance in corn (Nagy, 2009). Among the planting dates, the maximum fresh cob yield was obtained with April 15th planting which was statistically at par with March 29th and April 30th planting dates. All these three planting dates produced significantly higher fresh cob yield over all the other planting dates The highest fresh cob yield in the

Table 1. Effect of different cultivars and planting time on phenology of sweet corn

Treatment	Days to 50 % tasseling	Days to 50% silking	Days to harvest maturity	Green cob Yield (t/ha)
Cultivars				
Misthi	54.83	60.71	94.24	9.16
Sugar -75	54.47	60.32	93.10	7.07
Gold star	53.74	60.21	91.55	6.89
S.Em. (±)	0.13	0.15	0.16	0.28
CD(P=0.05)	0.54	-	0.63	1.10
Planting times				
March 29th	56.31	61.93	94.67	9.17
April 15th	55.62	61.79	94.57	10.89
April 30th	55.45	61.50	94.26	9.55
May 15th	53.35	59.62	92.47	7.01
May 30th	53.15	59.60	92.41	6.50
June 19th	52.22	58.00	89.40	3.12
S.Em. (±)	0.30	0.23	0.27	0.65
CD(P=0.05)	0.87	0.68	0.78	1.87

early sowings times was explained because of the fact that the 15th April sown crop got sufficient time for proper growth under suitable climatic conditions and also early planting in spring causes encountering of grain formation and filling stages with long days and maximum energy needed to photosynthesis results in higher yields in comparison to late sowing i.e. June 19th (Srinavasulu *et al.,* 2008).

CONCLUSION

Based on the one year study it can safely be concluded that among the three sweet corn cultivars and six planting dates, sweet corn cultivar Mishti when planted on 15th, April proved to be the more viable combination under irrigated sub-tropics of Shiwalik foothills of J&K.

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Effect of different weed control practices on grain amaranth

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Amaranth is one of the important underutilized crops in semi-arid tropics of Asia and Africa and often referred to as pseudo-cereal (Prasad *et* al. 2013). In India, it is cultivated in the hilly regions as well as in the plains, covering the entire Himalayas region, southern India and in some parts of a Gujarat, Maharashtra, Orissa and Eastern Uttar Pradesh. This crop grows slowly in the first few weeks after germination and hence is very susceptible to weed competition (Kudask *et al.*, 2012). Weed infestation reduces the seed yield of grain amaranth drastically. Suitable economic weed management practice for efficiently controlling weeds and higher grain yield of amaranth are essential for proper crop cultivation. In view of the above facts, an experiment was conducted to test the effect of various weed control practices on weeds and grain yield of amaranth.

METHODOLOGY

A field experiment was conducted during *kharif* season of 2011and 2012 at Ranichauri, Uttara Khand. The soil of the experimental field was silty clay loam in texture, acidic in reaction (pH 5.6) and medium in available nitrogen, phosphorus and potassium, respectively. The experiment comprised of 8 treatments viz. weedy check, weed free, fenoxaprop ethyl 50g/ha post emergent (3WAS), clodinofop ethyl 50g/ha post emergent (3WAS), oxyfluorfen 50g/ha pre-emergent, oxyfluorfen 50g/ha pre-emergent + one hand weeding (5WAS), oxadiargyl 50 g/ha post –emergent (3WAS), Two manual weeding 3 and 5 weeks after sowing (WAS) and one manual weeding (30DAS) was laid out in randomized block design with three replications. Grain amaranth variety PRA-3 was sown in first week of June in both the years. The crop was fertilized with 60 kg Nitrogen, 40 kg Phosphorus and 30 kg potash/ha. Weed count and dry matter was recorded at 60 DAS after sowing from two randomly selected spots form each plot with the help of quadrate and expressed in number/m2 and g/m2, respectively. Data pertaining to weed count and dry weight were subjected to square root transformation (“x+0.50). Yields were harvested from net plot. Treatment wise economics was computed based upon prevalent market price.

RESULTS

The prominent weed species were viz. *Echinochloa colona*, *Eleusine indica*, *Commelina benghalensis*, *Oxalis latifolia*, *Oxalis corniculata* and *Cyperus rotundus* etc. Weed control treatments caused significant reduction in the total weed count (number /m^2) and weed dry weight (g/m^2) over weedy check at 60 DAS. Two manual weeding at 3 weeks and 5 weeks after sowing recorded significantly lower weed dry weight and total weed density at 60 DAS over other weed control treatments. Use of pre-emergence or post emergence herbicides did not reduce weed density/m2 but weed dry

Table 1. Effect of different weed management practice on plant height, yield contributing characters, weed density, weed dry weight, weed control efficiency, seed yield and economics in grain amaranth (pooled data of two years).

Treatments	Plant height (cm)	No. of fingers/ inflorescence	Inflorescence length (cm)	Weed density (No./m^2)	Weed dry weight (g/m^2)	Weed control efficiency (%)	Seed yield (Kg/ha)	Net Returns (Rs/ha)	B:C ratio
Weedy check	116	18	26	230.67	81.00	0	514	1034	1.07
Weed free	192	45	57	0.00	0.00	100	1117	5118	1.18
Phenoxyprop ethyl 50g/ha post emergent (3WAS)	134	21	35	159.00	42.33	48	608	2430	1.15
Clodinofop ethyl 50g/ha post- emergence (3WAS)	126	22	25	177.33	48.00	41	592	1993	1.13
Oxyfluorfen 50g/ha pre-emergence	124	20	21	144.00	40.33	50	572	1859	1.12
Oxyfluorfen 50g/ha preemergence + one hand weeding (5WAS)	180	36	43	88.33	23.33	71	950	9192	1.48
Oxadiargyl 50 g/ha post –emergence (3WAS)	128	25	27	142.67	38.33	53	542	782	1.05
Two manual weeding at 3 and 5 WAS	180	43	52	30.67	11.00	86	1081	11035	1.52
One manual weeding(30DAS)	181	34	44	108.33	28.00	65	806	5784	1.31
CD (P=0.05)	22.3	6.9	5.6	0.48	0.43	-	103	-	-

weight was significantly lower in all weed control treatments as compare to weedy check. Amongst the treatments highest weed control efficiency (86.42) was recorded with two manual weeding at 3 and 5 weeksafter sowing followed by oxyfluorfen 50 g/ha pre-emergent + one hand weeding (5WAS) and one hand weeding. Plant height (cm), yield attributes *viz.* number of fingers per inflorescence, inflorescence length (cm) and seed yield of grain amaranth were significantly affected by different weed control treatments. Weed free treatment recorded higher plant height which was significantly higher except two hand weeding at 3 and5 WAS, one manual weeding at 30 DAS and oxyfluorfen 50g/ha pre-emergent + one hand weeding (5WAS). The number of finger per inflorescence and inflorescence length was higher in weed free treatment but at par with two hand weeding at 3 and 5 WAS. The seed yield (1117 kg/ha) was recorded in weed free treatment which was significantly higher in all treatments except two manual weedings at 3 and 5 WAS and oxyfluorfen 50 g/ha pre-emergent + one hand weeding (5WAS). Lowest seed yield 514 kg/ha was recorded under unweeded control. It was 54 % lower of weed free and 52% lower of two manual weeding at 3 and 5 WAS. Highest net return (Rs 11035 /ha) and B:C ratio (1.52) was recorded when two manual weeding at 3 and 5 weeks after sowing were used. It was much closer to net return and B:C ratio recorded in oxyfluorfen 50g/ha pre-emergent + one hand weeding (5WAS) and one hand weeding.

CONCLUSION

On the basis of above study it may be concluded that two manual weeding at 3 and 5 weeks after sowing was found more efficient and economic practice in controlling weeds and producing higher seed yield ofgrain amaranth in hilly areas. In case of labour scarcity oxyfluorfen 50g/ha pre-emergent + one hand weeding(5WAS) or one hand weeding may be used as second alternative of weed control in grain amaranth.

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Productivity of summer *moong* cultivars under various sowing dates and weed management

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The *rabi*/summer moong (*Vigna radiata*) is cultivated in an area of6.0 lakh hectares with aproduction of 2.9 lakh tonnes and productivity of477 kg/ha. The productivity is low due to improper time of sowing, heavy weed infestation and use local varieties. Early sowing encourages aphid incidence due prevalence of low temperature. Late sown crop is subjected to high temperature injury and damage by hailstorm. Summer moongis cultivated as an irrigated crop and the crop is infested by a number of weeds. The local varieties are low yielding and subjected to losses by shattering at maturity. Hence the present experiment was conducted to find out optimum time of sowing, appropriate weed management strategy and suitable cultivar for summer moong in coastal Odisha.

METHODOLOGY

The experiment was conducted during summer 2016 at Agronomy Main Research Farm, Orissa University of Agriculture and Technology, Bhubaneswar with latitude of $21^0 15'$ N, longitude of $85^0 52'$E and an altitude of 25.9 m above the MSL. It is situated at about 64 km away from the Bay of Bengal. Bhubaneswar is located in East and South Eastern Coastal Plain (Agro climatic Zone no. 63 under National Agricultural Research Project classification). The climate is hot moist sub humid. The length of growing season varies from 180 to 210 days. The average annual rainfall is 1571.6 mm. The moisture deficit index (MDI) value is 0 to (-20). The soil of the experimental site was *Arenic Haplustalfs* (alfisol). The treatments comprised three factors viz. date of sowing with three levels *i.e.* D_1-16 January, D_2-31 January and D_3-15 February, weed management practices with four levels i.e. W_1 -Pendimethalin 1 kg/ha, W_2 - Quizalofop ethyl 50 g/ha, W_3- Hoeing and weeding and W_4 - Weedy check and two varieties viz V_1 -Summer *Moong* Ludhiana 668 and V_2 -Nayagarh Local. The crop was grown with spacing of 30 cm x 10 cm and fertilizer dose of 20-40-20 kg N-P_2O_5-K_2O/ha, respectively. The treatments were tried in split split design with three replications.

RESULTS

Among various dates of sowing, 31st January proved the best with grain yield of 568 kg /ha (Table 1). This was due to congenial weather conditions. The crop sown on the preceding date was subjected to more aphid incidence. The crop sown on the succeeding date was subjected to heat stress. The preceding and the succeeding dates recorded 37 and 23% less grain yield compared to the optimum time of sowing. Takale *et al*.(2011) found 20 February as thebest time ofsowingat Navsari, Gujurat. Both 5 February and 7 march recorded less pods/plant, seeds/pod and grain yield as compared to 20 February. Among weed management practices, Weed management by herbicides or hoeing and weeding recorded higher pods/plant, seeds/pod and grain yield than the weedy check. Pre-emergence application of pendimethalin@ 1.0 kg/

Table 1. Yield attributes and grain yield of summer *moong* cultivars under various date of sowing and weed management

Treatment	Pods/ plant	Seeds/ pod	Grain yield (kg/ha)
Date of sowing			
16 January	11.0	10.9	359
31 January	11.7	9.5	568
15 February	10.3	9.7	440
SEm±	0.7	0.2	25
CD (P=0.05)	NS	0.6	99
Weed management			
Pendimethalin 1kg/ha as pre-emergence	11.9	10.3	582
Quizalofop ethyl 50g/ha aspost emergence at15-20 DAS	10.9	10.3	498
Hoeing & weeding at21 DAS	10.9	10.1	491
Weedy check	10.3	9.5	252
SEm±	0.4	0.2	24
CD (P=0.05)	1.1	0.4	72
Variety			
Summer *Moong* Ludhiana 668	10.4	10.0	513
Nayagarh Local	11.6	10.1	399
SEm±	0.3	0.1	15
CD (P=0.05)	0.8	NS	44

haproved the best with grain yield of 582 kg/ha. Quizalofop ethyl 50 g/ha and hoeing and weeding at 21 days after sowing proved significantly inferior. Quizalofop ethyl 50 g/ha only controlled the monocot weeds. The experimental site had the problem of dicot weeds. Performance of hoeing and weeding was not as good as quizalofop ethyl 50g/ha due occurrence ofnew flushes of weeds. Patil *et al*. (2014) reported both pendimethalin 1 kg/ha aspre-emergence application and quizalofop ethyl 50 g/ha as post emergence spray recorded significantly higher pods/plant, seeds/pod and grain yield than weedy check. The variety 'Summer Moong Ludhiana' recorded higher grain yield as compared to 'Nayagarh Local'.

CONCLUSION

The productivity of summer moong in coastal Odisha can be increased appreciably by sowing on 31^{st}January, using pendimethalin 1.0 kg/ha forweed management and growing the improved variety 'SML 668'.

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Effcet of bioregulators on productivity of wheat (*Triticum aestivum*) under abiotic stress

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Wheat is one of the most important cereal crop of the world on account of its wide adaptability to different agro-climatic and soil conditions. Variation in the seeding date and temperature interact to influence growth, development and yield of wheat. Plant productivity is severely affected by abiotic stress factors *viz*., salinity, drought, high and low temperature, and heavy metals.Out of the various abiotic stresses, high temperature is the second most important stress. For this purpose, a thorough understanding of physiological responses of plants to high temperature, and possible strategies for improving crop thermo tolerance is imperative. Plant growth regulators possibly acts as modulators of plant responses and have potential to increase crop production through redirecting the metabolism and partitioning of assimilates. Application of plant growth regulators is known to play an important role in plant response to stress. The exogenous application of bio-regulators *viz;* salicylic acid, putrescine and thiourea may also have beneficial role in mitigating the effect of water and heat stress in wheat. Considering above facts and lack of research on water stress in wheat by using bio regulators under field conditions, the present studies was planned.

METHODOLOGY

A field experiment was conducted at Instructional Farm, Rajasthan College of Agriculture, Udaipur (Rajasthan) during *Rabi* season of 2013-14 and 2014-15. The geographical co-ordinates of the station are 24^0 34'N latitude, 73^0 42'E longitude and altitude of 582.2 m above mean sea level. Soil of experimental field was clay loam in texture with pH (8.0-8.1), low nitrogen (281.4-295.3 kg ha^{-1}), medium phosphorus (18.4-19.5 kg ha^{-1}) and high potassium (361.8-369.2 kg ha^{-1}) and having good water holding capacity. The experiment consisted of 24 treatment combinations comprising six water stress (normal sowing with no stress, stress at tillering and tillering + 50 % heading and late sowing with no stress, stress at tillering and tillering + 50 % heading) and four levels of foliar spray of bio-regulators [water spray, salicylic acid (200 ppm), putrescine (10 ppm) and thiourea (1000 ppm)]. Wheat variety Raj-4037 was used as test crop. The crop was sown on 20^{th} November and 20^{th} December for normal and late sowing, respectively. Combinations of these treatments were evaluated under split plot design, allocating water stress in main plots and foliar spray of bio-regulators treatment in sub plots with four replications.

RESULTS

The results revealed that water stress at tillering + 50 %

Table 1. Effect of water stress and foliar spray of bio-regulators on yield attributes, yield and harvest index of wheat

	Effective tillers (m^{-1} row)	Number of grains ear^{-1}	Ear length (cm)	1000-grain weight (g)	Grain Yield (kg ha^{-1})	Straw Yield (kg ha^{-1})	Biological Yield (kg ha^{-1})	Harvest Index (%)	Net returns (ha^{-1})	B: C ratio
Date of sowing and water stress										
Normal - no stress (S_1)	148.7	44.3	9.3	39.3	5691	8815	14506	39.2	79520	2.03
Normal - at tillering (S_2)	139.1	41.2	9.2	38.4	5566	8722	14288	38.4	77655	2.00
Normal -at tillering +50% heading (S_3)	131.6	39.2	8.5	36.1	4817	8008	12825	37.2	63648	1.67
Late - no stress (S_4)	130.2	40.8	8.5	33.5	4547	7471	12017	37.9	56701	1.44
Late - at tillering (S_5)	118.6	39.1	7.9	31.6	4193	6813	11007	37.7	49555	1.28
Late - at tillering +50 % heading (S_6)	114.6	35.2	7.0	29.0	3849	6065	9914	37.5	42332	1.11
SEm$\underline{+}$	2.4	0.4	0.1	0.4	63	113	123	0.50	1135	0.03
CD (P=0.05)	6.9	1.1	0.4	1.1	182	325	356	NS	3277	0.08
Foliar spray of bio-regulators										
Water spray (F_0)	124.1	38.5	7.4	33.5	4603	7329	11932	38.3	58823	1.56
Salicylic acid 200 ppm (F_1)	132.2	40.6	8.9	35.5	4803	7785	12588	37.8	63028	1.65
Putrescine 10 ppm (F_2)	125.0	38.8	7.8	33.5	4675	7488	12163	37.9	57609	1.42
Thiourea 1000 ppm (F_3)	140.5	42.0	9.5	36.2	5028	7993	13022	37.9	66813	1.73
SEm±	1.1	0.2	0.1	0.1	29	63	67	0.28	506	0.01
CD (P=0.05)	3.0	0.5	0.2	0.3	82	176	188	NS	1420	0.04

heading recorded significantly lower yield attributes *viz.*, number of effective tillers at harvest, number of grains ear^{-1} and 1000-grain weight with water stress at tillering + 50 % heading under normal and late sown crop. Grain yield, straw yield and biological yield were significantly decreased with water stress at tillering + 50 % heading stage over no water stress under normal and late sown conditions (Table 1). The magnitude of reduction in grain yield with water stress at tillering + 50 % heading stage under normal and late sown crop was 15.3 and 15.4 per cent, respectively over no water stress. Further, significant reduction in grain yield was recorded under late sown crop with no water stress as compared to normal sown crop by 25.1 per cent. Normal sown crop with water stress at tillering + 50 % heading stage recorded significantly lower net returns and B: C ratio by ₹15872 ha^{-1} and 0.36, respectively over no water stress (₹79520 ha^{-1} and 2.03). The lowest net returns and B: C ratio of (₹42332 ha^{-1}) and 1.11 was recorded under late sown crop with water stress at tillering + 50 % heading stage. Mukharjee (2012) and Amrawat *et al.* (2014) also reported that normal sown crop gave higher yield attributes and yield over late sown wheat.

Grain, straw and biological yield were also significantly increased with foliar spray of salicylic acid (200 ppm) and thiourea (1000 ppm) over water spray. Foliar spray of salicylic acid (200 ppm) and thiourea (1000 ppm) gave significantly higher grain yield over water spray by 4.3 and 9.2 per cent respectively (Table 1). Further, foliar spray of salicylic acid (200 ppm) and thiourea (1000 ppm) significantly increased proline content, relative water content, total chlorophyll content over water spray. These results are in accordance with the findings of Sahu and Singh (1995) who also observed significant increase in yield attributes of wheat due to foliar spray of TU and Sanaa *et al*. (2006) who reported significant increase in 1000-grain weight, grain weight $plant^{-1}$ due to foliar spray of SA. The highest net returns and B:C ratio was obtained with foliar spray of thiourea (₹66813 ha^{-1} and 1.73) followed by of salicylic acid (₹63028 ha^{-1} and 1.65).

CONCLUSION

To minimize the effect of water stress at tillering + 50% heading stage, crop should be sprayed with thiourea (1000 ppm) at 40 and 70 DAS under normal as well as late sown conditions.

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Mitigating abiotic stresses in pulses under rice fallows in India

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In India, a considerable area of rice (11.7 m ha out of 43.95 m ha) remains fallow after rice harvest. A number of abiotic factors related to soil and water lead to low pulse production in rice fallows during past several years. Low moisture content in the soil after rice harvest followed by fast decline in water table with advancement of winter crop season results in mid-and terminal-drought at flowering and pod filling stages are major limitations in growing pulses after rice. During the post-rainy season (winter season) due to lack of irrigation facilities in these regions winter crops mainly depend on the effective utilization of carry-over residual soil moisture. The inherited hostile soil environment creates potential threat to seed germination, seedling emergence and crop establishment due to disruption of soil structure, poor aeration and mechanical impedance of the seed zone. Soil microbial activity, nutrient availability, root growth and water and nutrients uptake also get adversely affected. Short duration low water requiring pulses combine with suitable crop management techniques for utilization of residual soil moisture offers excellent opportunity to utilize carry-over residual soil moisture in rice fallows (Pratibha *et al*. 1996). Rice crop residue can be effectively utilized for reducing soil evaporation, increasing soil water and minimising weed infestation. Thus, it facilitates more retention of soil moisture and helps in control of temperature fluctuations, improves physical, chemical and biological properties of soil, as it adds nutrients to the soil and ultimately enhances the growth and yield of crops. Further, it boosts the yield by 50-60 %over no-mulching under rainfed situations (Kumar *et al*., 2006). Therefore, a set of studies was formulated to see the effect of rice and pulses varieties and rice residue management on pulses productivity under rice fallows.

METHODOLOGY

The set of field experiments were carried out at ICAR-Indian Institute of Pulses Research, Kanpur during *kharif* 2011 to 2016 to evaluate the effect of different growth habit varieties of rice and pulses (chickpea and lentil), rice residue management and soil moisture conservation practices for enhancing pulses productivity under rice fallows. The field experiments were planned with treatments like two rice cultivars (local and improved early maturing cultivar 'Pant Dhan-12'); two chickpea cultivars i.e., 'Jaki 92-18' (early high biomass) and 'DCP 92-3' (medium high biomass); two lentil cultivars ('DPL 62' and 'IPL 81'); three conservation tillage practices i.e., ZT, ZT+mulch (rice straw used as a mulch to prevent soil moisture loss) and ZT+ rice stubbles (20 cm of rice residues were left as surface cover); paired row planting; foliar nutrition; rice ratoons management and life saving irrigation. Recommended fertilizers (120:60:40 kg N, P_2O_5 and K_2O/ha) were applied to rice as per prescribed method. Other cultural practices were kept similar in both varieties. 'Pant Dhan 12' harvested between 15-20 October. Therefore, chickpea/lentil after Pant Dhan-12 was sown during 20-22 October. However, local rice varieties harvested during 8-12 November, therefore, chickpea/lentil after local rice was sown during 10-15 November. In case of no-mulch and rice straw mulch, rice crop was harvested at 5-6 cm above ground as commonly practiced by farmers. However, in stubble treatment, rice crop was harvested from 20 cm above ground so that 20 cm rice stubbles remain in field. Rice straw harvested from mulch plot was used for mulching after sowing of chickpea. Foliar nutrition of 2% urea and micro-nutrients were applied at flowering and pod development stages. Similarly, life saving irrigation was applied at critical level of soil moisture stress which coincides with flowering or pod development stage. Chickpea/lentil was sown by manual no till-drill developed by Indian Institute of Pulses Research for rice fallow conditions of northern and eastern India.

RESULTS

Soil moisture content (SMC) was recorded from different soil depth i.e. 10, 20, 30, 40, 60 and 100 cm with soil moisture probe at regular interval of 15 days. SMC at different soil depth was influenced significantly by improved rice cultivar and soil moisture conservation practices. During all crop growth stages of chickpea/lentil, SMC was higher after early rice variety 'Pant Dhan 12'. At 10 cm soil depth, significantly higher SMC was recorded in chickpea grown after 'Pant Dhan 12' by 10.2, 26.8, 21.9, 25.2, 11.1 and 16.7 % at 15, 30, 45, 60, 90 and 105 DAS, respectively over local rice cultivar. Similar trend were also recorded up to 40 cm soil depth. In case of conservation practices like rice residue mulch, 35.3, 10.9, 11.6, 23.1 and 36.3 % higher SMC was recorded at 15, 45, 60, 90 and 105 DAS, respectively over the no-mulch practice at 10 cm soil depth; however mulch and stubble gave statistically at par soil moisture results. Similar trend was also recorded in deeper soil layer. Improvement in soil physico-chemical and biological properties were recorded in mulch and stubbles over no-mulch. These resulted in maximum yield of chickpea/lentil grown after 'Pant Dhan 12'. Similarly, higher chickpea/lentil yield was recorded in mulch and stubble over no-mulch. The early high biomass chickpea variety 'JAKI 92-18' performance was better than medium high biomass variety 'DCP 92-3' in both rice varieties. Similar was true for lentil variety 'DPL 62'. Paired row planting of chickpea under conservation tillage and foliar nutrition of 2% urea and micronutrients solution at flowering and pod development stages have enhanced seed yield of chickpea by 10-15 per cent. Quizalofop-ethyl 100 g/ha as post-emergence herbicide found effective in containing rice ratoons.

CONCLUSION

The above results indicated that a successful pulse crops can be grown under rainfed in rice fallows with suitable interventions like use of early rice and pulses varieties, paired row planting, sowing of pulses under conservation tillage (zero tillage with mulch or stubble retention) for *in-situ* soil moisture conservation to mitigate terminal drought, ratoons management and foliar nutrition with 2% urea and micronutrients.

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Evaluation of post-emergence herbicides in clusterbean

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Clusterbean is mainly cultivated in marginal and rain fed areas where inadequate weed management is a major constraint in harnessing its production potential. Being a rainy season crop, it suffers badly due to severe competition by mixed weed flora. Yield reduction due to weed infestation is of the tune of 53.7 per cent (Saxena *et al.,* 2004). Hand weeding is a traditional and effective method of weed control, but untimely rains, unavailability of labour at peak time and increasing labour cost are the main limitations of manual weeding. Under such situations, the only alternative that needs to be explored is the use of suitable herbicide which may be effective and economically viable. Application of fluchloralin and pendimethalin at 0.75-1.0 kg/ha as pre emergence were effective against weeds in cluster bean (Dhaker *et al.,* 2009) but inadequate moisture and westerly winds blowing at time of sowing in this region left little moister for soil applied herbicide to act effectively and results in to poor efficiency of these herbicides in most of the time in arid zone soils.

METHODOLOGY

A field experiment was carried out for two consecutive years during *Kharif* seasons of 2012 and 2013 at Swami Keshwanand Rajasthan Agricultural University Farm, Bikaner There are seven treatments consisting of imazethapyr 40g/ha, quizalofop ethyl 37.5 g/ha, fenoxaprop-p-ethyl 50g/ha, imazethapyr + imazamox 40g/ha, pendimethalin 0.75kg/ha as pre- emergence (PE), hand weeding twice at 20 and 40 DAS and weedy check were evaluated in randomized block design (RBD) with three replications.

RESULTS

Imazethapyr + imazamox (factory mix) 40 g/ha, imazethapyr alone at 40 g/ha applied at 3-4 leaf stage (around 20 DAS) and pendimethalin at 0.75 kg/ha as pre-emergence

Table 1: Effect of weed control measures on weed density in clusterbean (pooled data of two years)

Treatment	Weed density (No./m^2)			Weed Dry weight (g/m^2)		
	Broad leaf	Grassy	Total	Broad leaf	Grassy	Total
Imazethapyr 40g/ha	3.75 (13.11)	5.95 (34.4)	6.97 (47.55)	15.1	14.4	29.5
Quizalofop ethyl 37.5 g/ha	6.95 (47.4)	2.02 (3.1)	7.17 (50.5)	98.1	1.3	99.4
Fenoxaprop-p-ethyl 50g/ha	7.13 (49.9)	2.07 (3.3)	7.36 (53.2)	88.3	1.83	90.1
Imazethapyr +Imazamox 40g/ha	3.11 (8.7)	3.59 (11.9)	4.65 (20.6)	9.9	4.35	14.2
Pendimethalin 0.75 kg/ha PE	4.35 (17.9)	2.84 (7.1)	5.10 (25.0)	12.81	3.83	16.6
Hand Weeding at 25 and 40 DAS	2.55 (5.55)	2.19(3.8)	3.21 (9.3)	3.25	1.53	4.8
Weedy check	9.67 (92.5)	6.50 (41.2)	11.61 (133.7)	102.4	16.83	119.2
SEm±	0.24	0.16	0.33	7.2	0.78	8.2
RBD at (0.05)	0.71	0.44	0.97	20.2	2.46	23.8

*Original values are in parenthesis, PE- Pre emergence, DAS- Day after sowing

significantly reduced the density and dry weight of broad leaf weeds in cluster bean as compared to weedy check and other herbicidal treatments during both the years (Table 1). Further, imazethapyr + imazamox (factory mix) at 40 g/ha and imazethapyr alone at 40 g/ha applied at 3-4 leaf stage (around 20DAS) significantly lower down the density and dry weight of broad leaf weeds as compared to pendimethalin at 0.75 kg/ha. The pooled data of two years revealed that imazethapyr + imazamox at 40 g/ha recorded significantly lower density and dry weight of total weeds as compare to all other herbicidal treatments except pendimethalin at 0.75 kg /ha PE. Quizalofop ethyl at 37.5 g/ha and fenoxaprop-p-ethyl 50g/ha at 3-4 leaf stage (around 20 DAS) failed to control density and dry weight of broad leaf weeds. As far as grassy weeds were concerned, imazethapyr + imazamox 40 g/ha , quizalofop-ethyl 37.5 g/ha and fenoxaprop-ethyl 50 g/ha significantly controlled the grassy weeds as compared to weedy check, imazethapyr alone at 40 g/ha but statically at par with pendimethalin at 0.75kg/ha PE during both the years and pooled basis.

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Effect of weed management on growth characteristics of fenugreek (*Trigonella foenum-graecum* L.)

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Fenugreek is an important seed spice crop of arid and semi-arid region of India. Weeds reduce grain yield of this crop up to an extent of 86 per cent (Tripathi and Singh, 2008) and these offered maximum competition up to 25-30 days of sowing (Tripathi and Singh, 1994). Therefore, fenugreek field should be weed free at initial stage of crop establishment by employing suitable weed control methods so that crop get weed free environment to express different growth characteristics. At present, hand weeding is a common practice used by majority of farmers in controlling weeds in this crop. High wages and non-availability of labour for weeding at right time sometimes compel the farmers for opting alternatively cheaper and easier method of weed control. Therefore, one cannot completely rely on hand weeding. Hence, it is the time to use some herbicides in combination with manual weeding to harness the yield potential of this crop.

METHODOLOGY

A field experiment was conducted during *rabi* 2011-2012 on clay loam soil of Instructional farm, Rajasthan College of

Table 1. Effect of weed management on growth characteristics of fenugreek

Treatment	Plant dry matter (g/plant)	Branches/ plant	Plant height (cm)	Weed control efficiency (%)
Pendimethalin 1.0 kg/ha	23.89	6.41	65.90	54.74
Pendimethalin 0.75 kg/ha	23.08	6.02	63.23	52.78
Pendimethalin 0.75 kg/ha + hand weeding 40 DAS	26.43	7.36	70.99	63.65
Metribuzin 0.20 kg/ha	22.73	5.79	61.58	52.70
Metribuzin 0.15 kg/ha	21.86	5.53	59.93	51.13
Metribuzin 0.15 kg/ha + hand weeding 40 DAS	25.12	6.90	66.94	61.71
Oxyfluorfen 0.15 kg/ha	21.32	5.70	52.10	51.68
Oxyfluorfen 0.10 kg/ha	20.24	5.23	51.20	49.38
Oxyfluorfen 0.10 kg/ha+ hand weeding 40 DAS	23.79	6.98	58.95	60.57
One hand weeding 20 DAS	20.62	5.36	53.32	52.92
Two hand weedings 20 and 40 DAS	25.43	6.98	68.35	63.02
Weedy check	17.83	4.92	48.26	-
CD (P=0.05)	1.97	0.96	7.28	-

Agriculture, Udaipur. The soil of experimental field was clay loam in texture and slightly alkaline in reaction and calcareous in nature, medium in available nitrogen, phosphorus and high in potassium status. The experiment involved 12 treatment combinations consisted of pendimethalin 1.0 kg/haas pre-emergence, pendimethalin 0.75 kg/ha as pre-emergence, pendimethalin 0.75 kg/ha as pre-emergence + hand weeding 40 DAS, metribuzin 0.20 kg/ha as pre-emergence, metribuzin 0.15 kg/ha as pre-emergence, metribuzin 0.15 kg/haas pre-emergence + hand weeding 40 DAS, oxyfluorfen 0.15 kg/ha as pre-emergence, oxyfluorfen 0.10 kg/ha as pre-emergence, oxyfluorfen 0.10 kg/ha as pre-emergence + hand weeding 40 DAS, one hand weeding 20 DAS, two hand weeding 20 and 40 DAS and weedy check. These herbicides were sprayed with knapsack sprayer fitted with flat fan nozzle using 750 litre of water per hectare. The variety of the fenugreek, R Mt -1 was sown on 6 th of November, 2011 with seed rate 25 kg/ ha at a spacing of 30 cm × 10 cm using package and practices of Sub-Humid Southern Plain and Aravalli Hills'' of Rajasthan.Various observations were recorded using standard methods.

RESULTS

The highest plant dry matter (26.43 g/plant) was recorded under pendimethalin 0.75 kg/ha integrated with hand weeding 40 DAS closely followed by two hand weedings 20 and 40 DAS (25.43 g/plant) and metribuzin 0.15 kg/ha + HW 40 DAS (25.12 g/plant), however it was found significantly superior in enhancing dry matter production per plant compared to oxyfluorfen 0.10 kg/ha+ HW 40 DAS. All herbicides when individually integrated with hand weeding 40 DAS were found significantly superior in enhancing crop dry matter accumulation compared to their application alone. Pendimethalin 0.75 kg/ha integrated with hand weeding 40 DAS recorded the maximum plant height (70.99 cm) which was closely followed by hand weeding twice 20 and 40 DAS (68.35 cm). The lower dose of pendimethalin or oxyfluorfen when integrated with hand weeding 40 DAS was found significantly superior in enhancing plant height at harvest compared to their lower doses applied alone and was found statistically at par with higher doses applied alone. In case of metribuzin, both higher and lower doses applied alone or lower dose along with HW 40 DAS was found statistically at par to each other in enhancing plant height. Pendimethalin 0.75 kg/ha alongwith one hand weeding 40 DAS recorded the highest number of branches/plant (7.36) which was closely followed by hand weeding twice and oxyfluorfen 0.10 kg/ha + hand weeding 40 DAS (6.98) and metribuzin 0.15 kg/ha with hand weeding 40 DAS (6.90). Maximum weed control efficiency of 65.12 and 63.65 %, respectively was achieved with pendimethalin 0.75 kg/ha integrated with hand weeding 40 DAS closely followed by hand weeding twice 20 and 40 DAS with values of 63.96 and 63.02%, respectively and this might be the reason that under these two treatments plantsexpress their full growth potential.

CONCLUSION

Pendimethalin 0.75 kg/ha integrated with hand weeding 40 DAS recorded the highest values of different growth parameters as well as total weed control efficiency. It can also be concluded that application of different herbicides integrated with hand weeding at appropriate time showed better results than their sole application.

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Effect of weed management practices on bio-chemical parameter of soybean

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Soybean (*Glycine max* L. Merrill) is an important oilseed crop that is widely grown as a valuable source of protein and oil for human nutrition in the world. It has outstanding nutritive value with 43% biological protein, 20% oil and is also very rich in vitamins, iron, mineral, salts and amino acids. Weed infestation is considered a persistent and complex constraint in soybean, as it influences soybean growth and development through competition for nutrients, water, light and space as well as through production of allelopathic compounds (Vollmann *et al*., 2010). Thus, weed control is considered a key factor for successful soybean production. Weed management through manual weeding or hoeing although effective in reducing weed competition but it is not free from several limitations such as non-availability of sufficient manpower during peak periods, high labour cost, time consuming and not feasible under heavy soils and high rainfall areas. Hence, the present investigation was undertaken to evaluate the effect of weed management treatments on the biochemical parameters of soybean.

METHODOLOGY

A field experiment was carried out at Rajasthan College of Agriculture, MPUAT, Udaipur during *kharif* 2014. The soil of the experiment plot was clay loam, alkaline in reaction (pH 8.1), medium in nitrogen (285 kg/ha) and phosphorus (20.42 kg/ha) and high in potassium (230.90 kg/ha). The experiment was laid out in randomized block design comprising of 14 treatments viz. T_1 - weedy check, T_2 - pendimethalin 0.750 kg/ha PE, T_3 - metribuzin 0.350 kg/ha PE, T_4 - fenoxaprop-p-ethyl 0.075 kg/ha 20 DAS, T_5 - imazethapyr 0.100 kg/ha 20 DAS, T_6 - pendimethalin 0.750 kg /ha PE + one hand weeding 30 DAS, T_7 - metribuzin 0.350 kg /ha PE + one hand weeding 30 DAS, T_8 - pendimethalin 0.750 kg/ha PE followed by fenoxaprop-p-ethyl 0.075 kg/ha 20 DAS, T_9 - pendimethalin 0.750 kg/ha PE followed by imazethapyr 0.100 kg/ha 20 DAS, T_{10} - metribuzin 0.350 kg/ha PE followed by fenoxaprop-p-ethyl 0.075 kg/ha 20 DAS, T_{11} - metribuzin 0.350 kg/ha PE followed by imazethapyr 0.100 kg/ha 20 DAS, T_{12} - one hand weeding 20 DAS, T_{13} - two

Table 1. Effect of weed management treatments on biochemical parameters of soybean

Treatments	Weed control efficiency	Seed oil content (%)	Seed protein content (%)	Chlorophyll content (mg/g fresh weight)	
				50 DAS	75 DAS
Weedy check	-	19.54	37.84	2.20	1.70
Pendimethalin 0.75 kg/ha PE	57.79	19.84	38.38	2.45	1.88
Metribuzin 0.35 kg/ha PE	58.79	19.85	38.53	2.43	1.89
Fenoxaprop-p-ethyl 0.075 kg/ha POE	59.82	19.95	38.59	2.50	1.94
Imazethapyr 0.1 kg/ha POE	61.65	19.95	38.74	2.55	1.95
T_2 + HW 30 DAS	76.96	20.86	40.44	2.80	2.22
T_3 + HW 30 DAS	71.09	20.45	40.14	2.76	2.15
$T_2 + T_4$	69.74	20.34	39.81	2.70	2.12
$T_2 + T_5$	71.56	20.34	40.06	2.75	2.20
$T_3 + T_4$	70.04	20.26	39.97	2.71	2.15
$T_3 + T_5$	69.89	20.22	40.00	2.73	2.18
One hand weeding at 20 DAS	66.61	20.15	39.50	2.65	2.05
Two hand weeding 15 and 30 DAS	74.58	20.75	40.31	2.78	2.17
Weed free up to 50 days	92.18	20.88	40.63	2.91	2.29
SEm±		0.66	0.66	0.06	0.06
CD (P=0.05)		NS	NS	0.17	0.14

hand weeding 15 and 30 DAS and T_{14} - weed free up to 50 days and replicated thrice. Soybean variety JS-9560 was sown on 16 July 2014 by drilling the seed 80 kg/ha at 30 cm row spacing. Oil, protein and percentage in seeds and chlorophyll content in plant leaves was estimeted following by standard procedure.

RESULTS

Dominant weed flora of the experiment field was *Amaranthus viridsi, Commelina benghalensis, Parthenium hysterophorus, Trianthema portulacastrum, Digera arvensis, Cynodon dactylon, Echinochloa colona* and *Cyperus rotundus*. All the weed control treatments were found significant in affecting the total chlorophyll content at 50 and 75 DAS. At 50 DAS, The maximum chlorophyll (2.91 mg/g) was recorded under weed free treatments which was closely followed by pre-emergence application of pendimethalin 0.750 kg/ha + hand weeding 30 DAS (2.80 mg/g). At 75 DAS, Amongst all weed management treatments weed free treatments recorded maximum total chlorophyll content in leaves 75 DAS (2.29 mg/g) which was significantly at par with pre emergence application of pendimethalin along with hand weeding combination as well as two hand weeding treatment. The increase in chlorophyll content of the crop under weed control treatments can be clearly attributed to the reduction in interference of the weeds as evident from the higher weed control efficiency which ultimately favoured better growth environment for the crop. All the weed control treatments failed to record significant influence on protein and oil content in seed. However, maximum protein content was recorded under weed free check (40.63 per cent) which was followed by pre-emergence application of pendimethalin along with hand weeding 30 DAS (40.44%) and two hand weeding 15 and 30 DAS (40.31%). The effective weed control owing to these treatments lead to higher nutrient uptake, consequently higher protein and oil content compared to unweeded control.

CONCLUSION

It can be concluded that maximum total chlorophyll content, oil and protein content in soybean could be realized with the pre-emergence application of pendimethalin alongwith hand weeding at 30 DAS in sub-humid southern plain and Aravalli hills zone of Rajasthan.

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Effect of different planting methods and weed management practices on population of *Anagalis arvensis* in wheat

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Wheat (*Triticumaestivum* L.) is the most extensively grown food crop in world, whereas second in India after rice.In India, wheat is grown in 30.97M ha with production of 86.53Mt and productivity of 2.79 tonnes/ha (Anonymous, 2016). It plays an important role in the food and nutritional security i.e. up to 40% of total food grain production of the country. A number of factors are responsible for stagnation of wheat production and productivity like weeds, excessive tillage and soil degradation that limit the wheat productivity. As there is hardly any scope for expansion of area under wheat, the main emphasis would be on increasing the productivity of wheat by adopting the improved cultivation practices and weed management practices.

METHODOLOGY

A field experiment was carried out during *Rabi* season of 2013-14 at CCS Haryana Agricultural University, Hisar, Haryana to study the performance of wheat under different

Table 1. Effect of planting methods and weed control treatments on population density of *A. arvensis*in wheat at different growth stages

Treatment	*Anagallisarvensis* (No. /m^2)				
	30 DAS	60 DAS	90 DAS	120 DAS	At harvest
Planting method					
Drill sowing at 20 cm (CT)	4.25 (20.60)	6.09 (62.80)	4.98 (40.20)	4.59 (34.47)	4.30 (30.00)
Drill sowing at 18 cm (CT)	4.16 (19.73)	6.08 (62.53)	4.96 (40.13)	4.58 (34.33)	4.27 (29.87)
Drill sowing at 20 cm (ZT)	4.14 (19.53)	6.06 (61.80)	4.93 (39.53)	4.55 (33.80)	4.25 (29.33)
Drill sowing at 18 cm (ZT)	4.15 (19.72)	5.99 (61.53)	4.90 (39.07)	4.51 (33.60)	4.20 (29.13)
Bed planting (3 rows)	4.20 (19.93)	6.14 (62.87)	5.01 (40.22)	4.63 (34.53)	4.32 (30.73)
Bed planting (2 rows)	4.26 (20.87)	6.29 (65.80)	5.16 (42.33)	4.74 (36.47)	4.40 (31.67)
SEm±	0.04	0.03	0.02	0.02	0.03
CD (P=0.05)	NS	0.10	0.08	0.07	0.11
Weed control treatment					
PDN (50 g/ha)	5.11 (26.67)	12.35 (151.78)	9.93 (97.67)	9.21 (84.06)	8.60 (73.50)
CZN+MSM(RM) (25 g/ha)	4.75 (23.28)	2.32 (4.56)	3.03 (3.17)	1.74 (2.11)	1.55 (1.44)
PDN+[CZN+MSM(RM)](50+25g)/ha	4.78 (23.56)	2.50 (5.33)	2.18 (3.83)	1.85 (2.50)	1.65 (1.78)
Weed free	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
Weedy check	5.13 (26.83)	12.37 (152.78)	9.86 (96.56)	9.20 (83.83)	8.64 (73.89)
SEm±	0.16	0.15	0.11	0.09	0.13
CD (P=0.05)	0.47	0.43	0.30	0.27	0.37

Original data given in parenthesis were subjected to square root ($\sqrt{x+1}$) transformation before analysis.

planting methods with varied row spacing and weed management practices. Experiment was laid out in split-plot design replicated thrice, having six planting methods as main-plot treatments, *viz*. bed planting (2 rows), bed planting (3 rows), drill sowing at 18 cm (conventional tillage), drill sowing at 20 cm (conventional tillage), drill sowing at 18 cm (zero tillage), drill sowing at 20 cm (zero tillage) and five weed control practices as subplot treatments, *viz.*pinoxaden 50 g/ha, [carfentrazone + metsulfuron (RM)] 25 g/ha, pinoxaden + [carfentrazone + metsulfuron (RM)] (50+25g)/ha, weed free and weedy check. Wheat variety HD-2967 was sown on 3rd December, 2013 as per package of practices recommended by CCS Haryana Agricultural University, Hisar. Herbicides as per treatments were sprayed at 35 DAS using 500 l/ha water by knapsack sprayer fitted with flat-fan nozzle.

RESULTS

Different planting methods failed to affect the density of *A. arvensis* at 30 DAS. The density of *A. arvensis* increased with increasing row spacing from 18 cm (drill sowing both in ZT and CT) to 35 cm (bed planting with two rows). At 60, 90, 120 DAS and at harvest, the density of *A. arvensis* in bed planting with two rows of wheat remained significantly higher than all other planting methods whereas density of *A. arvensis* in bedplanting with three rows remained at par with drill sowing of wheat (both ZT and CT) except in zero tillage at18 cm row spacing, where the density of *A. arvensis*was recorded to besignificantly lower (Table 1).Herbicidal treatments significantly influenced the population density of A. *arvensis* at various stages of observation.At 30 DAS, the density of *A. arvensis* remained at par in all plots except in weed free situation (Table 1). At 60, 90, 120 DAS and at harvest, significantly higher density of *A. arvensis* was observed under weedy check and alone application of pinoxaden (50 g/ha) at 35 DAS as compared to weed free situation, application of carfentrazone + metsulfuron (RM) (25 g/ha) at 35 DAS and tank mix application of pinoxaden + [carfentrazone + metsulfuron (RM)] (50 + 25 g)/ha at 35 DAS.

CONCLUSION

Sowing of wheat with drill sowing (both under zero and conventional tillage) at 18 cm and 20 cm results in lower population density of *A. arvensis* and application of carfentrazone + metsulfuron (RM) 25g/ha orpinoxaden + [carfentrazone + metsulfuron (RM)] (50 +25) g/ha at 35 DAS results in effective control of *A. arvensis*.

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Integrated weed management in seed crop of lentil (*Lens culinaris*)

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Lentil is an important *rabi* pulse crop which is globally grownon 4.24 million hectare area with a total production of 4.55 million tones with an average productivity of 1070kg/ha (FAOSTAT2013) Heavy infestation of weeds and its poor management in lentil is serious problem for increasing and sustaining its productivity.Lentil is slow growing and short statured crop due to which weeds pose a severe competition and reduce the yield of lentil up to 87 %. Pre-emergence herbicides such as pendimethalin have been recommended for controlling weeds in lentil, however these herbicides are effective only during the first 30-35 days and weeds emerging latter compete with crop. New herbicides like Imazethapyr and quizalofop ethyl have been used and have improved the yield of lentil (Singh *etal.,* 2008). However, sole application of neither pre-emergence nor post emergence herbicides controlthe weeds completely in lentil hence application of pre-emergence herbicides either followed by post emergence herbicides in sequence or integrated with weeding may reduce the weed pressure in lentil. In case of seed crop, information on the effect of pre and post emergence herbicides on seed quality is very essential, hence study was undertaken.

METHODOLOGY

Field experiment was conducted during rabi season of 2013-14 and 2014-15 on sandyclay loam soils, medium in organic carbon (0.60%), available phosphorus (20.5kg/ha), potash 278kg/ha) with pH of 7.5. Thrteen treatments were taken in randomized block design with three replications. Pre-emergence herbicide pendimethalin was sprayed after sowing keeping a spray volume of 500 lit/ha. Post-emergence herbicides viz. Imazethapyr (50, 75 and 100g/ha) and Quizalofop ethyl (25 g/ha) were applied at 30 and 45 days after sowing (DAS). In weed free plots three weeding were done at 30,45 and 60 days after sowing and no weeds were removed from weedy check plots.Weed density and weed dry weightwas recorded from quadrate of 1 m^2. Weed control efficiency (WCE), Weed index, Herbicide efficiency index (HEI) and Weed management index (WMI) were calculated as per standard procedures.

RESULTS

The experimental field was mainly infested with *Rumex dentatus, Anagalis arvensis, Chenopodium album,*

Table 1. Effect of pre and post emergence herbicides on weed parameters, seed yield and quality in lentil

Treatment Dose & Time	Weed density (m^2)	Weed Dry Weight (g/m^2)	WCE	Seed yield kg/ha	Weed Index	Germination (%)	Seedling dry weight (mg)
Imazethapyr 50g/ha 30 DAS	(68.0) 8.3	(58.2)7.5	60.6	503.9	29.3	83.3	4.6
Imazethapyr 75g/ha 30 DAS	(52.6)7.3	(53.9)7.2	63.5	530.0	25.6	82.0	4.5
Imazethapyr 100g/ha 30 DAS	(44.2) 6.7	(58.1)7.4	60.7	546.8	23.2	86.0	4.8
Imazethapyr 50g/ha 45 DAS	(52.6) 7.3	(76.0)8.6	48.6	448.6	37.0	86.0	4.5
Imazethapyr 75 g/ha 45 DAS	(44.0) 6.7	(44.5)6.6	69.9	534.5	24.9	86.7	5.5
Imazethapyr 100g/ha 45 DAS	(49.5) 7.1	(50.7)6.8	65.7	480.0	32.6	82.3	4.8
Quizalofop ethyl 25 g/ha 30 DAS	(86.0) 9.3	(105.8)10.4	28.0	401.0	33.9	82.0	5.5
Quizalofop ethyl 25g/ha 45 DAS	(81.3)8.9	(79.9)8.9	45.4	470.5	43.6	85.7	4.9
Pendimethalin +HW45DAS	(28.3)5.4	(26.4)5.2	82.0	649.4	8.8	85.0	4.6
Pendimethalin FbImazethapyr 1.0 kg & 50 g/ha 45 DAS	(31.3)5.7	(22.0)4.8	85.0	716.9	1.0	81.0	5.3
Pendimethalin Fb Quizalofop ethyl 1.0 kg & 25 g/ha 45 DAS	(62.6)7.9	(63.5)8.0	56.8	517.7	27.3	86.3	4.3
Weed Free	(0.0)1.0	(0.0)1.0	100.0	712.5	0.0	85.0	4.1
Weedy check	(135.0)11.6	(147.1)12.1	0.0	325.8	54.3	82.6	3.6
CD (P=0.05)	1.27	2.7		145.3		NS	NS

Chinopodium murale, Sprergula arvensis, Coronopus dydimus, Medicagodenticulate and Phalaris minor. Broad-leaf weeds were dominant over grassy weeds.Quizalofop ethyl applied at 30 DAS recorded significantly higher weed density and weed dry weight compared to Pendimethalin 1.0 kg/ha fb HW and sequential application of Pendimethalin fb Imazethapyr at45DAS due to the dominance of broadleaf weeds and quizalofop –ethyl is only effective in perennial and annual grasses weeds. Lowest herbicide efficiency index, weed management index and weed control efficiency was recorded by Quizalofop- ethyl 30 DAS whereas highest values were recorded by Pendimehalin fb Imazethapyr due better control of weeds. All the herbicides recorded significantly lower weed density and weed dry weight than weedy check except quizalofop ethyl applied 30DAS. Imazethapyr showed toxicity in all the doses 50, 75 and 100g/ha both at 30 and 45 DAS however plants recovered with time. The results are in accordance to that reported by Mishra *et al.* (2005). Quizalofop ethyl at 25 g/ha both at 30 and 45 DAS did not cause any visual toxicity to the lentil plants. Significantly higher seed yield of lentil was recorded under Pendimethalin fb Imazethapyr 45DAS compared to Quizalofop 25g/ha at 30 and 45DAS, sole application of Imazethapyr 50,75 and 100 g/ha at 30 and 45 DAS and at par with Pendimethalin 1.0kg/ha fb HW at 45DAS and weed free. There was reduction of 54.5 and 44.0percent in seed yield in weedycheck and quizalofop ethyl 25g/ha at 30DAS compared to sequential application of Pendimethalin fb Imaethapyr due to lower WCE, WMI and HEI and higher weed index values. Seed quality in terms of germination and seedling dry weight was not affected by application of different herbicides under sole and sequential application.

CONCLUSION

Based on the findings it can be concluded that sequential application of Pendimethalin 1.0kg/ha fb Imazethapyr 50g/ha 45DAS controls the weeds efficiently and gave significantly higher yield than sole application of Imazethapyr at 50, 75 and 100g/ha and Quizalofop ethyl 25g/ha both30and 45DAS under Karnal conditions.

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Bioefficacy of various doses of 2,4-D ethyl ester 80% EC on weed growth, crop yield of maize and the residual effect on succeeding pea crop

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A field investigation was carried out during 2012-13 to test the bioefficacy of 2,4-D Ethyl ester 80% EC at various doses (Sponsor vs Market sample) to control the weeds in maize crop. 2,4-D Ethyl ester 80% EC was applied at various doses as post emergence and its market sample was also used, atrazine also applied as post emergence. All weed control treatments significantly reduced the density as well as dry matter accumulation of weeds over weedy check during both the years. The maximum suppression of density as well as dry matter accumulation of weeds and highest WCE were obtained with the successive increase in the doses of 2,4-D EE (SS) from 450 to 1800 g a.i./ha resulted decreased density of dominant BLWs. None of the doses of 2,4-D EE (SS or MS) was found much effective towards density of grassy weeds. Among herbicidal treatments, maximum grain yield (4507 kg/ha and 4743 kg/ha) and percent increase in the grain yield (61.12% and 70.6%) was achieved with the application of atrazine at 250 g a.i./ha applied as post emergence during both the years.

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Association of physio-biochemical traits with drought resistance in 206 RIL population derived from WL 711 and C 306 in wheat

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Wheat (*Triticum aestivum* L.) is the most widely cultivated cereal in the world and it has a prominent position in the international food grain trade. Drought is the most common environmental stress affecting about 32% of 99 mha under wheat cultivation in developing countries and at least 60 million hectares under wheat cultivation in developed countries. Therefore, most of the countries of the world are facing the problem of drought. The insufficiency of water is the principal environmental stress that causes heavy damage of agricultural products in many parts of the world. To improve the livelihoods of the farmers of the rain-fed areas it is necessary to introduce new high yielding wheat varieties which are resistant to severe climatic adversities peculiar to drought (Naeem *et al*., 2016). Physiological and biochemical traits have a crucial role to determine the importance of each trait on increasing yield, as well as to use those traits at the breeding programs, which at least lead to improving yield and introducing commercial varieties under end seasonal drought stress condition (Zhou *et al.*, 2016). The present study would assess the physiological and biochemical traits of RIL population and their potential utility in context of drought resistance. The parent cultivars belonging to distinct adaptation groups, offer several morpho-physiological and biochemical contrasts. Further C306 is known for better stem reserves on account of larger peduncle and strong commitment to grain filling due to effective stem reserve mobilization. WL711, on the other hand, is known to possess high chlorophyll content and greater stomatal conductance.

METHODOLOGY

Plant material consisted of 206 recombinant inbred lines along with parents WL711 and C 306. Population with parents sown in the field of water technology Centre in randomized complete block design. The drought environment was created by withholding irrigation supply. Physiological and Biochemical traits such as plant height, peduncle length, peduncle width, chlorophyll flourescence (FV/Fm), stem reserve mobilization, water soluble carbohydrate, carotenoids and grain yield were recorded.

RESULTS

The result based on frequency distribution was found to be approximately normal for all the physiological traits. Chlorophyll fluorescence (Fv/Fm) at anthesis among RIL population along with parents showed distinct variation under irrigated and stress conditions. Khakwani *et al* (2012) observed decrease in chlorophyll fluorescence which was significantly lower than the varieties in irrigated condition. It is also reported that decrease of chlorophyll fluorescence under drought stress seems to indicate the occurrence of chronic photoinhibition due to photo-inactivation of photosystem II centers, possibly attributable to D1 protein damage which usually limit photosynthetic activity (Zlatev 2004). Peduncle length and width among RIL population along with parents showed variation under irrigated and stress conditions. The decrease in peduncle length under water stress condition was

Table 1. Ranges and mean values of physio-biochemical and yield traits of RILs population along with parents under water stress condition.

Traits	PHT	PL	PW	SRM	WSC	CAR	FV/FM	GY
MIN	84	24	2.18	50.9	16.6	0.0385	0.634	284
MAX	144	54	4.54	95.3	63.2	0.0426	0.852	719
Mean	114	38	3.14	70.5	40.2	0.0403	0.682	510
WL711	95	28	2.42	58.3	47.4	0.0324	0.683	650
C306	128	50	3.46	85.6	60.3	0.0425	0.739	448

PHT- Plant height (cm), PL- Peduncle length (cm), PW- Peduncle width (mm), SRM- Stem reserve mobilization, WSC- Water soluble carbohydrate, CAR- Carotenoid content, GY- Grain yield (g/m^2)

markedly more than irrigated condition among RIL population. This decrease in peduncle length would decrease in stem reserves during grain filling. In this study selection for traits viz, peduncle length, water soluble carbohydrates, stem reserve mobilization, carotenoid content may be effective for improvement of grain yield under drought stress conditions as it showed significant correlation only under drought stress.

CONCLUSION

In conclusion, selection for traits may be effective for improvement of grain yield under stress conditions as it showed significant correlation under drought stress and the traits from tall traditional cultivars (C306) can be combined in some lines and progress can be made towards confirming drought resistance with productivity.

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Effect of weed management practices on nutrient uptake by crop and weeds in *Kharif* maize (*Zeamays*)

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Maize is known as queen of cereals because of its high production potential and wider adaptability.In addition to staple food for human beings quality feed for poultry and animals, maize serves as a basic raw material as an ingredient for various industrial products that includes starch, oil, protein, alcoholic beverages, food sweeteners and more recently biofuels. Being a potential crop in India, maize occupies important place as food (25%), animal feed (12%), poultry feed (49%), industrial products mainly starch (12%) and 1% each in brewery and seed (Das *et al*., 2008).Weeds create an acute problem in rainy season crop. They compete for nutrients, moisture, light, space and $CO_{2,}$ harbor many pests and diseases eventually affect the growth, yield and quality of crop adversely. Sharma *et al*. (2000) gave a rough estimate on crop-weed competition and suggested reduction of 33-50 per cent in yield due to weed infestation. Earlier weeds were controlled mechanically by hoeing and bullock/tractor drawn implements but now the use of chemical herbicides is widespread.Weed control in maize can be highly sophisticated because of wider spacing. Mechanical control of weeds growing between the rows is labour intensive. Hence, weed control in developed countries is done by using herbicides. The choice of weed control measures therefore, depend largely on effectiveness and economics. Use of integrated approach would make weed control more acceptable to farmers which will not change the existing agronomic practices but will allow for more complete control of weeds.

METHODOLOGY

A field experiment was conducted at college of agriculture farm, Kolhapur during *kharif*, 2014. The soil of experimental field was medium deep with sandy clay loam in texture, slightly alkaline pH (7.24), low in organic carbon (0.36%) and available N (260 kg/ha), medium in available P (21.60 kg/ha) and available K_2O (254.67 kg/ha). The experiment was laid out in randomized block design with nine treatments viz., weedy check (T_1), weed free check (HW at 20, 40 and 60 DAS) (T_2), atrazine @ 1 kg a.i./ ha as pre-emergence +one HW at 30 DAS (T_3), atrazine @ 1kg a.i./ha as pre-emergence + 2,4-D @ 1 kg a.i./ha at 30 DAS as post-emergence (T_4), atrazine @ 1 kg a.i./ha as pre-emergence + metsulfuron methyl @ 4g a.i./ha at 30 DAS as post- emergence (T_5),

Table 1. Effect of weed management practices on yield (Grain and fodder) and Nutrient uptake by crop and weed

Treatments	Yield (t/ha)		Nutrient uptake by crop (kg/ha)			Nutrient uptake by weeds (kg/ha)		
	Grain	Fodder	N	P	K	N	P	K
Weedy check	3.15	8.62	54.10	10.22	48.3	60.50	10.67	40.23
Weed free check (HW at 20,40 and 60 DAS)	6.37	15.94	147.83	34.16	93.00	24.23	5.13	27.23
Atrazine @ 1 kg a.i./ha (PE) fb one HW at 30 DAS	6.02	15.22	145.70	30.06	86.23	25.87	5.60	28.16
Atrazine @ 1 kg a.i./ha(PE) fb 2,4-D @ 1 kg a.i./ ha at 30 DAS (POE)	5.67	14.51	135.33	25.13	80.73	34.40	6.10	32.61
Atrazine @ 1 kg a.i./ha(PE) fb Metsulfuron methyl @ 4 g a.i./ ha at 30 DAS (POE)	5.52	13.00	117.53	22.27	75.33	36.23	6.67	33.06
Metribuzin @ 0.5 kg a.i./ha(PE) fb one HW at 30 DAS	4.93	11.82	107.33	19.17	62.81	44.54	7.60	35.34
Metribuzin @ 0.5 kg a.i./ha (PE) fb 2,4-D @ 1 kg a.i./ha at 30 DAS (POE)	4.48	11.32	106.80	17.57	60.67	48.50	8.87	38.09
Metribuzin @ 0.5 kg a.i./ha (PE) fb Metsulfuron methyl @ 4 g a.i./ha at 25 DAS (POE)	4.07	10.09	104.40	15.05	58.82	52.00	9.40	38.97
Two hoeings at 15 & 45 DAS fb one HW at 30DAS	5.54	14.12	130.87	24.41	75.74	33.12	6.23	31.57
SEm±	0.21	0.56	2.31	0.65	1.44	0.97	0.25	0.60
CD (P=0.05)	0.62	1.69	6.93	1.94	4.33	2.92	0.76	1.88

metribuzin @ 0.5 kg a.i./haas pre-emergence + one HW at 30DAS (T_6), metribuzin @ 0.5 kg a.i./ha as pre-emergence + 2,4-D @ 1 kg a.i./ ha at 30 DAS as post-emergence (T_7), metribuzin @ 0.5 kg a.i./ha as pre-emergence + metsulfuron methyl @ 4 g a.i./ha at 25 DAS as post-emergence (T_8), two hoeings at 15 and 45 DAS + one HW at 30 DAS (T_9) replicated thrice. The variety Rajarshi was sown at 2nd fortnight of June with a spacing of 75 cm x 25 cm. Atrazine and metribuzin were applied as pre-emergence spray as per treatment one day after sowing the crop with a spray volume of 500 litre/ha,while the post-emergence herbicides were applied as per treatment. Hand weeding and hoeing was done as per treatment.

RESULTS

Atrazine @ 1 kg a.i./ha (PE) fb one HW at 30 DASrecorded significantly higher values of grain and fodder yield and it was comparable with weed free (HW at 20, 40 and 60 DAS). Significantly lower values of grain and fodder yield were obtained with weedy check treatment. This might be due to effective weed control in the treatments which enhanced the growth, yield contributing characters and dry matter production of maize.Among the herbicides, the highest uptake of NPK by crop was registered with the applicationof atrazine @ 1 kg a.i./ha (PE) fb one HW at 30 DAS which was comparable with weed free check (HW at 20, 40 and 60 DAS). This was followed by Atrazine @ 1 kg a.i./ha(PE) fb 2,4-D @ 1 kg a.i./ha at 30 DAS as POE, two hoeings at 15 and 45 DAS fb one HW at 30 DAS, Atrazine @ 1 kg a.i./ ha(PE) fb Metsulfuron methyl @ 4 g a.i./ha at 30 DAS as POE, Metribuzin @ 0.5 kg a.i./ha(PE) fb one HW at 30 DAS, Metribuzin @ 0.5 kg a.i./ha (PE) fb 2,4-D @ 1kg a.i./ha at 30DAS as POE, Metribuzin @ 0.5 kg a.i./ha(PE) fb Metsulfuron methyl @ 4 g a.i./ha at 25 DAS as POE.The treatment weedy check recorded significantly the lowest uptake of NPK. This is due to efficient control of the complex weed flora due to which nutrient availability for crop increased which helped to increase the dry matter accumulation in crop. As the nutrient uptake is directly related to the dry matter accumulation of plant, the nutrient uptake was higher. Perusal of data on uptake of NPK by weeds inferred that significantly higher quantity of NPK uptake by weeds was noticed in weedy check. Among herbicidal treatments lowest uptake of NPK by weeds was observed in atrazine @ 1 kg a.i./ ha (PE) fb one HW at 30 DAS which was comparable with weed free check (HW at 20, 40 and 60 DAS). Reduced uptake of nutrients (N, P and K) by weeds was due to increased weed control efficiency of herbicides.

CONCLUSION

Among the herbicidal treatments, higher values of grain and fodder yields were registered with the treatment atrazine @ 1 kg a. i./ha(PE) fb one HW at 30 DAS which was comparable with weed free (HW at 20, 40 and 60 DAS). This is due to the highest uptake of NPK by the crop in these treatment which led to better crop growth and development.

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Weed management practices in rice based cropping system in Madhya Pradesh: a farmer's perspective analysis

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Weed is becoming major problem now days in Madhya Pradesh mainly due to fast urbanization, industrialization, and ever increasing wages of agricultural labour as well as their scarce availability at critical crop stages viz. at the time of weeding. With the result, either farmers are unable to control the weeds in time and losing the yield substantially or they are giving weeding operation on contract at higher rates, which are not viable in long-term. Since, number of new and effective herbicide molecules isavailable these days especially for rice; therefore, if these molecules are properly demonstrated and popularize in scientific manner among farmers, the problem of weeds may be minimized up to the greater extent.

METHODOLOGY

The study was conducted in three localities i.e. Panager, Sihora and Sahpura block of Jabalpur district of the MadhyaPradesh. These localitieswere selected purposively because On-farm research cum demonstration activities of the ICAR-Directorate of Weed Research were carried out in the same localities and the localities/villages are almost representative of all the existing cropping as well as social environment of the state. For each selected locality/village, a list of farmers was prepared and 25 farmers (Including direct beneficiaries of the OFR) from each locality/village were selected randomly. In this way, a total of 75 farmers were taken as the respondents for this study. The data were collected through personal interview technique with the help of structured questionnaire. In addition to individual survey, closed observations, Focus group Discussions (FGDs), Group interviews and village level field functionaries were also utilized for collection of data.

RESULTS

Rice is the major rainy season crop in all the sites. Maize, greengram, blackgram, pigeonpea, and vegetables etc. were some of the other crops being cultivated by the farmers. During winter season, wheat, pea, chickpea lentil and linseedetc. are the major crops which were generally grown by the respondents in rice based cropping system. The farmers of all the sites feel that weeds are one of the major hindrances in achieving potential rice productivity, which cause the yield loss between 15-25%. Some of the respondents gave high to very high severity weight age to these problems. Contaminated seed,canal water for irrigation, bunds, flooding during rainy season and un-decomposed FYM were the major sources of weeds dispersal to the rice fields as reported by the respondents. Some other reasons were also uttered by the respondents for causing weed problem in rice fields. In all the selected sites, farmers were controlling the weeds by hand weeding or using some locally available old herbicides/molecule and only few respondents were adopting improved weed control technologies (chemicals control of weeds). Among various reasons for not utilizing the available new herbicides by the majorityof farmers, lack of awareness, lack of technical knowledge about new herbicide and their application time, dose and methods, psychological fear, old mind-set, sometimes non-significant/toxic effect of herbicides due to spurious/adulterated material, unavailability of good molecule at local level and economic condition of the farmers, etc. were theimportant reasons among many.

CONCLUSION

To strengthen the knowledge of rural farming community, and also to reap the fruits of advancement, extension approach needs to be restructured to make technology dissemination responsive to the needs of farmers.

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Mulching a convincing weed management practice for better herbage and oil yield production of sweet basil (*Ocimum basilicum*)

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There is a growing demand for plant-based medicines, health products, pharmaceuticals, food supplements, cosmetics etc. in the international market. The international market of medicinal plants is over 60 billion US dollar per year, which is growing at the rate of 7% per annum. Medicinal and aromatic plants (MAPs) contribute significantly to rural economy and health security of the country. More than 90% of the formulations under the Indian systems of medicine contain plant-based raw materials. It is necessary to develop agro-technologies for prioritized medicinal and aromatic plants. Sweet basil (*Ocimum basilicum*, family Lamiaceae) known as St. Joseph's Wort, is a plant of important industrial & medicinal value. The essential oil of Indian basil extracted via hydro-distillation from the leaves or whole plants is used to flavour foods, dental and oral products, in fragrances, and in traditional rituals and medicines. Extracted essential oil has also been shown to contain biologically active constituents that are insecticidal, nematicidal, fungicidal or which have antimicrobial properties. Sweet basil is grown mostly in *kharif* season, & face serious problem of weeds leading to increase in cost of labour and reduction in herb yield. Research work on weed management in the crop is very meagre. It is necessary to evaluate various weed management practices to find out the most economically viable method for increasing herb yield of sweet basil. Hence, the study was undertaken with the objective to find out a suitable method of weed management for sweet basil, an important medicinal crop.

METHODOLOGY

A field experiment was conducted during *kharif* season of 2013 at Medicinal Plant Research and Development Centre (MRDC), G.B. Pant University of Agriculture and Technology, Pantnagar to evaluate the weed dynamics, production of herbage and oil yield of sweet basil, under various weed management practices. The experiment was laid out in a randomized complete block design with three replications to evaluate ten treatments viz. weedy check, weed free, manual weeding at 30 Days After Transplanting (DAT), manual weeding at 30 and 60 DAT, straw mulch (5 cm), straw mulch (8 cm), polythene mulch (100 gauge), polythene mulch (160 gauge), pre emergence application of pendimethalin @ 0.5 kg/ha and pendimethalin @ 1.0 kg/ha. The major weed species in the experimental plot were *Echinochloa colona*, *Echinochloa crus-galli*. Standard recommended package of practices were followed for raising the crop. The data recorded for different parameters were analysed with the help of analysis of variance (ANOVA) technique for a RBD using MSTAT-C software. The results are presented at 5% level of significance (P=0.05).

RESULTS

Dry matter accumulation of total weeds recorded under weed free treatment was significantly lower than all other treatments except 100 gauge polythene mulch and 160 gauge polythene mulch. Two manual weeding at 30 and 60 DAT resulted in significantly lesser total weed dry matter accumulation as compared to one manual weeding at 30 DAT. Weed free and polythene mulch treatment recorded significantly higher WCE than all other treatments. This was followed by the treatment to two manual weeding at 30 and 60 DAT. Maximum fresh herbage yield & oil yield was obtained in weed free treatment which was succeeded by the treatment of 160 gauge polythene mulch. Treatments of weed free and 160 gauge polythene mulch were statistically at par for herbage & oil yield. Both the treatments of pendimethalin i.e., 0.5 kg/ha and 1.0 kg/ha were statistically at par with each other, in relation to the fresh herbage as well as oil yield. Black polythene mulch provided a better soil environment for plant growth than plots without mulch. Use of 160 gauge thickness of polythene mulch resulted in 92% increase in fresh herbage as well as oil yield over weedy check, whereas weed free treatment resulted in 95% increase in fresh herbage yield over weedy check. Higher oil yield of weed free treatment followed by 160 gauge thickness of polythene mulch treatment was due to higher herbage yield. Use of 160 gauge polythene mulch and weed free treatment gave 95 and 98% higher oil yield, respectively, than weedy check. The highest benefit cost ratio was recorded with non chemical method of 160 gauge thickness of polythene mulch and it can be used as an alterna-

Table 1. Dry matter, weed control efficiency, oil and oil yield, economics of *Ocimum* under weed management treatments

Treatment	Dry matter accumulation by weeds at 100 DAT (g/m^2)	WCE at 100 DAT	Weed Index (%)	Fresh Herbage yield of *Ocimum basilicum* (t/ha)	Oil content (%)	Oil yield (kg/ha)	B: C ratio
Weedy check	4.38(79.1)	0	49.38	17.92	0.63	113	1.77
Weed free	0.0(0.0)	100	0	35.01	0.64	224	1.82
Manual weeding, 30 DAT	3.21(23.8)	49.88	19.28	28.26	0.64	180	1.85
Manual weeding, 30 and 60 DAT	2.74(14.6)	81.51	5.65	33.03	0.63	208	1.83
Straw mulch, 5cm	3.97(52.1)	34.09	29.93	24.53	0.62	152	1.82
Straw mulch, 8cm	3.84(45.5)	42.47	22.10	27.27	0.62	170	1.83
Polythene mulch, 100 gauge	0.0(0.0)	100	8.42	32.06	0.64	205	1.86
Polythene mulch, 160 gauge	0.0(0.0)	100	1.37	34.53	0.64	221	1.91
Pendimethalin @ 0.5 kg *a.i.*/ha-PE	4.06(56.8)	28.18	35.41	22.61	0.62	140	1.81
Pendimethalin @ 1.0 kg *a.i*/ha-PE	3.95(50.9)	33.12	31.53	23.97	0.63	151	1.84
CD (P=0.05)	0.10	20.40	9.68	3.47	NS	23.01	

DAT- days after transplanting, original values are given in parentheses; WCE-weed control efficiency

tive weed management practice, particularly, when labour is limiting factor in cultivation. The decreasing order of treatments for B:C ratio was use of 160 gauge polythene mulch recorded the maximum B: C ratio followed by 100 gauge polythene mulch > one manual weeding 30 DAT > pendimethalin @1.0 kg ha-PE > use of 8 cm thickness straw mulch > manual weeding at 30 and 60 DAT > weed free > use of 5 cm thickness straw mulch, pendimethalin @0.5 kg/ha-PE > weedy check. Weed free treatment proved the best for yield and gross return followed by use of 160 gauge polythene mulch.

CONCLUSION

For an effective weed management in sweet basil (*Ocimum basilicum*), an important industrial and medicinal crop use of polythene mulch proved to be the best eco-friendly practice with maximum oil & herbage yield, net return and B:C ratio, as this treatment better suppress the weed population and resulted in maximum weed control efficiency.

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Weed management studies in spring planted sugarcane –based intercropping system under south Saurashtra region of India

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A field experiment was conducted to determine most suitable and profitable summer intercrop and appropriate weed management practices in spring planted sugarcane (*Saccharum officinarum* L.) – based intercropping system at Main Sugarcane Research Station, Junagadh Agricultural University, Kodinar, Gujarat, India during 2013-14 and 2014-15. The experiment was laid out in split plot design comprising five cropping system {Sole sugarcane, sugarcane + green gram (Vigna radiata L. Wilczek), sugarcane + black gram (Vigna mungo L. Hepper), sugarcane + sesame (Sesamum indicum L.) in 1:1 row ratios and sugarcane + groundnut (Arachis hypogaea L.) in 1:2 row ratio} in main plots and three weed control treatments (Un weeded control, hand weeding at 20 and 40 DAS of intercrop and pendimethalin 30 EC @ 0.90 kg a.i./ha as PE + one hand weeding at 30 DAS of intercrop) in sub plots and replicated thrice. Sugarcane variety CoN 91132 was planted in rows, spaced 90 cm apart. The pooled data of two years revealed that cane yield was not affected significantly due to different intercropping treatments. Significantly higher cane-equivalent yield was obtained under sugarcane + green gram (119.07 t/ha), sugarcane + black gram (115.54 t/ha) and sugarcane + sesame (119.19 t/ha) as compared to sole sugarcane (100.38 t/ha). Quality parameters of sugarcane were not affected by different intercropping systems. The weed density and weed dry matter reduced significantly due to different weed control measures. Cane yield increased significantly with the weed control treatments over unweeded control and was higher under two hand weeding at 20 and 40 DAS of intercrop (119.18 t/ha) which remained at par with pendimethalin 30 EC @ 0.90 kg a.i./ha + one hand weeding at 30 DAS of intercrop (118.81 t/ha). Similar trend was observed under number of millable canes and cane-equivalent yield. Sugarcane + green gram, sugarcane + black gram and sugarcane + sesame are promising summer season intercropping options for sustainability of sugarcane production.

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Efficacy of various herbicides against weed flora in soybean (*Glycine max* L.)

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Soybean (*Glycine max* L.) is a miracle "Golden bean" of 21st century mainly due to its high protein (40%) and oil (20%) content and is now making headway in Indian Agriculture.Soybean has been accredited as principle food crop since long time that produces 2-3 times more high quality protein yield per hectare than other pulses and cholesterol free oil. In Vidarbha, area covered under rainfed soybean is 15.90 Lakh ha with productivity of 1054 kg/ha.Weed competition is one of the most important causes of low yield which estimated to be of 31-84 % (Kachroo *et al*., 2003).In soybeanreduction in the yield due to weeds varies from 35 to 50 per cent, depending upon the type of weeds, their intensity and time of crop weed competition. The traditional method of weed control is expensive, tedious and time consuming. Under such circumstances, use of effective herbicides gives better and timely weed control. Hence the present investigation was undertaken.

METHODOLOGY

A field investigation was carried out at the farm of Agronomy Department, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (MS) during the *Kharif* season of 2015. The experiment was laid out in randomized block design with eight treatments replicated thrice. The experimental site was fairly uniform in topography with clayey in texture and slightly alkaline in reaction. Overall the rainfall and its distribution were satisfactory for crop. Sowing of soybean JS-335 was done on 23rd June 2015. Herbicidesdoses were applied as per the treatments. Phytotoxicity symptoms due to herbicides on crop was recorded by using a visual score scale of 0-10.

RESULTS

The major weed flora during kharif season in soybean crop in the selected area comprised of weed species*viz;*, *Commelina benghalensis, Dinebra Arabica, Poa annua, Echinochloa crusgalli, Eragrostis major, Cynodon dactylon, Cyperus rotundus, Lagasca mollis, Euphorbia hirta, Digera arvensis, Tridex procumbense, Parthenium hysterophorus, Celosia argentea, Euphorbia geniculata, Alysicarpus rugosus, Alternanathera triandra, Xanthium strumarium,, Portulaca oleracae, Amaranthis viridis*. All the herbicidal treatments significantly minimized the weed number and weed dry matter when compared with unweeded control. None of the herbicide under study showed any phytotoxicity

Table 1. Various parameters as influenced by weed controltreatments in soybean

Treatments	Weed population per m^2 at harvest	Weed dry matter g/m^2 at harvest	Weed control efficiency (%)	Seed yield (t/ha)	NMR (Rs/ha)	B:C Ratio
Pendimethalin 30 EC@ 1.0 kg a.i./ha PE	7.10 (50.00)	4.36 (18.50)	64.83	1.56	24828	1.91
Quizalofop ethyl 5 EC @ 0.050 kg a.i./ha PoE 15 DAS	7.58 (57.00)	4.76 (22.23)	57.73	1.47	21914	1.80
Imazethapyr 10 SL @ 0.100 kg a.i./ha PoE 15 DAS.	6.81 (46.00)	4.19 (17.03)	67.62	1.65	27650	2.01
Imazethapyr 10 SL @ 0.100 kg a.i./ha PoE + Quizalofop ethyl 5 EC @ 0.050 Kg a.i/ha PoE 15 DAS (*Tank mix*)	5.57 (31.00)	3.69 (13.13)	75.03	1.92	35104	2.22
Imazethapyr + Imazamox (*premix*) 70 WG @ 0.070 kg a.i./ha PoE 15 DAS.	6.46 (41.33)	4.25 (17.60)	66.54	1.68	28452	2.03
Quizalofop ethyl 5 EC @ 0.050 kg a.i./ha PoE 15 DAS + Chlorimuron ethyl 25 WP @ 0.010 kg a.i./ha PoE 15 DAS (*Tank mix*)	5.98 (35.33)	3.94 (15.03)	71.42	1.65	27652	2.01
Weed free	2.02(3.67)	1.09(0.70)	98.67	1.95	34838	2.15
Weedy check	8.85(78.00)	7.29(52.60)	-	0.93	5630	1.22
CD (P=0.05)	0.77	0.27	-	0.22	6716	-

Data are subjected to square root transformation ($\sqrt{x+0.5}$) Data given in parentheses are original values**.**

symptoms on crop. In all parameters under study weed free treatment recorded best results but among the various herbicidal combinations lowest total weed count was observed under treatmentImazethapyr 10 SL @ 0.100 kg a.i./ha PoE + Quizalofop ethyl 5 EC @ 0.050 Kg a.i/ha PoE 15 DAS (*Tank mix*). This might be due to combination of both herbicides that have longer effect on controlling both monocot and dicot weed population in tank mix solution similar trend was also observed in weed dry matter and weed control efficiency. Among the herbicide treatments,highestseed yield (t/ha), NMR (Rs/ha) was also recorded in weed free treatment followed by Imazethapyr 10 SL @ 0.100 kg a.i./ha PoE + Quizalofop ethyl 5 EC @ 0.050 Kg a.i/ha PoE 15 DAS (*Tank mix*) while highest B: C ratio was also recorded in same treatment combination.

CONCLUSION

The treatmentImazethapyr 10 SL @ 0.100 kg a.i./ha PoE + Quizalofop ethyl 5 EC @ 0.050 Kg a.i/ha PoE 15 DAS (*Tank mix*) was found better in controlling weeds, dry matter accumulation, weed control efficiency, seed yield, NMRand B:C ratio of soybean. Same treatment recorded 206 % increase in seed yield over weedy check.

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Predicting kala zeera (*Bunium persicum*) seed yield losses by weed competition in Gurez valley of temperate Kashmir

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Monoculture of Kala zeera in Gurez valley of temperate Kashmir has led to serious weed problems and enhanced cost of production. Yield loss prediction enables the economic analysis of weed control, providing a basis for strategic use of herbicides and diversified weed management, but site differences restrict prediction to the environments for which the models are calibrated (Kropff and Spitters, 1992). Weed problem in Kala Zeera gets exaggerated due to its perennial nature and very slow early growth. Here an attempt is being made to calibrate yield reduction models on the basis of relative biomass and relative density for predicting kalazeera production.

METHODOLOGY

An experiment was conducted at Mountain Agriculture Research and Extension Station (MAR & ES) previously Zeera Research Sub Station *Gurez* (78°, 20' N Longitude and 31° 20' E Latitude and at 2393 m amsl) *of Sher-e- Kashmir University of Agricultural Sciences and Technology of Kashmir*, Jammu & Kashmir during *Rabi* seasons of 2009-10 and 2010-11 on a flat narrow valley land. Two sets of treatments were imposed to represent both increasing duration of weed interference and the length of the weed-free period measured after germination. The first set of treatments consists of increasing duration of weed interference by delaying weed control from the time of crop emergence up to predetermined week (weedy up to 2, 4, 6, 8, 10 and 12 weeks after germination (WAG) of *Kala Zeera*) . The second set of treatments established six levels of increasing length of the weed-free period (weed free upto 2, 4, 6, 10 and 12 WAG). Besides two controls (Weed free and weedy check). These comprised of 14 treatments which were laid out in Randomized Complete Block design with three replications. Weeds were removed by hand pulling and hoeing and weed data is recorded from three 1m^2 quadrats staggered in each experimental unit. All the crop data and weed data was analysed by recommended procedures. The linear prediction models were tested on the basis of data observed at 08, 10 and 12 WAG. The treatments where weed population were zero, were excluded for regression analysis. Relative weed density and relative weed biomass with calculated by dividing weed density/ biomass of respective treatment with summation of crop and weed biomass/density.

RESULTS

As expected highest weed intensity and weed dry weight was recorded in weedy check control plots (Table 1). The weed data showed an increasing trend with the enhancement of weedy period and decreasing trend with the increase in weed free period. Nadeem*et al*, 2013 also reported different yields in varying weed competition periods. It was observed that data taken at early stages of crop emergence have strong relationship with weed infestation (R^2=0.90-0.95) as compared to data taken at later stages (R^2= 0.70-0.75). Further relative weeddensity and relative weed biomass at 08 WAG proved more defining variables for predicting yield losses in kalazeera seed yield.So both these derived parameters are further regressed for defining seed yield by multiple linear regression analysis. Both these factors define 96 % of yield of kalazeera and the model equation for this is Y = 404.62–252 RD (8WAG)- 18.58 RB (8WAG) with R^2 =0.96 on further partial regression analysis it was revealed that, Relative density and Relative biomass define 77.4 % and 22.5% of kalazeera seed yield, respectively.

CONCLUSION

Thus it was concluded that quantifying crop weed competitions at early season of crop germination that is upto 8 WAG was found more authentic as registering higher coefficient of determination irrespective of independent parameters taken for estimation. Mean interval prediction of linear regression also followed the skewed predicting trend at 8 WAG. Relative weed density appeared more defining parameters for predicting kalazeera seed yield. Thus maintenance of optimum plant population and minimizing weed population especially at initial stages of crop are essential for reducing crop weed competition in kalazeera.

Table 1. Seed , Straw yield and weed data as influenced by different weed management practices

Treatment	Seed yield	Straw yield	Weed Density (WAG)			Relative Weed Density (WAG)		
			8	10	12	8	10	12
Weed Free	307.5	1169.2	0.0	0.0	0.0	0.000	0.000	0.000
Weedy Check	160.0	637.5	106.2	111.5	125.3	0.869	0.875	0.887
Weeds were in crop 2 WAG	231.0	916.7	000	0.0	0.0	0.000	0.000	0.000
Weeds were in crop 4 WAG	221.0	880.5	0.0	0.0	0.0	0.000	0.000	0.000
Weeds were in crop 6 WAG	215.0	856.6	0.0	0.0	0.0	0.000	0.000	0.000
Weeds were in crop 8 WAG	196.0	780.9	106.3	0.0	0.0	0.869	0.000	0.000
Weeds were in crop 10 WAG	162.0	640.3	106.8	116.8	0.0	0.870	0.880	0.000
Weeds were in crop 12 WAG	160.0	634.9	105.6	118.6	128.6	0.868	0.881	0.889
Weeds weren't in crop 2WAG	165.0	645.7	86.5	98.5	98.8	0.844	0.860	0.861
Weeds weren't in crop 4 WAG	249.0	965.1	29.8	85.6	75.8	0.651	0.843	0.826
Weeds weren't in crop 6 WAG	251.0	961.7	20.2	40.4	45.8	0.558	0.716	0.741
Weeds weren't in crop 8 WAG	270.0	1110.4	0.0	15.3	18.5	0.000	0.489	0.536
Weeds weren't in crop 10 WAG	285.0	1064.6	0.0	0.0	6.5	0.000	0.000	0.289
Weeds weren't in crop 12 WAG	291.0	1106.5	0.0	5.8	0.0	0.000	0.266	0.000
CD (P = 0.05)	0.20	0.98	–	–	–	–	–	–

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Carryover effect of triasulfuron applied to wheat on following soybean crop

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Over the years, the application of herbicides is performing an effective job by managing weeds, the silent killer in crop production. Since the recent past, the use of herbicides is getting impetus in Indian agriculture due to high rise of labour wages. Within a couple of decades, the number of different herbicide molecules registered reached to over 60 from a few. Herbicides are replacing manual method of weed management in the major crops like rice, wheat, maize, soybean, sugarcane and others. For these crops, many choices of herbicides are available now in the market. Low dose herbicides are becoming popular over the old molecules like 2,4-D, isoproturon, butachlor, etc. Sulfonylureas and imidazolinones are grabbing the large market share in rice, wheat and soybean by virtue of their efficiency in managing weeds. But in the backdrop of their success, some of them cause phytotoxicity to the succeeding crops. For instance, the application of sulfosulfuron and mesosulfuron + iodosulfuron in wheat affects adversely the growth and development of following greengram and maize (Kaur and Brar, 2014). It was reported that a level of 0.25 µg/kg of triasulfuron significantly reduced lentil root dry weight by 40% (Kotoula-Syka *et al*., 1993). Triasulfuron is applied to wheat in limited areas of central India. More recently, devastation in soybean crop was caused by triasulfuron applied in the preceding crop wheat in farmers' field of Dhar district in Madhya Pradesh. In the present investigation, it was attempted to work out the extent of contamination of soil with triasulfuron in Bidwal region of Dhar district.

METHODOLOGY

During the *Rabi* season 2014-15, triasulfuron, a recently registered wheat herbicide of sulfonylurea group was applied by 36 farmers in around 64 ha area in Bidal region of Dhar district. The recommended rate of application was 20 g ai per ha (100 g of 20% WDP formulation per ha). In next *Kharif* season, the entire area was under soybean cultivation. Due to delayed monsoon, the farmers could not apply any pre/post-emergence herbicide during the season. After a good germination, soybean plants showed severe phytotoxicity symptoms. Representative soil samples were collected from the affected field on 4-5 August, 2015, which was around seven months after the application of triasulfuron. Soil samples were analysed by bioassay technique and by chemical method to identify the presence of herbicide residues. Triasulfuron residues were extracted chromatographically from the soil following a standard method and analysed by high resolution LC-MS/MS.

RESULTS

Application of triasulfuron was found very effective for controlling broad-leaved weeds in wheat. In the next *Kharif* season, the entire area was under soybean cultivation. The soybean germination was proper, but the plants developed phytotoxicity symptoms gradually and finally got dried. In the adjoining fields where soybean was grown after chickpea or garlic, there was no such symptom observed. Crop injuries were observed in those fields only where triasulfuron was applied during *Rabi* season in wheat crop.Soil samples were analysed by bioassay technique and by chemical method to identify the presence of herbicide residues. In bioassay analysis, it was observed that broad-leaved crops like soybean and mungbean were affected badly after a good germination (Table 1). It was found on LC-MS/MS analysis that collected soil samples contained triasulfuron residues within the range of 1.28 to 7.48 g/ha. Degradation productsof triasulfuron were also identified.

Sulfonylurea herbicides, in general, are very sensitive to soil pH (Sarmah and Sabadie, 2002). They are quite stable in the soil having pH above 6.0. The pH of the soil of Bidwal region is within the range of 7.1 to 7.9. In this soil, the chemical degradation, i.e. hydrolysis on sulfonylurea bridge of triasulfuron is not possible. Moreover, the soil of this region is rich in clay and organic matter. Such soils adsorb more herbicide onto soil colloids. Herbicides bound to soil colloids cannot be taken up by plants, move through the soil profile, or easily degrade. Crops in rotation can be injured when water displaces soil-bound herbicide residues. During the period between wheat season and the onset of soybean cultivation, Bidwal did not receive any rainfall. Dry conditions helped to increase triasulfuron adsorption to soil colloids, and decrease the chemical hydrolysis and microbial degradation of the herbicide. After the first irrigation in soybean, water displaced soil-bound triasulfuron residues, which injured the crop causing total yield loss. The available herbicide residues in soils collected seven months after the application of triasulfuron were in the range of 1.28 to 7.48 g/ha, i.e. 0.57 to 3.32 µg/kg, which was sufficient for causing damage to crops. To overcome the problem of triasulfuron contamination in soil, frequent irrigation or heavy and frequent rain fall is required to leach down the herbicide residues from surface layer of the soil. The addition of organic matter and frequent tillage of the field may increase adsorption and bio-degradation of the herbicide residue in soil.

Table 1. Effect of triasulfuron residues on sesame, soybean, mungbean and rice growth

Crop	Untreated soil		Contaminated soil	
	% Germination	% Survival	% Germination	% Survival
Sesame	100	100	100	65
Soybean	100	100	100	0
Mungbean	100	100	100	30
Rice	100	100	100	100

CONCLUSION

It was, thus, simply a case of wrong positioning of a product. Although triasulfuron is a recommended herbicide for wheat, the application rate was, probably on higher side for this type of soil and climate. In Australia, the maximum dose of triasulfuron is 26 g ai/ha (35 g 750 WG formulation/ha) for a very light soil with the warning of replanting interval of at least 12 months and minimum rainfall requirement between application of the herbicide and sowing of the following crop should be 500 mm. Thus prior to using this herbicide, careful consideration should be given to crop rotation plans.

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Biochemical parameters and economics of wheat as affected by different weed control treatments

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Wheat is an important crop worldwide and in India.Weed infestation is one of the major biotic constraints in wheat production. It is infested with diverse type of weed flora under diverse agro-climatic conditions. The yield losses due to weeds vary depending on the weed species, their density and environmental factors. The crop was infested with heavy population of common broadleaf weeds and annual grassy weeds like*Chenopodium*spp, *Melilotusindica*,*Phalaris minor*and*Avenafatua* etc. Weed management is necessary to achieve higher yield as weeds compete for different growth

Table 1. Effect of weed managements on different parameter of wheat

Treatment	Nutrient content (%)		Protein yield (kg/ ha)	Grain yield (kg/ha)	WCE (%) (₹/ha)	Net returns
	N content in grain	P content in grain				
2,4-D	1.75	0.300	452.94	4169	71.89	38502
Metsulfuron	1.74	0.297	459.68	4224	74.05	39610
Isoproturon	1.77	0.303	458.12	4130	70.64	37695
Sulfosulfuron	1.77	0.303	470.40	4240	68.67	39814
2,4-D + Isoproturon	1.82	0.310	511.19	4576	88.40	43690
2,4-D + Sulfosulfuron	1.82	0.310	481.51	4456	88.71	41258
Metsulfuron + Isoproturon	1.85	0.313	542.80	4864	90.65	47915
Metsulfuron + Sulfosulfuron	1.85	0.310	581.37	5222	91.49	52603
Weedy check	1.77	0.300	386.70	3547	-	30908
Weed free	1.85	0.327	595.40	5350	-	52359
CD (P=0.05)	NS	NS	100.09	908	-	11437

factors especially nutrients and natural resources with crops, causing significant yield reduction. Due to industrialization, labour constraints at peak growth, small family size and under specific situations where weeds are very difficult to remove manually, use of herbicides and their mixtures become inevitable (Garcia-Martin *et al.,* 2007). For these reasons this experiment was carried out to minimize the nutrient drain by the weeds so as to increase biochemical parameters of the crop and thus increase the grain yield and net returns of wheat crop.

METHODOLOGY

A field study was conducted during winter season of 2014-15 at Instructional Farm, Rajasthan College of Agriculture, Udaipur. The soil of the experimental field was clay loam in texture with alkaline in reaction. The available N, P_2O_5 and K_2O were 259.51, 20.59 and 399.35 kg/ha, respectively. Ten treatments consisting of 2,4-D (0.5 kg/ha), metsulfuron (4 g/ ha), isoproturon (1.0 kg/ha), sulfosulfuron (25 g/ha), 2,4-D + isoproturon (0.25 kg/ha + 0.75 kg/ha), 2,4-D + sulfosulfuron (0.25 kg/ha + 20 g/ha), metsulfuron + isoproturon (3 g/ha + 0.75 kg/ha), metsulfuron + sulfosulfuron (3 g/ha + 20 g/ha), weed free and weedy check. The experiment was conducted in randomized block design with 3 replications. Wheat variety 'Raj.4037' was sown in rows 22.5 cm apart on 6th December in 2014with seed rate of 150 kg/ha using package of practices available for "Sub-Humid Southern Plain and Aravalli Hills'' of Rajasthan.All the herbicides were sprayed 35 DAS by knapsack sprayer using a spray volume of 600 liters/ha. Different parameters were measuredby using standard methods.

RESULTS

The experimental results showed that different weed control treatments could not found significant in influencing different bio-chemical parameters like N and P in content in wheat grain. Protein yield was enhanced under all the weed control treatments compared to weedy check. Data in Table 1 further showed that among the weed control treatments after weed free treatment (595.40 kg/ha) the highest protein yield (581.37 kg/ha) was recorded under post emergence application of metsulfuron 3 g/ha + sulfosulfuron20 g/ha, whereas, the lowest protein yield was recorded under weedy check (386.70 kg/ha). This is mainly because of the fact that protein yield is a function of grain yield and nutrient content and results of protein yield was in same order as grain yield of wheat under different treatments. The weed control efficiency wasrecorded the highest under metsulfuron 3 g/ha + sulfosulfuron 20 g/ha, so the corresponding grain yield of wheat also followed the foot step of the same. This corroborate with the findings of Jat*et a*l. (2014). Maximum net return (₹ 52603/ha) was recorded under the same treatment followed by weed free and metsulfuron 3 g/ha + isoproturon0.75 kg/ha.

CONCLUSION

From the results it can be concluded that the tank mixture of metsulfuron 3 g/ha + sulfosulfuron20 g/ha at 35 DAS recorded the highest seed yield (5222 kg/ha) which was at par with metsulfuron 3 g/ha + isoproturon0.75 kg/ha (4864 kg/ha) as well as weed free treatment (5350 kg/ha). It can be used for control of mixed weed flora as this treatment also recoded the maximum net returns of52603/ha compared to rest of the treatments.

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Sustainable weed management in fodder crops through crop husbandry and crop rotation

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Generally in grain crop ecosystem all kinds of agrochemicals like herbicide, fungicide and insecticide are used to control the target organisms. However, application of these chemicals makes the micro-climate of agro-ecosystem toxic which resulted in catastrophic effects on the existing population. This catastrophic effect not only bring the changes of the organisms in terms of their biology, breeding capacity, adaptation and invasion capacity but also kill the non-target organisms which could become the biotic stress of other organisms for maintaining the ecological balance. Imposing selection pressure on the existing population through catastrophic effect and elimination of biotic stresses make the agro-ecosystem more vulnerable against dangerous pest attach which in turn makes no choice than more application of diverse agro-chemicals in order save the agro-ecosystem. At the fodder farm of ICAR-IVRI, the fodder crops are grown without application of those agro-chemicals and fodder crop ecosystem is maintained like natural eco-system in which ecological balance getsoperated. Thecontinuoussurvey has been made at the fodder farm of IVRI, Izatnagarsince September 2014 with the objective to study the weed flora and their association with several fodder crops at different seasons, the biological stresses like insect and pathogen against the weeds and the effect of tillage, crop rotation and mixed cropping on associated weed flora.

METHODOLOGY

The survey has been made by adopting the field manual for weed ecology and herbicide research developed by R A Raju in 1997(Agrotech Publishing Academy, Udaipur p 78) in order to determine absolute density, relative density, absolute frequency, relative frequency, importance value and summed dominance ratio of weed flora appearing in different fodder crops at different growing seasons and weed flora after interventions through crop rotation and mixed cropping.

RESULTS

The survey result showed that the broad leaved weed *Trianthemaportulacastrum, Trianthemamonogyne Celosia argentea, Cleome viscosa, Cocciniagrandis,* the sedges *Cyperusesculentus,Cyperusrotundus* and the grasses *Echinochloacolona, Eleusineindica* were appearing in all the fodder crops like fodder maize, fodder sorghum and fodder cowpea grown during summer and rainy season whereas the broadleaved weeds *Coronopusdidymus, Rumexdentatus, Cichoriumintybus, Spilanthes sp.* and the grass *Poaannua* were appearing in fodder crops like berseem grown during winter season. *Trianthema* (Aizoaceae) is a branched, prostrate, succulent, annual herb. Two biotypes (red and green) of *T. portulacastrum* are found at fodder farm of ICAR-IVRI among which red biotype was abundant in the farm. *Trianthema* is aterrestrial, annual, prostrateherb, up to 40 cm long. Its germination and emergence started with the rise of temperature at the terminal phase of the winter season (During 1st fortnight of March) and it continuously grown up to the beginning of winter season with several flushes. Growth of *Trianthema* was gradually restricted with the onset of winter season and it perished completely during 1stfortnight of December. *Trianthema* was propagated by seeds and by fragments of stem. *Trianthema* propagated easily from the fragments of stem. More tillage operations result in more fragmentation of stems, which put forth new growth during current season. Seeds did not have the dormancy and germinate immediately after maturity. *Trianthema* produced flower continuously up to second fortnight of October and in case of mild winter it produced flowers up to 2nd fortnight of November. It developed seeds up to 2nd fortnight of December before it perished completely. Each *Trianthema* flower produced 8 to 12 seeds and one mature *Trianthema* plant under crop field condition produced 28 to 42 flowers altogether can produce total 224 to 504 seeds. More than 80% germination of current seeds was recorded. In field condition initially a few seeds germinated after pre-sowing irrigation and reached to the flowering and seed setting stage when majority of the seeds started to germinate 2 to 3 % of the total current seeds germinated within 6 days after starting of imbibition, majority of the seeds germinated within 17 to 20 days after imbibition and remaining seeds germinated afterwards.Seeds of *Trianthema, Cocciniagrandis* and *Cleome viscose* showed the character of endozoochory mechanism and easily passed through the cattle rumen. The seeds were viable into the fresh cattle dung. Application of manure without proper decomposition disseminated these weeds into the fodder fields. The natural infection on leaves of *Trianthemaportulacastrum* was observed and identified as leaf spot disease during 2nd fortnight of September. The fungal pathogen isolated from the disease was *Gibbagotrianthemae*. The larva of the insect has been identified as a voracious feeder of *Trianthema* leaf and high feeding activity was observed during high humid condition with rainfall. Dense foliage coverage of the fodder crops developed high humidity in micro-climate and that led to high feeding activity of the larva. Turning the land to cowpea and maize+cowpea mixed cropping has been found effective for reducing *Trianthema* population and its distribution within the fodder crop. Dense foliage created by cowpea and maize+ cowpea mixed cropping increased feeding activity of insect larva. *Celosiaargentea* has been reorded as a numerous seed producer and also an associated weed of fodder sorghumas it preferred to grow well within the canopy of sorghum. Mature plant of *Celosia argentea* produced 12 to 19 flowers and each flower produced 143 to 184 seeds, altogether produced 1,716 to 3,496 seeds when associated with sorghum. *Celosiaargentea* has been managed successfully by turning the land to cowpea. Both prostrate and trailing growth habit of cowpea restricted growth and seed production of *Celosia argentea.* Cowpea reduced average seed production capacity of *Celosia argentea* to the tune of 2238 seeds/plant. More earthworms were recorded in the field occupied by cowpea (24 earthworms/m^2 area at 20 cm depth) than that of fodder sorghum (9 earth worms/m^2 area at 20 cm depth). One mature *Cocciniagrandis* plant produced 18 to 27 fruits and each fruit produced 136 to 164 seeds altogether produced 2934 to 4428 seeds. It has been recorded that berseem cultivation during winter season under puddled condition reduced infestation of *Cocciniagrandis* in summer and *kharif* fodder crops. This indicated that puddling operation reduced germination capacity of the seeds and thus reduced seed bank potential of *Cocciniagrandis. Coronopusdidymus* was very much aggressive in berseem due to slow initial growth of berseem. Mixed cropping of berseem + gobhisarson (*Brassica napus)* reduced infestation of *Coronopusdidymus* during winter season of 2015 as compared to sole cropping of berseem during winter season of 2014 (N-14-November 2014/berseem, N-15-November 2015/berseem + *Brassicanapus,* D-14-December 2014/berseem, D-15-December 2015/berseem + *Brassicanapus,* J-15-January 2015/berseem, J-16-January 2016/berseem + *Brassicanapus*).

CONCLUSION

Trianthema was widely distributed into the fodder farm mainly because of its strong character on seed production and multiplication capacity both by seed and vegetative means. Tillage played an important role for continuous emergence of *Trianthema* by imposing enforced dormancy of current seeds and breaking enforced dormancy of old seeds.More than 80% germination of current seed of *Trianthema* has been recorded. Cowpea showed significant effect in minimising distribution and seed production capacity of *Celosia argentea*. Field grown with fodder cowpea has improved earthworm population in comparison to the field grown with fodder sorghum. Puddled soil has the influence in reducing germination capacity of *Cocciniagrandis*and growing of berseem under puddled condition during winter season reduced seed bank potential and infestation of *Cocciniagrandis* in summer and *kharif* fodder crops. Mixed cropping of berseem + gobhi sarson (*Brassica napus*) reduced infestation of *Coronopusdidymus* in berseem crop.

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Effect of fertility levels and weed management on weed dynamics, yield and economics of lentil (*Lens culinaris* Medikus) under eastern U.P. conditions

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At the global level, though India's share in lentil production is quite large (30%), yet the production (0.95 mt) and productivity level (633.33 kg/ha) in the country is substantially low (FAOSTAT, 2014). The low average yield might be due to poor level of crop management, growing lentil on marginal lands with low fertilizer inputs and inadequate weed management. Urea is the most suitable nitrogen source for foliar application due to its low salt index and high solubility in comparison to other nitrogen sources PlantGRO MAGIC is a fertilizer product which is amultinutrient water soluble fertilizer (57.1% total nutrients) and includes nitrogen, phosphorus and potassium as primary nutrients. It has been found that weeds reduce yield of lentil to the extent of 73% (Phogat*et al*., 2003) and under high densities of weeds losses can reach even up to 100%. Weed infestation in lentil is high due to its slow initial growth, short stature and shallow root system. The use of herbicides as an alternative to hand weeding can be feasible and more economical than hand weeding. Pre-emergence herbicides like pendimethalin are effective only for a period of initial 30 days and at later stages, crop gets infested with weeds. Therefore, the use of post-emergence herbicide needs to be advocated in lentil.There is a need to develop most effective and economical fertilizer management and weed control practices for obtaining higher yield as well as profitability. Keeping these facts in view,the present experiment was designed to determine the best suitable fertilizer and weed management technique for lentil crop.

METHODOLOGY

A field experiment was conducted during the winter season of 2012-13 and 2013-14 at dryland research farm of Banaras Hindu University, Varanasi (U.P.). The soil was clay loam in texture with pH 7.31 (1:25 soil and water ratio), 0.37% organic carbon, 212.50 kg/ha available nitrogen, 25.17 kg/haavailable phosphorus (Olsen *et al*., 1954)and 234.15 kg/ha potassium before the start of the experiment. The experiment was replicated thrice in split-plot design with six fertility levels *viz*. Control (F_0), 100% RDF (F_1), 75% RDF + 2% urea spray at pre-flowering and pod initiation (F_2), 75% RDF + Plantgro 9 kg/ha at 35, 50 and 65 DAS as foliar spray (F3), 100% RDF + 2 % urea spray at pre-flowering at pod initiation (F_4), 100% RDF + Plantgro 9 kg/ha at 35, 50 and 65 DAS as foliar spray (F_5) and four weed management practices *viz*., Unweeded (W_0), weed free (W_1), pendimethalin 1.0 kg/ha (W_2), imazethapyr 37.5 g/ ha (W_3). A uniform dose of 20, 40, 30 kg N, P_2O_5, K_2O/hawas applied todifferent plots as per the treatment requirements through urea, Single super phosphate and Muriate of potash respectively. Hand weeing was done with the help of khurpi at an interval of 25 days or whenever weeds were observed in weed free plots. Pendimethalin was applied as pre-emergence using Knapsack sprayer fitted with flat fan nozzle by mixing 500 litres of water/ha. Post-emergence herbicide Imazethapyr was applied at 2-4 leaf stage of weed. The observations on weed dry matter were taken randomly from 0.5m x 0.5 m quadrate from 2 spots from each plot at the time of harvest. The weed samples were sun-dried for 2-3 days and then dried in oven at 70^0C for 48 hours to obtain a constant weight. The data on weed experiment were subjected to square root transformation $\sqrt{x + 0.5}$ for uniformity. The crop was harvested at 24 March in 2013 and 22 March in 2014respectively. Weed free and unweeded control treatments were kept for comparison with different treatments. Yield attributes *viz*. number of seeds/pod, test weight and yield *i.e*. grain yield (kg/ha) and straw yield (kg/ha) were recorded at harvest during both the years. Net returns was cal-

Table 1. Total weed count, weed dry weight, weed control efficiency, yield and economics by weeds as influenced by fertility levels and weed management (pooled data of two years)

Treatments	Total weed count (No./m²)	Total weed dry weight (g /m²)	Weed control efficiency (%)	Nutrient depletion (kg/ha)		
				Grain yield	Net returns (Rs/ha)	B C ratio
Fertility levels						
Control	6.99 (70.34)	7.03 (68.26)	56.40	900.33	17550.48	2.19
100% RDF	6.40 (57.82)	6.30 (52.88)	60.03	1096.98	22486.75	2.37
75% RDF+ 2% urea spray at pre-flowering and pod initiation	6.72 (63.57)	6.42 (54.94)	56.99	1027.41	19491.01	2.11
75% RDF + Plantgro 9 kg/ha at 35, 50, 65 DAS as foliar spray	5.86 (48.99)	5.79 (45.49)	60.25	1283.08	22783.24	2.00
100% RDF + 2% urea spray at pre-flowering and pod initiation	6.16 (53.49)	5.99 (47.62)	60.14	1136.59	23218.09	2.29
100% RDF + Plantgro 9 kg/ha at 35, 50, 65 DAS as foliar spray	6.73 (65.51)	6.72 (62.05)	56.47	1028.37	14270.28	1.62
SEm ±	0.03	0.04	-	20.80	-	-
CD (P=0.05)	0.09	0.12	-	61.37	-	-
Weed management						
Unweeded	12.70 (161.49)	11.52 (133.29)	0.00	953.66	18653.62	2.17
Weed free	0.71 (0.00)	0.71 (0.00)	100.00	1230.94	18293.52	1.71
Pendimethalin 1.0 kg/ha	6.91 (47.47)	6.84 (46.54)	64.64	1042.53	20293.67	2.16
Imazethapyr 37.5 g/ha	5.59 (30.85)	6.43 (40.93)	68.87	1088.05	22625.76	2.35
SEm ±	0.02	0.03	-	12.33	-	-
CD (P=0.05)	0.06	0.07	-	34.75	-	-

*Figure in parenthesis are original values.

culated by using prevailing prices of inputs and outputs during the respective crop season.Benefit:cost ratio was calculated by dividing the net returns from the cost of cultivation. The data was analysed using standard ANOVA for split-plot design and the significance of differences between the treatment means were compared with critical differences at 5% level of probability.

RESULTS

Weed flora of the experimental field consisted of grasses, sedges and broad leaved weeds. The dominant weed flora included *Cyperus* spp. among sedges, *Chenopodium album* and *Solanum nigrum* among broad-leaved weeds and *Cynodondactylon* among the grassy weeds. *Parthenium hysterophorus*, *Fumaria parviflora*, *Anagallis arvensis*, *Vicia sativa*, *Melilotusindica*, *Medicago polymorpha* were found in negligible presence. Sedges dominated the experimental field to the extent of 42% followed by broad-leaved and grassy weeds. It was observed that lowest weed count and dry weight of weeds was recorded with 75% RDF + Plantgro 9 kg/ha and was at par with the application of 100 % RDF + 2% urea spray. However, all the fertility level treatments were significantly superior to control in minimizing the total weed count of all weeds. Weed management treatments significantly influenced total weed count and total weed dry weight. Significantly lowest weed count and dry weight was noted under the post-emergence application of imazethapyr 37.5 g/ha and was at par with the application of pendimethalin 1 kg/ha and highest with unweeded control. The higher weed control efficiency was achieved under application of 75% RDF + Plantgro 9 kg/ha and was at par with 100% RDF + 2% urea spray application. Among the herbicidal treatments, higher weed control efficiency was obtained with post-emergence application of imazethapyr 37.5 g/ha. Different fertility levels produced significant impact on yield attributes and yield of lentil over control. Significantly higher number of pods/plant, seeds/pod and test weight was recorded with the application of 75% RDF + Plantgro 9 kg/ha and it was at par with the application of 100 % RDF + 2% urea spray (Table 2). 75% RDF + Plantgro 9 kg/ha increased lentil grain yield increased to the tune of 11.41 % and 29.83% over 100% RDF + 2% urea spray and control, respectively.Among herbicide treatments, higher yield attributes and yield was recorded with the application of imazethapyr 37.5g/ha and was comparable with pendimethalin 1 kg/ha. From the economics point of view, the highest net return was obtained with the treatment 100% RDF and 100% RDF + 2% urea spray with a B:C ratio of 2.37 and 2.29 respectively. Different weed management treatments produced significant effect on economics of lentil and maximum net return of Rs. 22,625.76/ha with BC ratio of 2.35 was registered with application of imazethapyr 37.5 g/ha.

CONCLUSION

It is inferred that application of 100% RDF + 2% urea spray or 75 % RDF + Plantgro 9 kg/ha and weed management with imazethapyr 37.5 g/ha found to be most suitable for lentil crop.

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Extended Summaries Vol. 1 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Bioregulators induced the heat tolerance by mediating the operation of zeaxanthin pigments cycle in chickpea

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High temperature at reproductive stage is a major constraint to chickpea production in India. A minimum decrease of 53 kg/ha of chickpea yield was observed in India per 1°C increase in seasonal temperature (Kalra *et al.,* 2008). Photosynthesis is the most heat-sensitive processes and it can be suppressed by high temperature due to the inhibition of photosystem II (PSII) activity. Chlorophyll fluorescence, the ratio of variable fluorescence to maximum fluorescence (*F*v/Fm) has been shown to correlate with heat tolerance. Carotenoids have ubiquitous roles in quenching excess excitation energy (Li *et al*., 2000) and protect photosynthetic machinery during light harvesting. The carotenoids of the zeaxanthincycle are involved in non-photochemical quenching (NPQ) under abiotic stress. Globally, itiswidespread research concern to achieve stress tolerance in crop plants without compromising with their yield. Exogenous application of

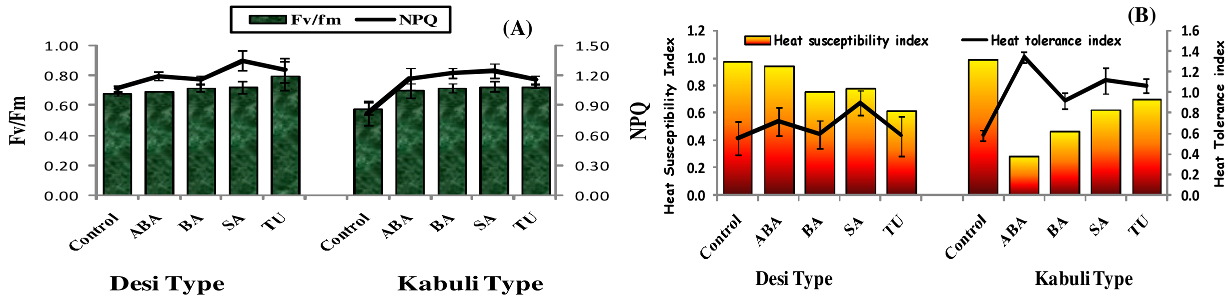

Fig. 1. Effect of foliar application of bioregulators on Fv/Fm and NPQ (A) and heat susceptibility and heat tolerance (B) in Desi and Kabuli chickpea varieties under heat stress condition.

bioregulators provides an alternative approach to counter stress conditions.Cytokinins increase crop productivity by protecting the photosynthetic machinery from stress (Chernyad'ev, 2009).Thiourea has been shown to possess antioxidant property by suppressing hydroxyl radical formation (Garg *et al*., 2006). Therefore, it was thought interesting to interlink bioregulators induced heat tolerance with zeaxanthin pigments cycle.

METHODOLOGY

An experiment was conducted using two chickpea varieties viz., *Desi* type (JG 14) and *Kabuli* type (Pusa 1108) with4 replicates in Factorial CRD. High temperature was imposed by altering the sowing dates i.e. normal sown (18^{th} Nov. 2013-14) and late sown over one month (20^{th} Nov. 2013-14). Foliar application of bioregulators viz. ABA (10 ppm), Benzyladenine (BA) (40 ppm), Salicylic acid (SA) (100 ppm) and Thiourea (1000 ppm) and water spray (control) were made before flowering. Leaf Photosynthetic pigments were extracted as per the method of Hiscox and Israelstam, 1979 and their contents were estimated using Arnon, 1949 formulae. Carotenoids were separated using thin layer chromatography. Gas exchange parameters were measured using 3^{rd} leaf from top with help of portable photosynthesis system (LICOR-6200) and chlorophyll parameters using Junior-PAMfluorometer (Heinz Walz, Germany). Yield, its attributes and heat tolerance were determined at harvest.

RESULTS

Under late sown condition reproductive phase of crop was coincided with heat stress. In general, foliar spray of bioregulators enhanced the yield by increasing the photosynthetic rate, level of photosynthetic pigments including zeaxanthin, quantum yield of PS II, NPQ, heat tolerance index, yield and its attributes and by reducing heat susceptibility index over the control (water) under late sown high temperature condition. *Kabuli* type chickpea had better response to plant growth regulators than the *Desi* one. *Desi* variety showed the highest photosynthetic rate and Fv/Fm with the application of thiourea (1000 ppm) while *Kabuli* had the highest photosynthetic and Fv/Fm response to SA (100 ppm). Similarly NPQ was recorded highest with the application of salicylic acid in both chickpea varieties under heat stress (Fig. 1 (A)). In *Desi* chickpea highest heat tolerance was reported with application of SA while in *Kabuli* type it was highest with the treatment of ABA followed by SA (Fig. 1 (B)).

Foliar spray of salicylic acid, BA and ABA induced the level of zeaxanthin by reducing the level of violaxanthin which indicated that application of PGRs protected the photosynthetic machinery by operating the zeaxanthin pigments cycle.

CONCLUSION

Present findings suggest that bioregulatos induce the heat tolerance and thereby yield under heat stress by activating operation of zeaxanthin cycle in chickpea. Moreover, *Kabuli* chickpea variety responded better to bioregulators than *Desi* type in terms of photosynthesis and grain yield particularly under late sown high temperature condition.

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Weed management by live mulches, cover crops and herbicides in DSR

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Growing of live mulches and cover crops improve soil health and controls weed ecologically in direct seeded rice.Integration of brown manuring practices (knock down of *Sesbania* at 25 day after sowing by 2, 4-D 0.5 kg/ha) with either pendimethalin 1.0 kg/ha or bispyribac-sodium 0.025 kg/ha or both was significantly superior in suppressing weed infestations with lesser weed index and higher weed control efficiency, yield attributes, yields and harvest index (Chongtham *et al.,* 2016). Highest grain yield was obtained in *Sesbania* (*Sesbania w*as row seeded with direct seeded rice and 2, 4-D was applied at 0.3 kg/ha to kill weed) + pendimethalin + 2, 4-D (0.3 kg) 25 DAS + HW where (Dhyani *et al.,* 2009). Keeping above facts in view the present investigation was carried out to evaluate performance of live mulches, cover crops and herbicides in direct seeded rice.

METHODOLOGY

An experiment was conducted at Agricultural Research Farm, Banaras Hindu University, Varanasi during *Kharif* season of 2014 and 2015 to study the effect of live mulches, cover crops and herbicides on weed management in direct seeded rice. The experiment comprised of nine treatments as given in the table no.1 replicated thrice in Randomized Block Design. Rice variety 'MTU-7029' was sown by zero till drill with 20 cm row spacing. A uniform dose of fertilizers 150 kg N, 60 kg P_2O_5 and 60 kg K_2O/ha were applied through urea,

Table 1. Effect of different treatments on weed density, weed control efficiency, grain and straw yields in direct seeded rice.(mean data of two years)

Treatment	Weed dry weight (g/m²)		Weed control efficiency (%)		Grain yield (t/ha)	Straw yield (t/ha)
	60 DAS	At harvest	60 DAS	At harvest		
Sesbania cover crop *fb* bispyribac Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS	2.46[e] (5.58)	2.61[g] (6.33)	90.68	89.98	4.83[b]	5.99[b]
Sunhemp cover crop *fb* Bispyribac Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS	2.48[de] (5.66)	2.94[f] (8.15)	90.54	88.67	4.76[bc]	5.77[b]
Sesbania cover crop *fbSesbania* coculture *fb*2, 4 D 0.5 kg/ha at 30 DAS	2.51[bcd] (5.81)	3.33[d] (10.64)	90.29	84.47	4.65[bcd]	5.70[b]
Sunhemp cover crop *fb* Sunhemp coculture *fb* 2, 4 D 0.5 kg/ha at 30 DAS	2.52[bcd] (5.88)	3.49[c] (11.71)	90.16	83.14	4.59[bcd]	5.68[b]
Sesbania coculture *fb* 2, 4 -D 0.5 kg/ha at 30 DAS	2.54[bc] (5.96)	3.57[c] (12.25)	90.04	81.91	4.54[cd]	5.60[b]
Sunhemp coculture *fb* 2, 4- D 0.5 kg/ha at30 DAS	2.55[b] (6.03)	3.72[b] (13.35)	89.92	80.21	4.50[d]	5.54[b]
Bispyribac Na 25 g/ha + azimsulfuron 30g/ha at 15 DAS	2.49[cde] (5.74)	3.13[e] (9.34)	90.41	86.11	4.70[bcd]	5.78[b]
Hand Weeding at 15 and 35 DAS	0.71[f] (0.00)	1.48[h] (1.71)	100.00	100.00	5.74[a]	7.08[a]
Weedy	7.76[a] (59.81)	8.30[a] (68.44)	0.00	0.00	2.35[e]	3.36[c]
CV (%)	0.88	2.28	-	-	3.08	6.3

Values in parentheses are original. Data were analyzed after square root transformation.

single super phosphate and muriate of potash. Data on weed growth and yield were recorded as per the standard procedure. Duncan Multiple Range Test (DMRT) was used for comparing treatment means.

RESULTS

At 60 DAS, *Sesbania* cover crop *fb* bispyribac Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS significantly reduced dry weight which was at par to Sunhemp cover crop *fb* Bispyribac Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS and Bispyribac Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS treatment. However, at 60 DAS and harvest, the same treatment had higherweedcontrol efficiency as compared to the rest of the treatments. *Sesbania* cover crop *fb* bispyribac Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS recorded significantly higher grain yield which was found at par to Sunhemp cover crop *fb* bispyribac Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS, *Sesbania* cover crop *fbSesbania* coculture *fb*2, 4 D 0.5 kg/ha at 30 DAS, Sunhemp cover crop *fb* Sunhemp coculture *fb* 2, 4 D 0.5 kg/ha at 30 DAS and Bispyribac Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS. Straw yield was significantly higher which was to at par with rest of weed management treatments except 2 hand weeding.

CONCLUSION

It may be concluded that *Sesbania* cover crop *fb* bispyribac Na 25 g/ha + azimsulfuron 30 g/ha at 15 DAS maximally reduced weed dry weight and recordedhigher weed control efficiency as compared to rest of the weed management treatments except two hand weeding.

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Bio-Efficacy of bentazone against weeds and yield of soybean (*Glycine max* L. Merill)

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Soybean (*Glycine max* L. Merill) is called "Golden Bean" or "Miracle crop" of the 21st century because of its multiple uses. In India, it is cultivated in 12.20 million hectare area with the annual production of 11.99 million tonnes and average productivity of 983 Kg/ha while in Madhya Pradesh, it is grown in 6.38 million hectare area with the production and productivity of 5.37 million tonnes and 842 kg/ha, respectively. (Annonymous, 2014). Apart from other constraints responsible for low productivity in the state, crop weed competition is one of the main constraint. Therefore, present investigation was undertaken with the object to assess the influence of different doses of Bentazone alone and in combination with Imazethapyr @ 100g/ha along with hand weeding / hoeing and weedy check on weeds, growth and yield of soybean.

METHODOLOGY

A field experiment was conducted during kharif season of 2015 at Product Testing Unit, College of Agriculture, JNKVV, Jabalpur The experiment was carried out on sandy clay loam soil analyzing medium in organic carbon (0.60 %), available nitrogen (367.00 kg/ha), phosphorus (16.23 kg/ha) and potassium (317.10 kg /ha) contents, neutral in reaction (7.1) and soluble salt concentration (0.34). The ten treatments comprising five doses of Bentazone (600, 800, 1000, 1200 and 1600 g/ha), Imazethapyr (100 g/ha) and Bentazone + Imazethapyr (625+50 g/ha) as post-emergence, hand weeding and hand hoeing twice at 20 and 40 DAS including weedy check, were laid out in randomized block design with 3 replications. The data on weeds, growth, yield attributes and yield of soybean were recorded.

RESULTS

It is apparent from the data presented in that in general, weed index was minimum under hand hoeing twice at 20 and

Table 1. Influence of herbicidal treatments on seed index, pods per plant, seed yield, weed index, net profit and benefit cost ratio

Treatment	Seed index(g)	Pods/ plant	Seed yield (kg/ha)	Weed index (%)	Net profit	B:C Ratio
T_1 Bentazone 600 g/ha	5.77	14.8	524	34.58	-3438	0.86
T_2 Bentazone 800 g/ha	5.80	15.2	568	29.09	-1834	0.93
T_3 Bentazone 1000 g/ha	5.84	16.8	598	25.34	-804	0.97
T_4 Bentazone 1200 g/ha	5.88	17.7	648	19.10	1046	1.04
T_5 Bentazone 1600 g/ha	5.93	18.1	683	14.73	2081	1.08
T_6 Imazethapyr 100 g/ha	6.03	19.3	730	8.86	5438	1.22
T_7 Bentazone + Imazethapyr 625+50 g/ha	5.97	18.7	687	14.43	3135	1.13
T_8 Hand weeding twice (20 and 40DAS)	6.17	21.5	801	-	-181	0.99
T_9 Hand hoeing twice (20 and 40DAS)	6.10	20.3	748	6.62	5146	1.20
T_{10} Control (weedy check)	5.23	10.5	394	50.81	-7868	0.67
CD (P=0.05)	0.46	3.55	92.234	-		

40 DAS (6.62) followed by post emergence application of Imazethapyr @ 100g/ha (8.86) (Table 1). Seed index of soybean varied appreciably due to different treatments. However, minimum seed index (5.23) was observed under weedy check plot and maximum under hand weeding (6.17). Among different herbicidal treatments higher seed index was recorded in case of Imazethapyr applied at 100 g/ha (6.03) followed by combined application of Bentazone+Imazethapyr @ 625+50 g/ha (5.97). The weed control treatments exerted significant effect on pods/plant. Increase in the dose of Bentazone (600 to 1600 g/ha) cause non-significant increase in pods/plant. Application of Imazethapyr @ 100 g/ha resulted in aprreciably more number of pods/plant (19.3) over all the doses of Bentazone and control. Though the pods/plant were maximum (21.5) under hand weeding twice closely followed by hand hoeing twice (20.3). The probable reason may be ascribed to greater accumulation of protein and its translocation to the reproductive organs which in turn maximized the yield components. Remarkable variations in seed yield were also noted. Application of Imazethapyr @ 100 g/ha gave significantly higher seed yield (730 kg/ha) in comparison to lower doses of Bentazone (600, 800 and 1000 g/ha) and control. Among the herbicidal treatments, Imazethapyr @ 100 g/ha registered appreciably higher seed yield closely followed by the combined application of Bentazone + Imazethapyr @ 625+50 g/ha. In all the teatments, hand weeding twice resulted in maximum seed yield (801 kg/ha). It was also noticed that application of Bentazone @ 1600 g/ha had appreciably more seed yield (683 kg/ha) over Bentazone applied at 600, 800 and 1000 g/ha. The crop under hand weeded plots and Imzethapyr @ 100 g/ha alone, Bentazone @ 1600 g/ha and their combination (50+625 g/ha) attained lush growth due to elimination of weeds resulted in more number of pods/plant and higher seed index which resulted in higher seed yield. In general, weedy check plot caused a loss of Rs 7868/ha owing to no adoption of any weed control measures. Application of Imazethapyr @ 100 g/ha fetched maximum net return (Rs 5438/ha) and B:C ratio (1.22) followed by hand hoeing twice at 20 and 40 DAS with NMR of Rs 5146/ha and B:C ratio of 1.20.

CONCLUSION

On the basis of one season data it could be concluded that application of Imazethapyr @ 100 g/ha followed by hand hoeing twice was more remunerative in terms of NMR (Rs 5438 and 5146/ha) and B:C ratio (1.22 and 1.20)

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Efficacy of different weed control methods on yield and economics in spring planting maize

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Maize (*Zea mays* L.) is an important cereal crop next only to rice and wheat in the country with acreage of around 8.3 m ha and production of 22.2 mt with the highest productivity of 5.2 t/ha. The average productivity of India is much low (25.07 q/ha) than the world average productivity (52 q/ha). Maize production suffers greatly due to weeds, which offers multifarious limitations in production. Weed interference in maize leads to 25 to 80% reduction in crop yield (Chikoye*et al*., 2004). It was found that due to continuous and heavy rains during the entire vegetative and early reproductive stages of maize growth, weeds infestation becomes unmanageable using the traditional method of inter-culturing and manual weeding. Though these methods are effective in controlling weeds during normal to low rainfall areas, they are tedious and time consuming besides labour intensive,costly and provide lower weed control efficiency (WCE). However, with the introduction ofherbicides, weed management has become timely, efficient, easy application that saves time and is more economical. Because of increased cost and non-availability of manual labour in the required quantity for hand weeding, herbicides not only control the weeds timely and effectively, but also offer a great scope for minimizing the cost of weed control irrespective of the situation. Use of pre-emergence (PRE) and post-emergence (POE) herbicides would make the herbicidal weed control more acceptable to farmers.

METHODOLOGY

A field experiment on the efficacy of different weed control methods on weed control efficiency in spring planted maize was conducted at Regional Research Station Karnal, CCS, Haryana Agricultural University, Hisar, Haryana during spring 2013. Twelve treatments of different herbicides and their combinations comprising of pendimethalin 1.0 and 1.5 kg/haPRE, atrazine 0.50 and 0.75 kg/haPRE and POE (15 DAS), metribuzin 140 and 210 g/ha applied PRE, tank mix PRE application of metribuzin 70 g/ha + atrazine 0.25 kg/ha

Table 1. Effect of different treatments on yield and economics

Treatments	Grain yield (q/ha)	Fodder yield (q/ha)	Total cost (Rs/ha)	Return over variable cost(Rs/ha)	B:C Ratio
Pendimethalin 1.0 kg/ha PRE	55.2	77.0	35500	44511	2.25
Pendimethalin 1.5 kg/ha PRE	56.6	78.7	36034	45458	2.26
Atrazine 0.50 kg/ha PRE	53.7	76.3	34734	43243	2.24
Atrazine 0.75 kg/ha PRE	55.5	77.3	34884	45551	2.30
Atrazine 0.50 kg/ha POE at 15 DAS	54.7	73.8	34734	44303	2.27
Atrazine 0.75 kg/ha POE at 15 DAS	55.9	75.5	34884	44895	2.31
Metribuzin 140 g/ha PRE	44.6	65.1	34746	30190	1.86
Metribuzin 210 g/ha PRE	41.5	56.8	34902	25643	1.73
Metribuzin 70 g/ha + atrazine 0.25 kg/haPRE	53.1	71.2	34665	34618	2.21
Pendimethalin 0.75 kg/ha + atrazine 0.25 kg/ha PRE	57.8	78.6	35384	48194	2.36
Atrazine 0.50 kg/ha PRE *fb* 2, 4-D Na salt 0.5 kg/ha at 40 DAS	56.3	75.6	34858	46455	2.33
Hoeing at 20 DAS*fb* atrazine 0.50 kg/ha (PRE to weeds)	59.3	79.9	42134	43539	2.03
Two hand hoeing (20 and 40 DAS)	61.1	80.5	49914	38177	1.76
Weedy check	36.8	52.5	34434	19051	1.55
Weed free	63.4	81.2	65124	26050	1.40
SEm±	1.6	2.0	-	-	-
CD (P=0.05)	4.8	6.0	-	-	-

and pendimethalin 0.75 kg/ha + atrazine 0.25 kg/ha, atrazine 0.50 kg/ha PRE fb 2,4-D Na salt 0.50 kg/ha at 40 DAS and hoeing at 20 DAS fb atrazine0.50 kg/ha PRE were compared with two hand weeding (HW) 20 and 40 DAS, weedy check and weed free treatment. All the fifteen treatments were arranged in a Random Block Design (RBD) with three replications. Full dose of phosphorus (60 kg/ha) and potassium (60 kg/ha) and 1/4th dose of nitrogen (37.5kg/ha) through DAP, MOP and Urea, respectively were applied as a basal dose at the time of sowing and remaining 3/4th dose of nitrogen (112.5 kg/ha) was top dressed through Urea in 3 equal splits i.e. at knee high stage, tasseling stage and dough stage. Hybrid maize CV. HQPM 1 was planted on 06 March 2013 using 20 kg seed/ha at row-row spacing of 60 cm and plant–plant spacing of 20 cm.

RESULTSAND DISCUSSION

Grain and fodder yield was significantly affected by weed control methods (Table 1). The highest grain and fodder yield was obtained in weed free whereas, the lowest in weedy check. Two HW (20 and 40 DAS), followed by hoeing at 20 DAS *fb*atrazine 0.50 kg/haPRE, recorded significantly higher grain yield as compared to rest of the treatments. In herbicidal treatments maximum grain yield recorded in pendimethalin 0.75 kg/ha+ atrazine 0.25 kg/haPRE.Return over variable cost influenced by different weed control treatments (Table 1). The return over variable was highest with pendimethalin 0.75kg/ha+ atrazine 0.25kg/ha PRE and lowest in weedy check. Maximum B:C ratio was recorded under pendimethalin 0.75 kg/ha+ atrazine 0.25 kg/haPRE and lowest in weed free. Among different weed control treatments net return and B:C ratio was highest in pendimethalin 0.75 kg/ha+ atrazine 0.25 kg/haPRE.

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Efficacy of post emergence herbicides for controlling weeds in pigeon pea (*Cajanus cajan*)

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In Madhya Pradesh, pigeonpea cultivated on 0.53 million hectare with an annual production of 0.35 million tonnes and productivity of 659 kg/ha during 2012-13 (Anonymous, 2013). During rainy season, initially slow growth and sowing in wider row spacing, infestation of weeds is sever which results in low grain yield. Hence, it is essential to use the post emergence herbicides coupled with pre emergence herbicides for the effective control of weeds. At present, Propaquizafop (50 g/ha) is found effective post emergence herbicide for controlling grassy weeds in soybean Singh (2010) reported that application of Imazethapyr (75 g/ha) was effective in controlling grassy as well as broad leaved weeds in soybean. Considering the above facts and availability of the newer herbicides it is imperative to find out the suitable post-emergence herbicide for controlling weeds in pigeon pea. Therefore, the present investigation was under taken to evaluate the efficacy of post emergence either alone or in combination to control weeds in pigeon pea.

METHODOLOGY

A field experiment was conducted during *rabi* season of 20014 at the product testing unit, JNKVV, Jabalpur. The treatment comprised of four doses of Propaquizafop 50, 62.5,100 and 125 g/ha, Fenoxaprop-p-ethyl 100 g/ha Imazethapyr 100 g/ha alone and combined application of Propaquizafop 62.5 g/ha+ Imazethapyr 75 g/ha and Propaquizafop 100 g/ha+ Imazethapyr 100 g/ha as post emergence, hand weeding twice (20 and 40 DAS) including weedy check, were laid out in randomized block design in three replications on *cv.* ICPL-87119.

RESULTS

Among the weed control treatments, combined application of Propaquizafop 100 g/ha + Imezethapyr 100 g/ha had higher WCE (82.22%) followed by Propaquizafop 62.5 g/ha + Imezethapyr 75 g/ha which curtail the weed biomass to 71.97%. However, the WCE was maximum (92.08%) under

Table 1. Effect of different herbicides on weed control efficiency, seed index, seed yield and net monetary return (NMR) of pigeon pea during 2014-15

Treatment	Weed control efficiency (%)	Seed index(g)	Seed yield (t/ha)	Harvest index (%)	NMR (Rs/ha)
Propaquizafop 50 g/ha POE	24.33	10.03	1.19	18.52	43952
Propaquizafop 62.5 g/ha POE	26.01	10.07	1.21	18.76	44736
Propaquizafop 100 g/ha POE	48.82	10.34	1.38	19.62	52227
Propaquizafop 125 g/ha POE	52.81	10.38	1.41	19.92	53512
Propaquizafop 100 g/ha POE	43.56	10.29	1.33	19.24	49043
Imezethapyr 100 g/ha POE	53.74	10.60	1.54	20.75	59483
Propaquizafop 62.5 g/ha + Imezethapyr 75 g/ha POE	71.97	10.80	1.80	22.65	70868
Propaquizafop 100 g/ha + Imezethapyr 100 g/ha POE	82.22	10.84	1.86	22.97	73164
Hand weeding twice (20 and 40 DAS)	92.08	11.07	1.98	23.54	70868
Weedy check	00.00	9.81	1.0	17.34	73164
SEm±	-	0.05	0.35	-	70323
CD (P=0.05)	-	0.15	1.06	-	35196

hand weeding twice. Among all the treatments the minimum seed index (9.81 g) and seed yield was observed under weedy check. Application of Propaquizafop at lower doses (50 and 62.5 g/ha) increased the seed index (10.03 and 10.07 g). But yield increased with the increase in the doses of Propaquizafop (50, 62.5, 100 and 125 g/ha) being higher (1.41 t/ha) at the higher dose of Propaquizafop 125 g/ha. Further improvement in seed yield was noticed with the application of Imazethapyr 100 g/ha (1.54/ha). The later treatment (i.e. Imazethapyr 100 g/ha) was superior over all the doses of Propaquizafop and Fenoxaprop-p-ethyl 100 g/ha. The minimum harvest index was noted under weedy check plots (17.34%) where. The index increased in ascending order with the increase in application of Propaquizafop at different doses (i.e. 50, 62.5, 100 and 125 g/ha), Fenoxaprop-p-ethyl 100 g/ha Imazethapyr 100 g/ha applied at alone. The combined application of Propaquizafop 100 g/ha+ Imezethapyr 100 g/ha resulted in higher value of HI (22.97%), which was closely followed by the combined application of Propaquizafop 62.5 g/ha + Imezethapyr 75 g/ha. However, hand weeding twice registered the maximum harvest index (23.54%). The minimum NMR of Rs. 35182/ha was recorded in weekly check and it was maximum (Rs. 73164/ha) with the combined application of Propaquizafop 100 g/ha + Imezethapyr 100 g/ha followed with combined application of these herbicides at 62.5 + 75 g/ha (Rs 70868/ ha). These findings suggests that weed control with combined application of Propaquizafop 62.5 g/ha + Imezethapyr 75 g/ha or Propaquizafop 100 g/ha + Imezethapyr 100 g/ha was more remunerative as compared to the hand weeding twice which fetched lesser NMR (Rs 70323/ ha) due to higher cost involved in cultivation of Rs 28418/ ha.

CONCLUSION

Among the herbicidal treatments, combined application of Propaquizafop 62.5 g/ha+ Imazethapyr 75 g/ha [post emergence] was found better for recording higher growth parameters, yield attributes and seed yield. However, hand weeding twice (20 and 40 DAS) was most suitable. Combined application of Propaquizafop 62.5 g/ha+ Imazethapyr 75 g/ha as post emergence was found more remunerative (NMR Rs. 70868/ ha)

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Possible allelopathic effect of brown mustard extracts on weed flora in transplanted rice

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Allelopathy is a mechanism in which chemicals produced by weed plants may increase or decrease the associated plant growth. Molish (1937), coined the term "allelopathy" as an interaction among the plants and the microorganisms. Rice (1984), defined allelopathy as the effects of one plant (including microorganisms) on another plant via the release of chemicals into the environments.Allelopathy is an interference mechanism, in which live or dead plant materials release chemical substances, which inhibit or stimulate the associated plant growth. Allelopathy, may also play an eminent role in the intraspecific and interspecific competition and may determine the type of interspecific association. The plant may exhibit inhibitory or rarely stimulatory effects on germination and growth of other plants in the immediate vicinity.Several workers have shown that allelopathy plays an important part in weed and weed interaction and weed crop interaction.

METHODOLOGY

A field experiment was carried out during *Kharif*, 2013 at Research Farm of SKUAST-Kashmir, Shalimar to evaluate the effect of brown mustard extracts in different dilutions on transplanted rice and associated weeds. Treatments include three soaking times (12, 24, 36 hr), four dilutions (100%, 1:10, 1:20, 1:30) and three applications times (5, 10, 15 days after transplanting) was laid out for comparison for finding out the best combination. These comprise of 36 treatment combinations which were replicated thrice. The experiment was laid out in Split Plot Design.

RESULTS

Weed flora in Weedy check control at 60 DAT mainly comprised of *Echinochloa crus gali* (25.5%), among grassy weeds *Ammania baccifera* (15.2%), *Gratula japonica* (12.3%), *Monocoriavignalis* (6.1%), *Aeschynomene indica* (10.2 %), and *Polygonum hydropiper* (10.7 %) among broadleaf weeds and *Cyperus difformis* (8.3%) and *Cyperusiria* (4.3 %) among sedges. All these weeds constitute about 92.6 % of total weed population. The other weeds which appear in very low density (7.4%) were *Alisma plantegoaquatica*, *Lindernia procumbens*, and *Eclipta alba*. The maximum density of total weeds was found in weedy check control plot. Among treatment combinations the lowest density was observed with the application of 100 percent brown mustard extract of 36 and 24 hrs soaking at 5 and 10 DAT followed by 1:10 dilution brown mustard extract of 36 and 24 hrs soaking at 5 and 10 DAT which in turn is followed by100 percent brown mustard extract of 12 hrs soaking at 5 and 10 DAT and then by 1:10 dilution. This resulted due to presence of Allylisothiocynate present in the straw of the brown mustard, which has a depressing effect on weeds. There was a detectable impact on thegrowth by the weed explained according to Shaukat&Siddiqui (2001) due to inhibitory compounds in soil which cause marked reduction or stop growth of plant. Present trial alsoshowed the same effect.Uncontrolled growth of weeds (weedy check) resulted in 75% reduction in grain yield of rice. The highest recorded yield of rice due to influence of most effective weed control treatment combinations was in the order of Brown mustard extracts (100%) of 36 hrs sprayed at 5 DAT (8.67 t/ha) > Brown mustard extracts (100%) of 36 hrs sprayed at 10 DAT (8.12 t/ha) > 1:10 percent dilution of 36 hr at 5 DAT (7.83 t/ha) >100 percent concentrates of brown mustard extracts of 24 hr at 5 DAT (7.67 t/ha) > 1:10 percent dilution of 36hr at 15 DAT (7.2 t/ha) > 1:10 percent dilution of 24 hr at 5 DAT (7 /ha). However least yield was recorded in weedy check plots (2 t/ha).

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Evaluation of tillage and weed control methods on productivity and profitability of maize-wheat cropping system

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Maize (*Zea mays* L.) has wide adaptability and compatibility under diverse soil and climatic conditions and hence it is cultivated in sequence with different crops under various agro-ecologies of the country. The weeds are the major problem in the productivity of maize – wheat system. Weeds can be controlled effectively by the conservation tillage which includes reduced tillage. Hence, considering the above facts in view, an experiment was conducted with the objective to find out the effect of tillage and weed control methods on productivity of maize-wheat cropping system.

METHODOLOGY

The present investigation was conducted in agronomical farm of Birsa Agricultural University, Ranchi during 2013-14 and 2014-15. The experimental soil was low in available nitrogen (167 kg/ha) and medium in phosphorus (19 kg/ha) and potash (187 kg/ha) and the pH was 6.2. The treatments comprised of five different tillage sequences in main plots i.e. conventional tillage both in rainy and winter seasons (CT-CT), conventional tillage in rainy and zero tillage in winter seasons (CT-ZT), zero tillage both in rainy and winter seasons (ZT-ZT), zero tillage in rainy and zero tillage along with crop residue in winter season (ZT-ZT+R) and zero tillage along with crop residue in rainy and winter seasons (ZT+R-ZT+R). Weed control methods in sub plots namely recommended herbicide i.e. atrazine 1.0 kg/ha pre emergence in maize and 2,4-D 0.5kg/ha post emergence in wheat (RH – RH), integrated weed management containing intercropping with black gram + pre emergence application of pendimethalin 1.0 kg/ha followed by (*fb*) manual weeding at 30 days after sowing (DAS) in maize and application of 2,4-D 0.5 kg/ha post emergence in wheat *fb* hand weeding at 40 DAS (IWM-IWM), and weedy check in rainy and winter seasons (WC-WC). Maize variety 'Suwan' composite' and wheat 'K9107' were sown during both the years under irrigated conditions. The recommended dose of N, P_2O_5 and K_2O for maize and wheat was 120:60:40 kg/ha.

RESULTS

Conventional tillage performed in rainy and winter seasons (CT-CT) significantly affected system yield (8019 kg/ha) and gross return (Rs 120290/ha) during 2013-14, while during

Table 1. Effect of tillage and weed control methods on yield and economics of maize- wheat cropping system (pooled of 2 years)

Treatment	System yield (kg/ha)	Cost of cultivation (Rs./ha)	Gross return (Rs/ha)	Net Return (Rs/ha)	B:C ratio
Tillage Method					
CT-CT	7650	43194	114748	71554	2.64
CT-ZT	7206	41444	108096	66652	2.61
ZT-ZT	7250	37144	108751	71607	2.92
ZT-ZT+R	7690	37144	115353	78209	3.13
ZT+R-ZT+R	7915	37144	118725	81581	3.22
SEm±	220		3306	3306	0.09
CD (P=0.05)	NS		NS	NS	0.29
Weed control					
R H — RH	7898	37093	118476	81383	3.22
IWM – IWM	8603	46296	129051	82754	2.79
WC – WC	6125	34252	91877	57625	2.70
SEm±	135		2020	2020	0.05
CD (P=0.05)	529		7928	7928	0.20

2014-15, ZT+R-ZT+R being similar to ZT-ZT+R and ZT-ZT recorded maximum net return (Rs 94086/ha) and B:C (3.57) (Table 1). In case of pooled analysis ZT+R-ZT+R was similar to ZT-ZT+R recorded maximum B:C ratio (3.22) which was 18.01%, 18.94%, 9.32% and 2.80% more than CT-CT, CT-ZT, ZT-ZT, ZT-ZT+R tillage sequences, respectively owing to saving in tillage operations thus reduced cost of cultivation.Integrated weed management (IWM–IWM) sequences in maize–wheat recorded maximum system yield as well as gross return during both the years and in pooled analysis. The increase in pooled yield was 8.19% and 28.80% and gross return was 8.19% and 28.81% than RH-RH and WC-WC, respectively. IWM-IWM recorded maximum net return similar to RH-RH, which was 1.66% and 30.37% more than RH-RH and WC-WC, respectively. However, application of RH-RH in maize and wheat recorded maximum B:C ratio that was 13.35 and 16.15% more compared to IWM-IWM and WC-WC.

CONCLUSION

It can be concluded that in maize-wheat system zero tillage sequences with or without residue is more beneficial than conventional tillage. Application of recommended herbicide in maize and wheat is more profitable to farmers while, integrated weed management sequences in maize–wheat is the second profitable method for controlling weeds and attaining higher yield.

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Weed management in high density planting system of *hirsutum* cotton compact genotype

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High density planting systems (HDPS) using varieties is an option for sustainably improving yields and also improves the input use efficiency. Cotton being a long duration and widely spaced crop is very prone to weed infestation and loss of seed cotton yield in India due to weeds ranged from 50 to 85%. No single weed management technique is enough for controlling vast species range and agro-climates of India. Manual weeding is becoming prohibitive due to increased scarcity of labor, and cost of cultivation. The opportunities for interculture are limited in HDPS and hence weed management becomes more critical. Nevertheless, early closure of canopy results in reduced weed competition. However improper plant stand due to uneven germination and seedling establishment may increase weed density within crop rows and these weeds are difficult to manage and under these circumstances, application of post emergence herbicides become necessary (Venugopalan *et al.,* 2013). Many pre emergence herbicides presently used in cotton for weed control take care of weeds for a limited period and are not able to control the late emerging weeds (Rao, 2011). The option of a combination of the herbicides or single application of either of them depends upon the nature of weed flora.

METHODOLOGY

A Field experiment was conducted at Agricultural Research Station, Dharwad, Karnataka, India during*kharif* season of 2015-16. The soil was medium deep black clay having pH 7.01 and electrical conductivity (EC) of 0.20 dS/m. The soil had medium organic carbon (0.51%), low available nitrogen (215.0 kg/ha), high available phosphorus (31.0 kg/ha) and high available potassium (550.0 kg/ha). Twelve treatments comprising T_1: pendimethalin 30 EC @1.5 kg a.i./ha (PE) fb quizolofop ethyl 5 EC @ 50 g a.i./ha(Post emergent at 30 DAS); T_2: pendimethalin 30 EC @ 1.5 kg a.i./ha (PE) fb pyrithiobac sodium 10 EC@ 62.5 g a.i./ha (POST at 30 DAS); T_3: pendimethalin 30 EC@ 1.5 kg a.i./ha (PE) fb quizolofop ethyl 5 EC @ 50 g a.i./ha+ pyrithiobac sodium 10EC @ 62.5 g a.i./ha tank mix @ 30 DAS; T_4: quizolofop ethyl 5 EC @ 50 g a.i./ha+pyrithiobac sodium 10EC @ 62.5 g a.i./ha tank mix @ 30 DAS; T_5: T_4 fb glyphosate directed

Table 1. Effect of weed management strategies on seed cotton yield (kg/ha), weed dry wt. (g/m^2) and weed control efficiency at 60 DAS of *hirsutum* compact genotype under HDPS.

Treatments	No. of Bolls/ plant	Boll Wt (g)	Seed cotton yield	Weed dry wt.	WCE (%)
Pendimethalin@1.5 kg a.i./ha (PRE) fb quizolofop ethyl@50 g a.i./ha (POST at 30 DAS) (Recommendation)	8.40	4.68	2095	25.67	77.75
Pendimethalin@1.5 kg a.i./ha (PE) fb pyrithiobac sodium@62.5 g a.i./ha (POST at 30 DAS)	8.70	4.77	2139	23.00	79.87
Pendimethalin@1.5 kg a.i./ha (PE) fb quizolofop ethyl@50 g a.i./ha+ pyrithiobac sodium@62.5 g a.i./ha tank mix @ 30 DAS	9.10	4.78	2231	16.33	85.85
Quizolofop ethyl@50 g a.i./ha+pyrithiobac sodium@62.5 g a.i./ha tank mix @ 30 DAS	7.47	4.33	1827	41.00	63.80
T_4 fb glyphosate directed spray @ 1.0 kg a.i./ha at 60 DAS	7.30	4.65	2071	36.67	68.10
Pendimethalin@1.5 kg a.i./ha (PE) fb glyphosate directed spray @ 1.0 kg a.i./ha at 30 & 60 DAS	7.47	4.67	2069	32.33	71.61
Fp (2 intercultivations & 2 hand weeding)	7.20	4.53	1799	42.33	63.11
Weed free check	9.27	4.80	2484	0.00	100.00
Weedy check	5.90	4.28	1397	115.64	0.00
SEm ±	0.41	0.13	98	3.58	2.74
CD (P=0.05)	1.22	NS	294	10.72	8.21

spray @ 1.0 kg a.i./ha at 60 DAS ; T_6: pendimethalin 30 EC @ 1.5 kg a.i./ha (PE) fb glyphosate 72 SG directed spray @ 1.0 kg a.i./ha at 30 and 60 DAS; T_7: farmers practice (2 intercultivationand 2 hand weeding); T_8: weed free check and T_9: weedy check were laid out in a randomized block design with three replications.DSC-1351 compact *hirsutum* variety was sown under high density planting system(90cm×10cm). One intercultivation & one hand weeding was done at 45-50 DAS for treatment T_1 to T_6. The crop was fertilized with 60:30:30 kg NPK/ha. Weed control operations were executed as per treatments. The periodical observations on weeds and cotton growth and yield were recorded.

RESULTS

Weed management practices had significant effect on seed cotton yield (table 1). Pendimethalin 30 EC @ 1.5 kg a.i./ha (PE) fb quizolofop ethyl 5 EC@ 50 g a.i./ha+pyrithiobac sodium 10EC @ 62.5 g a.i./ha tank mix @ 30 DAS recorded the highest seed cotton yield (2231 kg/ha) closely followed by (T_2) i.e. pendimethalin 30 EC @ 1.5 kg a.i./ha (PE) fb pyrithiobac sodium 10 EC@ 62.5 g a.i./ha(POST at 30 DAS) with SCY of 2139 kg/ha and T_1 i.e., pendimethalin 30 EC @ 1.5 kg a.i./ha (PRE) fb quizolofop ethyl 5 EC @ 50 g a.i./ ha(POST at 30 DAS) (2095 kg/ha). The SCY obtained under T_3 (pendimethalin 30 EC @ 1.5 kg a.i./ha (PRE) fb quizolofop ethyl 5 EC @ 50 g a.i./ha+pyrithiobac sodium 10EC @ 62.5 g a.i./ha tank mix @ 30 DAS) was on par with the SCY obtained with the weed free check (2484 kg/ha). Lowest seed cotton yield was obtained with weedy check (1397 kg/ ha).Weed free check recorded significantly higher no. of bolls/plant (9.27), boll weight (4.8 g) and Seed cotton yield per plant (34.32 g/plant) closely followed bypendimethalin 30 EC @ 1.5 kg a.i. as pre emergent followed by post emergent application of quizolofop ethyl 5 EC @ 50 g a.i./ ha+pyrithiobac sodium 10EC @ 62.5 g a.i./ha tank mix at 30 DAS (9.10 4.78 gand 34.13 g/plant,respectively). Lower weed dry weight and higherweed controlefficiency (WCE) were recorded with T_3(pendimethalin 30 EC @ 1.5 kg a.i./ha (PRE) fb quizolofop ethyl 5 EC @ 50 g a.i./ha+pyrithiobac sodium 10EC @ 62.5 g a.i./ha tank mix @ 30 DAS) at 60 DAS (16.33 & 85.85%, respectively) and closely followed by T_2 (pendimethalin 30 EC @ 1.5 kg a.i./ha (PRE) fb pyrithiobac sodium 10 EC@ 62.5 g a.i./ha (POST 30 DAS). All other herbicide treatments had higher weed dry weight and lower weed control efficiency.

CONCLUSION

Based on the seed cotton yield of different weed management strategies under HDPS, it was concluded that post emergent application of quizolofop ethyl 5 EC @ 50 g a.i./ ha+pyrithiobac sodium 10EC @ 62.5 g a.i./ha (tank mix) at 30 DAS with one intercultivation & one hand weeding at 45-50 DAS is optimum and best alternative to the present recommendation of pendimethalin 30 EC @ 1.5 kg a.i./ha (PRE) fb quizolofop ethyl 5 EC @ 50 g a.i./ha+pyrithiobacsodium 10EC @ 62.5 g a.i./ha tank mix @ 30 DAS for the *hirsutum* varieties under HDPS.

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Utility of microbes in alleviating water stress for growth and yield of rainfed paddy

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Rice production in Asia needs to be escalated to feed the increasing population. There are signs that declining water quality and quantity, is threatening the productivity and sustainability of the rice-based production systems. During present scenario, drought is one of the main constraints for high yield of rainfed rice. Exploring ways to produce more rice with less water demand, should be the utmost priority to fulfill the demandand sustaining the environment. The present investigation was carried outto improve the growth and yield of rainfed paddy through intervening the microbes, at Distant Research Centres of CSIR-NBRI, Lucknow. Two varieties, '*Heena*' and '*Kiran*' were transplanted at different water stress levels including no irrigation, one irrigation at maximum tillering stage, and irrigations at critical growth stages. These paddy varieties were treated with different strains of *Trichoderma* and *Pseudomonas* developed by CSIR-NBRI, Lucknow, to find out the performance of these microbes in terms of improved growth and yield of paddy, under water stress conditions. During the investigation, '*Heena*' responded well in terms ofgrowth and yield, with combined treatment of *Trichoderma* and *Pseudomonas* during different water stress levels. In both the varieties, moisture stress reduced the 100 seed weight, however the degree of reduction was different within varieties. Lower soil moisture might be a reason, to decrease translocation of assimilates to the grain resulting shrinking the seed size and lowering its weight, ultimately resulting in reduction in grain yield. Kiran was more influenced by moisture scarcity.

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Effect of integrated weed management on weed control, yield attributes and yield of aerobic rice (*Oryza sativa* L.)

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The field investigation was conducted during *Kharif* season of 2013 at Upland Paddy Research Scheme Farm, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani with an object to find out best method of weed management under aerobic rice and to develop cost effective weed management in aerobic rice system. The experiment was laid out in Randomized Block Design (RBD) with eleven treatments. The treatments were T_1-POE-Byspyribac-sodium (10% SC) @ 35 g/haat 15-20 DAS, T_2-POE-Byspyribac-sodium (10% SC) @ 35 g/haat 15-20 DAS + one hoeing at 45 DAS, T_3-PE-Pendimethalin (30EC) @1.00 kg/ha at 3-4 DAS + POE-Bispyribac-sodium (10%SC) @ 35 g/ha at 15-20 DAS, T_4-PE-Butachlor (50EC) @ 1.5 kg/ha at 3-4 DAS + POE-Bispyribac- sodium (10%SC) @ 35 g/ha at 15-20 DAS, T_5-

Table 1. Effect of different weed management treatments on grain yield (t/ha), weed density, weed dry weight (g/m^2) andweed control efficiency (%)

Treatment	Grain yield (t/ha)	Weed density at 60 DAS		Weed dry weight at 60 DAS (g/m^2)		WCE (%)
		Monocot and sedges	Dicot	Monocot and sedges	Dicot	
POE-Bispyribac-sodium (10% SC) @ 35 g/ha	2.55	3.15 (7.05)	4.96 (19.90)	3.93 (11.83)	6.28 (33.42)	57.71
POE-Bispyribac-sodium (10% SC) @ 35 g/ha fb one hoeing	3.30	2.95 (6.03)	4.37 (15.03)	3.42 (8.56)	5.12 (21.37)	72.02
PE-Pendimethalin (30EC) @1.00 kg/ha fb POEBispyribac sodium (10%SC) @ 35 g/ha	3.50	3.14 (7.02)	3.96 (12.00)	3.56 (9.41)	4.58 (16.66)	75.63
PE-Butachlor (50EC)@ 1.5 kg/ha fb POE Bispyribac-sodium (10%SC) @ 35 g/ha	3.40	2.75 (5.10)	4.24 (14.01)	3.43(8.61)	4.94 (19.77)	73.47
PE-Pendimethalin (30EC) @1.00 kg/hafb POE- Mesulfuron methyal + chlorimuron (20WP) @ 40g/ha	2.90	2.51 (4.06)	4.38 (15.06)	3.36 (8.18)	5.28 (22.85)	71.00
PE-Butachlor (30EC) @ 1.00 kg/ha fb POE Almix (20WP) @ 40 g/ha	2.80	2.94 (6.00)	4.75 (18.07)	3.34 (8.09)	5.43 (24.38)	69.96
POE-Azimsulfuron @ 20-30 g/ha	2.40	3.16 (7.09)	4.54 (16.40)	4.28 (14.31)	5.43 (25.97)	62.35
PE-Butachlor @ 1.00 kg/hafb1HW	3.60	2.92 (5.88)	3.7 (10.00)	4.02 (12.46)	5.59 (21.21)	68.55
2 Hand weeding fb 2 hoeing	3.71	2.74 (5.05)	3.56 (9.38)	3.92 (11.74)	5.10 (17.58)	77.57
3 Need based hand weeding	3.90	2.23 (3.00)	2.52 (4.12)	2.00 (2.26)	2.26 (3.11)	94.79
Unweeded control	1.50	3.50 (9.06)	6.48(35.80)	4.89 (17.62)	9.95 (89.38)	-
CD (P=0.05)	0.195	0.45	1.07	0.62	3.63	-

Figures in parentheses are transformed values.

PE-Pendimethalin (30EC) @ 1.00 kg/ha at 3-4 DAS + POE-MSM+CME (20WP) @ 40 g/ha at 25-30 DAS, T_6-PE-Butachlor (50EC) @ 1.00 kg/ha at 3-4 DAS + POE-MSM+CME (20WP) @ 40 g/ha at 25-30 DAS, T_7-POE-Azimsulfuron @ 20-30 g/haat 20 DAS, T_8-PE-Butachlor @ 1.00 kg/ha+ 1 HW at 30 DAS, T_9- 2 HW at 20 and 45 DAS + 2 hoeing at 25 and 45 DAS, T_{10}-3 Need based hand weeding, T_{11}-Unweeded control. Each treatment was repeated three times having gross and net plot size of 4.0 m x 4.5 m and 3.0 m x 3.6 m, respectively. Variety used for experimental study was PBNR-03-02 with recommended dose of fertilizer of 80:50:50 NPK kg/haand 60 kg seed rate/ha. Sowing was done by hand drilling on 02nd July, 2013. Experimental results revealed that, 2 hand weeding + 2 hoeing (T_9) recorded significantly higher grain yield (3.71t/ha), straw yield (5.80 t/ha), and NMR (29650 Rs/ha), lowest weed index (5.12) and higher weed control efficiency (72.59%) over rest of the weed control treatments. Amongst herbicides or combination of herbicides with cultural practices/ another herbicide, PE-Butachlor @ 1.00 kg/ha+ 1HW (T_8) recorded the highest grain (3.71t) and straw (5.80 t) yield, and NMR (30550 Rs/ha) than rest of the herbicides or integrations of herbicides. Amongst, application of single herbicide or combination of two herbicides, PE-Pendimethalin (30EC) @ 1.00 kg/ha + POE-Bispyribac-sodium (10%SC) @ 35 g/ha (T_3) recorded the highest grain (3.50 t) and straw yield (5.50 t) and NMR (28980 Rs/ha) than rest of the herbicides or herbicide combinations and was at par with PE-Butachlor (50 EC) @ 1.5 kg/ha + POE-Bispyribac-sodium (10%SC) @ 35 g/ha(T_4). Amongst herbicides and combination of herbicides, PE-Pendimethalin (30EC) @ 1.00 kg/ha + POE-Bispyribac-sodium (10%SC) @ 35 g/ha (T_3) recorded the lowest weed count, weed dry weight, weed index (10.25) and highest weed control efficiency (75.63%) than rest of the herbicides or combination of herbicides and was at par with PE-Butachlor (50 EC) @ 1.5 kg/ha + POE-Bispyribac-sodium (10%SC) @ 35 g/ha (T_4) at 60 DAS. Per cent NMR loss due to unweeded control (T_{11}) was 90.01 comparable to weed free plot. % reduction in NMR with PE-Butachlor @ 1.00 kg/ha+ 1HW (T_8) and PE-Pendimethalin (30EC) @ 1.00 kg/ha + POE-Bispyribac-sodium (10% SC) @ 35 g/ha (T_3) was 6.14 and 11.05, respectively comparable to weed free plot. *Similar results were reported by* Walia *et al.* (2009) and Khawar Jabran *et al*. (2012) due to herbicides or combination of herbicides.

CONCLUSION

Post emergence application of bispyriback-sodium (10% SC) @ 35 g/haat 10-15 DAS along with pre emergence application of pendimethalin (30 EC) @1 kg/haor butachlor (50 EC) @ 1.5 kg/ha showed highest weed control efficiency, grain yield, straw yield and net monitory returns amongst various combination of herbicides in present investigation.

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Integrated weed management in sweetcorn (*Zea mays* var. *saccharata*)

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Sweetcorn (*Zea mays* L.var. *saccharata* Sturt)gaining gradual momentum in the Gujarat state owing to big market potential. There are some production problems and weed problem is one of them owing to wider spacing and non-tillering habit. Uncontrolled weed growth throughout the crop growing period caused 43% reduction in grain yield of maize. Herbicides alone or in combination with other weed management techniques reduce weed-crop competition and the risk of weeds growing unchecked in initial growing period. Hence, it seems worthwhile to study integrated weed management in sweetcorn.

METHODOLOGY

A field experiment was conducted at Weed Control Research Scheme, Department of Agronomy, College of Agriculture, Junagadh Agricultural University, Junagadh (Gujarat) during summer seasons of 2013 to 2015. The soil of the experimental plot was clayey in texture and slightly alkaline in reaction (pH 7.8 and EC 0.34 dS/m) as well as low in available nitrogen (228-237 kg/ha), available phosphorus (21-24 kg/ha) and medium in available potash (267-375 kg/ha). The experiment comprising of eight treatments *viz.*, T_1: atrazine0.5 kg/ha aspre-emergence *fb*IC &HW at 40 DAS, T_2: pendimethalin 0.9 kg/ha aspre-emergence *fb*IC &HW at 40 DAS, T_3: oxadiargyl75 g/ha aspre-emergence *fb*IC &HW at 40 DAS, T_4: IC & HW at 20 DAS *fb* 2,4-D (SS) 0.5 kg/ha as post-emergence at 40 DAS,T_5: IC & HW at 20 DAS *fb* Metsulfuron methyl 4 g/ha as post-emergence at 40 DAS,T_6: HW & IC twice at 20 and 40 DAS,T_7: weed-free check, and T_8: weedy check was laid out in randomized block design with three replications. The sweetcorn variety 'Madhuri' was sown at 60 cm x 20 cm spacing using seed rate of 25 kg/ha. The crop was fertilized with 120-60-0 kg N-P_2O_5-K_2O/ha; the half N and full Pas basal and half N at 30 DAS. The pre-emergence herbicides were applied to soil on next day of sowing, while post-emergence spray was done at 40 DAS. The spray volume herbicide application was 500 L/ha. The crop was raised as per the recommended package of practices.

RESULTS

Weed management practices significantly influenced growth and yield attributes of sweetcorn (Table 1). Significantly the highest plant height, cob length, cob girth, grains/cob and fresh weight of cob were recorded under the weed-free check, however it remained mostly at par with atrazine *fb* IC & HWand pendimethalin *fb* IC & HW.Whereas, significantly the lowest values of these growth and yield attributes were registered under the weedy check. The data furnished in Table-2 showed that different weed management treatments significantly influenced the cob and fodder yields of sweetcorn. The weed-free check out yielded by producing significantly the highest mean cob yield of 8376 kg/ha and fod-

Table 1. Effect of integrated weed management on growth and yield attributes of sweetcorn (Pooled over three years).

Treatment	Plant height (cm)	Cob length (cm)	Cob girth (cm)	Grains/ cob	Fresh cob weight (g)
Atrazine + IC & HW	158	20.9	16.9	318	182
Pendimethalin + IC & HW	156	20.7	16.0	314	179
Oxadiargyl + IC & HW	134	16.4	12.7	238	171
IC & HW + 2,4-D	146	17.9	14.8	282	166
IC & HW + Metsulfuron	141	17.3	13.7	222	160
IC & HW twice	155	19.6	15.4	311	180
Weed-free check	158	21.2	17.2	325	185
Weedy check	118	15.8	11.2	196	141
S.Em.±	4	0.5	0.5	10	4
CD (P=0.05)	11	1.3	1.5	29	11

Table 2. Effect of integrated weed management on yield of sweetcorn and weed dry weight (Pooled over three years).

Treatment	Cob yield (kg/ha)	Fodder yield (kg/ha)	Weed dry weight (kg/ha)	WCE (%)	B:C
Atrazine + IC & HW	8180 a	25605 ab	167 e	90.67	3.25
Pendimethalin + IC & HW	7804 ab	24472 bc	204 de	88.57	3.08
Oxadiargyl + IC & HW	3143 e	13829 e	1150 b	35.60	1.34
IC & HW + 2,4-D	6608 c	21848 c	574 c	67.84	2.68
IC & HW + Metsulfuron	4542 d	17151 d	1076 b	39.75	1.91
IC & HW twice	7127 bc	23328 bc	280 d	84.34	2.78
Weed-free check	8376 a	28634 a	31 f	98.24	2.85
Weedy check	2507 e	10404 f	1786 a	0.00	1.17
S.Em.±	294	1082	26		
CD (P=0.05)	840	3089	73		

der yield of 28634 kg/haover three years. The next best treatments in this regard were atrazine *fb* IC & HWand pendimethalin *fb* IC & HW. These treatmentsincreased cob yield by 234, 226 and 211%over the unweeded control having B:C ratio of 2.85, 3.25 and 3.08, respectively. Efficient control of weeds and improved growth and yield attributes under these treatments might have reflected in increased cob and fodder yields. The data (Table 2) indicated that different weed management treatments exerted significant effect on dry weight of weeds. The weed-free recorded significantly the lowest dry weight of weeds, followed by atrazine *fb* IC & HW,pendimethalin *fb* IC & HW and HW & IC twice havingWCE of 98.24, 90.67, 88.57 and 84.34%, respectively.

CONCLUSION

It was concluded that effective control of weeds in summer sweetcorn along with higher yield could be achieved by pre-emergence application of either atrazine 0.5 kg/ha or pendimethalin 0.9 kg/hasupplemented with IC & HWat 40 DAS under south Saurashtra agro-climatic conditions of Gujarat.

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On-farm validation of integrated pest management in basmati rice cultivar pusa-1121: a success story

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Pusa Basmati 1121, a high yielding aromatic rice variety released is widely popular among farmers of Punjab, Western Uttar Pradesh and Haryana in India due to higher yield and good price in the market. But, the variety is highly susceptible bakanae foot rot disease (*Fusarium fujikuroi).* Incidence of the disease varies from 20-50% at different locations. Bamabwad village in district Gautam Budh Nagar (UP) is a hot spot for bakanae disease as the area is dominated by Pusa Basmati 1121 (80%). Based on the baseline information collected, ICAR-National Research Centre for Integrated Pest Management (NCIPM) synthesized an integrated pest management (IPM) module and validated the module at Bambawad village in farmers' participatory mode during 2013-15. The trial was conducted in initiated 200, 286 and 350 ha during 2013, 2014 and 2015, respectively. The IPM module involved green manuring, seed treatment with carbendazim, seedling root dipping in *Pseudomonas fluorescens,* planting of two-three seedlings /hill, judicious use of fertilizers, pest monitoring and need-based application of bioagents/ pesticides. Farmers' practices (FP) generally followed in the area comprised of growing crop without green manuring and no seed treatment, planting of one seedlings /hill, higher doses of fertilizer (220 N: 40 P: 0 K kg /ha), no pest monitoring and application of 2-4 chemical pesticides (Cartap hydrochloride, phoratae, carbofuran, monochrotophos, hexaconazole, dichlorovos and streptocycline, etc.) on the advice of pesticide dealers. Zinc sulphate was also used by a few farmers in FP fields but in low doses. Incidence or population of major insect pests and diseases along with beneficial spiders was recorded at weekly intervals from 40 IPM fields and 20 FP fields of 0.40 ha each by selecting 20 hills (five spots; four hills from each spot) per field. Records of all the inputs applied in fields and the grain yield were maintained to calculate benefit-cost ratio (Total return/total cost). Total cost included the material cost along with labour cost for land preparation, nursery sowing, transplanting, fertilizer application, hand weeding, pesticide application, Irrigation etc. Soil analysis was carried out for availability of organic carbon, nitrogen, phosphorus, potash and zinc in IPM and FP fields (five fields from each block) and for microbial population. Rice grain samples from 10 fields (five samples each from IPM and non IPM fields; 200 g per sample) were got analyzed for the presence residue of carbendazim, carbofuran, buprofezin and phorate using Liquid Chromatography (LC/MS/MS). Farmers Field School (FFS) were organized at 15 days interval in adopted village during each crop season for dissemination of IPM strategies. FFS included the training on identification of insect pests, diseases and beneficial, Economic Threshold level (ETL) concept, use of bioagents and management tactics including safer pesticides.

RESULTS

Implementation of the module resulted in a significant reduction in the incidence of bakanae in IPM fields. Brown plant hopper (*Nilaparvata lugens*) population (average of the season) remained, 1.22, 4.32 and 0.49 nymphs and adults /hill in IPM against 1.36, 7.24 and 0.82 in FP fields during 2013, 2014 and 2015, respectively. Regular pest monitoring and ETL-based application of pesticides helped in conservation of spider population in IPM as compared to FP with very low application of chemical pesticides i.e., 39.33 g air./ha. in IPM as compared to FP 619.67 g a.i./ha. [Average of 2013-15]. Soil samples, in the present study, indicated 26.5 and 121.9% higher available N and Zn in IPM over FP, respectively. Analysis of rice grain samples for pesticide residue indicated carbendazim below detectable level. IPM trial also resulted higher yield (36.85 q/ha in IPM against 29.90 q/ha in FP) and benefit- cost ratio (4.00 in IPM and 2.75 in FP) as compared to FP (Average of three years).

CONCLUSION

It is evident from the study that regular pest monitoring, adoption of IPM package along with green manuring resulted in higher benefit-cost ratio with lesser application of chemical pesticides in IPM as compared to FP. Organizing FFS at regular interval adopted in the present trial, helped in developing strong linkages among farmers, scientists, extension workers and enabled farmers to understand the role of monitoring, concept of ETL and need based application of pesticides.

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Relative performance of flucetosulfuron for weed control in direct seeded rice under puddled irrigated conditions

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Rice production in India is an important part of the national economy. Water shortage during flowering and grain filling stages reduce grain yields drastically. Delay in flowering under water limiting conditions is a function of lower water status and the delay in maturity of rice varieties could relate to drought susceptibility (Guhey *et al.,* 2004). There are several reasons held responsible for low productivity in direct seeded rice. Weeds caused most serious problem in rice fields because of the liberal use of organic manures, chemical fertilizers and irrigation, which provides congenial conditions for weed growth. It has been well established that losses from weeds accounts for 45 % more than when compared to insect pests and diseases of about 30 and 20 % respectively (Rao, 1983). The early growth period is the most critical stage for weed competition in rice. Hand weeding is a common method of weed control adopted by farmers but comparatively this method is costly and time consuming. This problem assumes added significance due to non-availability of adequate laborers during peak period of weed competition. But due to high wages and unavailability of labourers timely control of weeds is not possible by hand weeding. Under such condition the use of suitable herbicides is the better substitute to gain high productivity with low cost. Ample scopes exist for improving herbicides besides with hand weeding or alone herbicides for the purpose of increasing productivity and reducing cost of cultivation (Mishra and Singh 2007). Post-emergence herbicides kill weeds and keep the hardy uncontrolled weeds under control by arresting their growth through various kinds of deformities in foliage and growing point. Keeping in view, the present investigation was carried out to study relative performance of flucetosulfuron for weed control in direct seeded rice under puddled irrigated conditions.

METHODOLOGY

The experiment field is situated in the North eastern part of Madhya Pradesh, Rewa, at 200º 21' North latitude, 810º 15'East longitude and 365.7 meters above sea level. The study was conducted during two consecutive *Kharif* seasons of 2011 and 2012 at Research Farm of College of Agricultural, Rewa, Madhya Pradesh. Total annual rainfall is about 39 inches (980 mm) and more than 75-80% generally occurs during the monsoon season (June-September). The soil of the experimental field was mixed red and black with clay loam in texture and slightly alkaline in reaction with pH 7.7, EC 0.32 dS/m having organic carbon 0.61 % and available nitrogen 270 kg/ha, phosphorus 16.4 kg/ha and potassium 352 kg/ha at 0-15 cm soil depth. The experiment was laid out in randomized block design keeping with seven treatments viz: T_1 Flucetosulfuron 10% WG 20 (20 g a.i./ha), T_2 Flucetosulfuron 10% WG 20 (25 g a.i./ha), T_3Penoxsulam (1.02%w/v) + Cyhalofop butyl 5.1%w/w (120 g a.i./ha), T_4 Penoxsulam(1.02%w/v)+ Cyhalofop butyl 5.1%w/w (135 g a.i./ha), T_5 Bispyribacsodium 10% SC (35 g a.i./ha), T_6 Hand weeding and T_7 Non weeded control with three replications. A uniform dose of 60 kg P_2O_5 and 40 kg K_2O was applied through single super phosphate and muriate of potash, respectively. The nitrogen (80 kg) was applied through urea in three split doses. Half dose of N and full doses of P and K were applied as basal just before transplanting and remaining half dose of N was applied in two equal splits i.e. at active tillering and panicle initiation stage of the crop. For weed studies, weed dry weight was recorded (at 30 days stage) from 0.25 m^{-2} areas by placing a quadrate of 0.5 ×0.5 m randomly at three places in border rows of each plot. The net plot area was harvested manually at the maturity and the grain and straw yields were recorded.

RESULTS

The results from the present experiment clearly indicate that apart from mechanical weeding, the chemicals used for weed control had a significant effect on grain and straw yield of direct seeded rice under puddled irrigated conditions. The maximum grain yield 3.4 t/ha was recorded in plot of hand weeding (T_6) and significantly superior to other treatments and which were at par with Flucetosulfuron 10%WG 25g a.i./ ha. (3.26 t/ha). However, the treatment non weeded control (T_7) was noted minimum 1.83 t/ha grain yield. The probable reason for enhanced grain yield may be due to primitive effects of nutrient (macro and micro) on growth which ultimately lead to more photosynthetic activities which enhance carbohydrate and nitrogen metabolism of peptic substances in the plants. Similar results have been reported by Reddy and Krishna (1998). Similarly, hand weeding (T_6) and Flucetosulfuron 10%WG 25g a.i./ha. (T_2) were recorded maximum straw yields 4.91 and 4.74 t/ha., respectively and which were at par with each other. The weed biomass accumulated by weed is the real index which determines the efficiency of herbicides to control the weeds. Minimum overall weed biomass was noted in Flucetosulfuron 10%WG 25g a.i./ ha. followed by Flucetosulfuron 10%WG 20g a.i./ha. and

Table 1. Relative performance of Flucetosulfuron for weed control in direct seeded rice under puddled irrigated conditions

Treat.Sym.	Grain yield (t/ha)	Straw yield (t/ha)	Overall Weed biomass (g/m^2)	Overall Weed control efficiency (%)	Net return (/ha) x 10^3	B:C ratio
T_1	2.94	4.23	15.21	76.30	29.38	3.27
T_2	3.26	4.74	11.91	81.44	33.89	3.61
T_3	2.65	4.07	39.36	38.66	25.16	2.92
T_4	2.67	4.11	41.61	35.16	25.39	2.94
T_5	2.58	3.93	38.36	40.22	24.10	2.83
T_6	3.40	4.91	26.79	58.25	33.43	3.16
T_7	1.83	3.60	64.17	-	14.51	2.19
CD (P=0.05)	0.216	0.373	-	-	-	-

hand weeding. It is revealed that maximum 81.44% overall weed control efficiency was exhibited in the treatment Flucetosulfuron 10%WG 25g a.i./ha. followed by Flucetosulfuron 10%WG 20g a.i./ha. (76.30 %). Hand weeding was recorded 58.25 % overall weed control efficiency. It could be possible due to reduce the weed population and weed dry weight. The net return of ‘ 33,893/ha and benefit cost ratio 3.61 was also obtained under treatment Flucetosulfuron 10%WG 25g a.i./ha followed by hand weeding gave grain yield of 3.4 t/ha and straw yield 4.91 t/ha. along with net return of 33428/ha and benefit cost ratio of 3.16. While, lowest grain yield of 1.83 t/ha, straw yield 3.60 t/ha and net return of 14512/ha along with benefit cost ratio 2.19 was observed in non weeded control.

CONCLUSION

On the basis of present investigation, it is concluded that the application of Flucetosulfuron 10% WG 25g a.i./ha. and Flucetosulfuron 10%WG 20g a.i./ha. as pre emergence on direct seeded rice under puddled irrigated condition responded well in terms of chemical weed control of weeds, obtaining significantly highest grain yields (3.26 t/ha) and straw yields (4.74 t/ha).

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Efficiency of post emergence herbicides on chickpea

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Chickpea (*Cicerarietinum* L.) is an important pulse crop grown in tropical and sub-tropical regions on light textured soil in limited water supply conditions in arid and semi-arid region of Rajasthan. Besides other production constraints, weed infestations considered as one of the most important constraint to limit its yield. Chickpea, however, is a poor competitor to weeds because of slow growth rate and limited leaf area development at early stages of crop growth (30-45 DAS). In addition to slow initial crop growth, wider crop spacing also facilitates crop-weed competition which poses a serious limitation in chickpea production and thus, estimated seed yield loss may likely to go to the extent of 88 per cent (Ballad *et al*., 1998).

METHODOLOGY

A field study was conducted for two years during *Rabi* season of 2013-14 and 2014-15 at Research farm of Agriculture Research Station, Swami Keshwanand Rajasthan Agricultural University, Bikaner.Ten weed control treatments comprising of *viz*., weedy check, two hand weeding at 20 and 40 DAS, imazathapyr 20 g, imazethapyr 30 g, mazethapyr 40 g, imazethapyr 50 g, imazethapyr 60 g, oxifluorfen 50 g, oxifluorfen 75 g, and pendimethalin 0.75 kg (PPE)were evaluated in randomized block design with three replications. The soil of experimental site was loamy sand having 0.08% organic carbon, 8.22 pH, 78, 22 and 210 kg/ha available N, P andK, respectively.

RESULTS

The density and dry weight of both monocot and dicot weeds were significantly reduced by all weed control treatments compared to weedy check (Table 1). Two hand weeding resulted in lowest weed density and dry weight of weeds. However, among the different treatments, application of imazethapyr60 g/ha was found effective in reducing the density and dry weight of dicot and total weeds followed by application of its respective lower doses, while pendimethalin 0.75 kg/hawas effective against monocot weeds. Lower density of weeds by imazethapyr in reducing weed dry matter might be primarily appeared due to broad spectrum activity

Table 1. Effect of weed control measures on weed density and weed dry weight in gram(Pooled data of two years)

Treatments	Monocot/m^2	Dicot/m^2	Total Weeds/m^2	WDW (g/m^2)
Weedy check	7.58	19.96	27.54	207.5
Two hand weeding	0.54	0.54	1.08	9.79
Imazethapyr 20 g/ha	4.75	2.71	7.46	16.21
Imazethapyr 30 g/ha	4.58	1.79	6.38	10.88
Imazethapyr 40 g/ha	2.42	2.71	5.13	9.71
Imazethapyr 50 g/ha	4.17	1.13	5.29	9.69
Imazethapyr 60/ha	2.25	1.29	3.54	6.78
Oxifluorfen 50/ha	2.88	2.83	5.71	23.66
Oxifluorfen 75 g/ha	3.08	2.71	5.79	16.90
Pendimethalin 0.75 kg/ha	1.63	11.25	12.88	122.7
SEm±	-	-	-	-
CD (P=0.05)	-	-	-	-

particularly on establishment of plants of dicot weeds and its greater efficiency to retard cell division of meristems as a result of which weeds dry rapidly. The results were confirmed by the findings of Kantar *et al.* (1999), where about 84.6% weed biomass was controlled with application of imazethapyr. Papierniks*et al.* (2003) also recommended use of imazethapyr in legumes, which inhibit acetohydroxy acid synthase and the synthesis of branched chain amino acids. Data further revealed that application of fenoxaprop p-ethyl 50g and propaquizafop 62g as post emergence also reduced the weed dry matter compared to weedy check and other dose. Application of pendamethalin was effective for the plots where only grassy weeds were dominated as against imazethapyr which was effective against annual broadleaf weeds, grassy weeds and perennial sedges.

CONCLUSION

Imazethapyr 60 g/ha was found effective in reducing the density and dry weight of dicot and total weeds followed by application of its respective lower doses, while pendamethalin 0.75 kg/hawas effective against monocot weeds.

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Evaluation of herbicides efficacy for weed control in direct dry seeded rice (*Oryza sativa*)

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Direct dry seeding of rice is a promising resource conservation technology in rice-wheat growing regions but its acceptance is obstructed due to heavy weed conquest. Weeds cause heavy damage to direct dry seeded rice which can be to the tune of 5-100% (Kolhe, 1989). Weed infestation in direct seeded rice (DSR) fields remains the single largest constraint limiting their productivity. A DSR crop generally lacks a "head start" over weeds due to dry tillage, absence of flooding and alternate wetting and drying conditions making it particularly vulnerable to weed competition during early part of its growth (Rao *et al.,* 2007). As the weeds and rice emerge simultaneously in DSR, the proper time and method of weed control remains a complex phenomenon (Khaliq and Matloob, 2011). Weed control in direct seeded rice can be accomplished by cultural and mechanical methods, which are very much labour intensive and reduces the benefit: cost ratio. Weed management in direct dry seeded rice through herbicide application may be best suited as it can take care of weeds right from the beginning of crop growth. It also save valuable time or and less investment of expenditure. Therefore, the present investigation was carried out to evaluate the efficacy of different herbicides in dry direct seeded rice conditions.

METHODOLOGY

A field study was conducted during *Kharif* 2010 in D2 block of N.E Borlaug Crop Research Centre of GBPUAT, Pantnagar (U.K.) to evaluate the efficacy of herbicides for weed control in direct dry seeded rice. Total ten herbicides were evaluated in the experiment which were consisted application of Pyrazosulfuron 25, Pretilachlor 750, Chyhalofop butyl 90, Fenoxaprop 60, Cyhalofop butyl + (chlorimuron + metsulfuron) 90+20, Fenoxaprop + (chlorimuron + metsulfuron) 60+20, Azimsulfuron 35, Bispyribac sodium 25, Fenoxaprop + Ethoxysulfuron 60+15, Oxyflurofen + 2,4-D 300+500 g *a.i.* /ha, respectively. A weedy check and manual weeding (20 and 40 DAS) were maintained for comparison. Experiment was laid out in randomized block design (RBD) with three replications. The rice variety Narendra-359 was sown on 9th June using a seed rate of 40 kg /ha and maintaining 20 cm distance between crop rows. Fertilizers were applied @ 150 kg N, 60 kg P_2O_5 and 40 kg K_2O/ha, respectively. Data on weed growth, yield performance and economics were recorded.

RESULTS

Application of Byspiribac sodium 60 g, Azimsulfuron 35 g, Fenoxprop + (chlorimuron+metsulfuron) 60+20 g and Fenoxprop+Etoxysulfuron 60+15 g /ha was found very effective against weed flora as compared to other treatments in DSR. However lowest weed density was recorded in case of Azimsulfuron 35 g and lowest weed dry matter accumulation was recorded in case of Fenoxprop+Etoxysulfuron 60+15 g / ha which at par with two hand weeding at 60 DAS. All other treatments were found not effective to control weeds and recorded very high weed density and dry matter accumulation witch at par with weedy plot at 60 DAS. Highest weed control efficiency was recorded in case of Fenoxaprop + Ethoxysulfuron 60+20 g (92.3%) followed by Bispyribac sodium 25 g (85.8%) followed by Azimsulfuron 35 g (85.6%) followed by Fenoxaprop + (chlorimuron + metsulfuron) at 60+20 g /ha (85.5%) which were as effective as Two hand weeding (94.5%) and lowest in case of Pyrazosulfuron 25 g (35.6%) followed by Pretilachlor 750 g/ha (46.2%) at 60 DAS.

Fenoxaprop + (chlorimuron + metsulfuron) 60+20 g recorded the highest grain yield followed by Fenoxaprop + Ethoxysulfuron 60+15 g and Bispyribac sodium 25 g/ha which were at par with two hand weeding and lowest Pyrazosulfuron at 25 g, Pretilachlor 750 g/ha which were at par with weedy.

CONCLUSION

It was concluded that post-emergence herbicides proved more promising than pre-emergence herbicides in direct dry seeded rice. Fenoxaprop + (chlorimuron + metsulfuron) 60+20 g, Fenoxaprop +Ethoxysulfuron 60+15 g and Bispyribac sodium at 25 g/ha as effective as two hand weed-

Table 1. Weed growth at (60 DAS) weed control efficiency in rice as influenced by different weed control treatments

Treatment	Weed density (No./m^2)	Weed drymatter (g/m^2)	Weed control efficiency (%)
Pyrazosulfuron 25 g /ha	4.3 (74.7)	296.3	35.6
Pretilachloar 750 g /ha	4.2 (66.7)	247.7	46.2
Cyhalofop butyl 90 g /ha	4.97 (143.3)	142.3	69.1
Fenoxprop 60 g /ha	4.3 (76.0)	118.0	74.4
Cyhalofopbutyl + (chlorimuron+metsulfuron) 90+20 g /ha	4.7 (108.7)	130.7	71.6
Fenoxprop + (chlorimuron+metsulfuron) 60+20 g /ha	4.1 (60.0)	66.8	85.5
Azimsulfuron 35 g /ha	3.4 (29.3)	66.4	85.6
Byspiribac sodium 25 g /ha	3.7 (40.0)	65.3	85.8
Fenoxprop+Etoxysulfuron 60+15 g /ha	4.3 (73.3)	35.2	92.3
Oxyfluron + 2,4-D 300+500 g /ha	4.8 (125.3)	186.5	59.5
Two hand weeding 20 & 40 days	3.4 (29.3)	25.5	94.5
Weedy	4.5 (92.0)	460.4	0.0
SEm±	0.08	8.36	-
CD (P=0.05)	0.25	24.5	-

Note: Original values are given in parenthesis ing and can substitute hand weeding because of labour scarcity now a day's which finally reduces net return.

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Competitive behavior of different cultivars on weed dynamics and yield of Indian mustard in Jammu region

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Rapeseed and mustard are the major group of oilseed crops grown in Jammu region on a sizeable acreage in Jammu and Kashmir on an area of more than 60000 hectares with an average productivity of 801 kg/ha which is far below the national average productivity of 1176 kg/ha (Anonymous, 2013-14). Weeds are one of the major biotic stresses which cause considerable reduction in the yield of Indian mustard which ranges to an extent of 30-70 per cent and more (Kachroo and Bazaya, 2006). Different weed management strategies viz. herbicides, cultural and biological etc. are used to manage the weeds below economic threshold. However, growing of recently developed competitive cultivars of Indian mustard for managing weeds holds promise. Therefore, the present study was undertaken with an objective to study the competitive behaviour of newly released varieties of Indian mustard against weeds under Jammu conditions.

METHODOLOGY

The field experiment was conducted during the *rabi* season of 2010-11 and 2011-12 at the Research Farm, Chatha of the Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Jammu and Kashmir, India, which is situated at 32^0 40' N latitude and 74^0 58' E longitude with an altitude of 332 m above mean sea level. The soil of the experimental field was low in organic carbon (0.37%) and nitrogen (208 kg/ha), medium in available phosphorus (15.3 kg/ha) and potassium (128 kg/ha) and slightly alkaline in pH (7.1). The experiment consisted of twelve treatments which were laid down in factorial RBD with 3 replications and comprised of two factors namely six Indian mustard (*Brassica juncea* L.) varieties (kranti, RL 1359, Navgold, NRCDR 2, CS 56 and RSPR 01.) as Factor A and two levels of weed management as Factor B (weed free and weedy check). One more variety of Indian mustard namely NRCDR 601 was included and one variety CS 54 was replaced with a local cultivar namely RSPR 03 during the second year 2011-12 thus increasing the number of treatments to 14. In the weed free plots 3 hand weedings at 25-30 days interval were done to kept the field weed free throughout the crop season. All the standard package and practices of SKUAST-Jammu were followed for raising the crop. The data was analyzed and presented using standard formulas and statistical tools.

RESULTS

The major weeds present in the experimental field were *Medicago denticulata, Euphorbia helioscopia, Ranunculus arvensis, Rumex retroflexus, Anagallis arvensis, Cirsium arvensis and Cannabis sativa.* Weedy check caused an average reduction in seed yield of Indian mustard (27.84%) which was significantly lower than weed free situation in comparison. Among the different Indian mustard cultivars NRCDR 2 (1398 kg/ha) though at par with Nov gold (1316 kg/ha) resulted in significant increase in the seed yield of Indian mustard than other cultivars in comparison during the second year of experiment. However, during the second year of experimentation Indian mustard cultivar NRCDR 601(1298 kg/ha) proved to be equally competitive along with cultivars NRCDR 2 (1368 kg/ha) and Navgold (1274 kg/ha) in increasing the seed yield of Indian mustard than other cultivars in comparison (Table 1). This may be due to the lower weed density and weed suppression efficiency of newly developed cultivars such as NRCDR 2, NRCDR 601 and Navgold thereby resulting in better utilization of nutrients, moisture, space and light thereby resulting in higher LAI of the said

Table 1. Effect of competitive behaviour of different cultivars on seed yield, weed Index and economics of India Mustard in Jammu region

Treatment	Seed yield (kg/ha)		Weed Index (%)		B:C ratio	
	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12
Variety						
Kranti	1284	1252	12.53	15.69	1.26	0.85
RL1359	1266	1209	13.76	18.59	1.23	0.78
Navgold	1318	1274	10.22	14.21	1.32	0.88
NRCDR 2	1398	1368	4.77	7.88	1.51	1.03
CS 56	1297	-	11.65	-	1.28	-
RSPR 01	1199	1174	18.32	20.94	1.11	0.73
RSPR 03	-	1187	-	20.07	-	0.76
NRCDR 601	-	1298	-	12.59	-	0.91
CD (P=0.05)	82	109	-	-	-	-
Weed Management						
Weedy check	11.17	1018	23.91	31.45	1.20	0.69
Weed free	14.68	1485	0.00	0.00	1.36	1.01
CD (P=0.05)	47	58	-	-	-	-

Table 2. Effect of competitive behaviour of different cultivars on weed density and weed suppression efficiency in Indian mustard

Treatments	Total weed density (no./m^2) at 60 DAS				Weed Suppression Efficiency (%)	
	Broad leaf 2010-11	Grasses 2010-11	Broad leaf 2011-12	Grasses 2011-12	2010-11	2011-12
Varieties						
Kranti	5.80 (33.64)	3.11 (9.67)	6.02 (42.33)	5.78 (38.00)	60.19	72.21
RL1359	5.99 (35.88)	3.70 (13.69)	6.05 (42.67)	5.93 (40.00)	54.44	70.75
Navgold	5.83 (33.99)	3.40 (11.56)	5.68 (39.33)	5.64 (36.67)	58.13	73.19
NRCDR 2	5.44 (29.60)	3.02 (9.12)	5.40 (36.67)	5.41 (33.33)	64.41	75.63
CS 56	5.72 (32.72)	3.57 (12.74)	-	-	58.21	-
RSPR 01	6.29 (39.56)	3.81 (14.51)	6.13 (43.33)	6.08 (41.33)	50.30	69.78
RSPR 03	-	-	6.0 (42.00)	5.94 (40.00)	-	70.75
NRCDR 601	-	-	5.81 (40.33)	5.61 (35.33)	-	74.17
CD (*P=0.05*)	NS	NS	NS	NS	-	-
Weed Management						
Weedy check	9.28 (85.56)	4.82 (23.23)	8.59 (72.95)	8.02 (63.81)	0.00	0.00
Weed free	2.41 (5.80)	2.05 (4.20)	3.12 (8.95)	3.56 (11.81)	90.81	91.36
CD (P=0.05)	0.32	0.35	0.29	0.36	60.19	-

* Figures in parenthesis are original values subject to $\sqrt{x+1}$ square root transformation

genotypes thereby increasing their weed suppressing ability over other genotypes during the early stages of crop growth (Table 2). The lowest weed Index was recorded with cultivar NRCDR 2 (4.77 and 7.88 % respectively) during both the years of experimentation.

CONCLUSION

Based on average of two years of experimentation in 2010-11 and 2011-12 on competitive behavior of Indian mustard (*Brassica juncea* L.) varieties against weeds vis-à-vis weed smothering potential of various newly developed genotypes at SKUAST-J, Chatha centre it was concluded that new high yielding variety NRCDR 2 gave highest seed yield of mustard and was found to be most competitive cultivars of Indian mustard for suppression of weeds in Indian mustard crop in the Jammu region.

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Effect of combination of herbicides against complex weed flora in soybean

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Soybean [*Glycine max* (L.) Merill] popular as golden bean has become the miracle crop of 21stcentury. It serves the dual purpose for being grown both as an oilseed crop and pulse crop as well. Reduction in soybean yield due to weed infestation varies from 27 to 77%, depending on type of weed, soil, seasons and weed infestation intensities. Some have reported the yield decline as high as 84%. Hand weeding is a traditional and effective method of weed control, but untimely and continuous rains as well as unavailability of labour at peak time are main limitations of manual weeding. The lower seed yield under untreated control due to the high weed interference (Yadav *et al.,* 2009; Pal *et al.,* 2013). The only alternative that needs to be explored is the use of pre as well as post-emergence herbicides. The screening of such herbicides and their combination in soybean reveals their efficiency against either monocotyledonous or dicotyledonous and both weeds.

METHODOLOGY

A field experiment was conducted at Research cum Instructional Farm, Indira Gandhi KrishiVishwavidyalaya, Raipur (C.G.) during *kharif* seasons of 2012-13 and 2013-2014. The soil of experimental field was *clayey* in texture, low in nitrogen, medium in phosphorus and high in potassium contents with neutral pH. The experiment was laid out in Randomized Block Design, comprising four replication and eight treatments which includedSulfentrazone 48 % F 300 g *a.i*/ha as pre-emergance (T_1), Sulfentrazone 48 % F 360 g *a.i*/ha as pre- emergence (T_2), Pendimethalin 30 EC 1 kg *a.i*/ha as pre-emergence (T_3), Sulfentrazone 48 % F 300 g *a.i*/ha as pre – emergance + Imazethapyr 10 SL as Post-emergance (T_4), Sulfentrazone 48 % F 300 g *a.i*/ha as pre-emergance+one hand weeding (T_5), Imazethapyr 10 SL @ 100 ga.i ha $^{-1}$ as PoE(T_6), Metribuzin 70 WP @ 750 g a.i ha $^{-1}$ as PE(T_7), Odyssey (imazethapyr 35% + imazamox 35%) 70 WG @ 100 g a.i/ha as PE(T_8) Sulfentrazone 48 % F 300 g *a.i*/ha as pre–emergance+hoeing (T_9), hand weeding twice at 20 and 40 DAS(T_{10}) and untreated control (T_{11}). Soybean variety JS 97-52 was sown with 45 cm x 5 cm and 30 cm x 7cm during the last week of June andtheseed rate of 75 kg /ha and fertilizer dose was 25, 60 and 40 kg/ ha of N, P_2O_5 and K_2O respectively was used, at the time of sowing.

Table 1. Effect of weed control treatments on nodulation, soil microbial population, weeddensity, weed control efficiency, weed indexand seed yield of soybean

Treatments	Rhizobial population (x 10^6cfu/g soil)	Total weed density (per m^2)	Weed control efficiency (%)	Weed index (%)	Seed yield (kg /ha)
T_1-Sulfentrazone 48 % F @ 300 g a.i ha $^{-1}$ as PE	45.3	4.0	89.77	12.67	2368
T_2-Sulfentrazone 48 % F@ 360 g a.i ha $^{-1}$ as PE	43.8	2.4	95.28	9.37	2448
T_3- Pendimethalin 30 EC @ 1 kg a.i ha $^{-1}$ as PE	32.0	6.3	71.39	27.81	1748
T_4- Sulfentrazone 48 % F @ 300 g a.i ha $^{-1}$ as PE fbImazethapyr 10 SL @ 100 ga.i ha $^{-1}$ as PoE	26.0	1.2	99.05	0.11	2779
T_5-Sulfentrazone 48 % F@ 300 g a.i ha $^{-1}$ as PEfb One Hand Weeding at 25 DAS	47.0	2.8	94.90	24.29	2406
T_6-Imazethapyr 10 SL @ 100 ga.i ha $^{-1}$ as PoE	33.3	6.2	76.72	33.05	1389
T_7-Metribuzin 70 WP @ 750 g a.i ha $^{-1}$ as PE	44.5	4.7	88.05	8.40	1754
T_8-Odyssey (imazethapyr 35% + imazamox 35%) 70 WG @ 100 g a.iha $^{-1}$ as PE	39.3	4.2	83.39	21.26	1635
T_9-Sulfentrazone 48 % F@ 300 g a.i ha $^{-1}$ as PE fb Hoeing at 25 DAS	49.0	3.8	89.49	13.51	1993
T_{10}-Hand weeding twice at 20 and 40 DAS	54.8	2.0	98.05	40.79	2676
T_{11}-Untreated control	48.9	10.4		46.33	1358
CD (P=0.05)	4.2	5.6			270

RESULTS

Significantlymaximum seed yield was produced by treatmentsSulfentrazone@ 300 g *a.i.*/haas PE + Imazethapyr @ 100g *a.i.*/ha as PoEwhich was found at par with Hand weeding twice at 20 and 40 DAS. However, minimum Seed yield was recorded under untreated control. The lower seed yield under untreated control may be due to the high weed interference. Higher number of root nodules/plant was observed under Odyssy 70 WG (imazethapyr 35% + imazamox 35%) @ 100 g *a.i.*/ha as PoEhowever it was found at par toSulfentrazone@ 300 g *a.i.*/haas PE + Imazethapyr @ 100g *a.i.*/ha as PoE. Higher dry weight of nodules plant^{-1} of two year was recorded under Hand weeding twice at 20 and 40 DAS as compared to other treatments; however it was comparable to Sulfentrazone@ 300 g*a.i.*/haasPE +Imazethapyr @ 100g *a.i.*/ha as PoE.Significantly maximum rhizobial population was observed under treatment Hand Weeding twice at 20 and 40 DAS, followed by Sulfentrazone@ 360 gm.a.i. /ha as PEfb One hand weeding at 25 DAS. Significantly minimum density was recorded under Sulfentrazone@ 300 g *a.i.*/ha as PE + Imazethapyr @ 100g *a.i.*/ha as PoE. Significantly highest weed control efficiency and minimum weed index noted under treatment Sulfentrazone@ 300 g *a.i.*/haas PE + Imazethapyr @ 100g *a.i.*/ha as PoE. However, least weed control efficiency was observed in untreated control. It was due to higher total weed population and total weed dry weight.

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Weed management through sequential and tank mix application of herbicides in onion (*Allium cepa L.*)

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Onion (*Allium cepa L.*) is extremely important commercial crop grown throughout the country not only for internal consumption but also as the highest foreign exchange earlier among the fruits and vegetables. In India onion occupies about 1.06 million hectares area having 15-12 million metric tons of production and average productivity of 14.2 tons per hectare (Anonymous, 2011). India is the second largest producer of onion in the world after China but the productivity of onion in India is relatively very low as compared to other countries, Crop-weed competition has long been recognized as one of the major constraints for low production in onion. Weeds cause reduction in bulb yield to an extent of 40-80 percent (Gandolkar *et al.*, 2015). Due to its poor competitive ability with its slow growth and lack of adequate foliage makes onion crop weak competitor against weeds. In addition, their cylindrical upright leaves do not shade the soil to smoother weed growth. Due to closer planting and shallow root system of onion, manual weeding is tedious, expensive and time consuming. Chemical weed control is the best option to conventional methods. The use of pre-emergent herbicides like pendimethalin and oxyflurzofen and pre-planting incorporation of fluchloralin is a common practice for weed management in onion. But alone pre-emergence application of herbicides could not able to control the successive flushes of weeds. Moreover, late emerging weeds hinder bulls development and create problem during bulb uprooting operation. Therefore the need for sequential application of herbicides and post-emergance application of tank mixed herbicides was realized for broad spectrum control of weeds in onion. Hence the present investigation was planned and undertaken involving sequential application of herbicides and post-emergance application of two tanks mixed herbicides.

METHODOLOGY

Field experiment was conducted during *rabi* season of 2012-13 and 2013-14 in randomized block design with four

Table 1. Effect of weed control treatments on weeds growth and bulb yield of onion

Treatment	Dose (kg a.i./ha)	Weed population (No./sq.m) at 70 DATP	Bulb yield (t/ha)	Weed index (%)
Pendimethalin pre-em.	1.0	176.00	16.10	41.51
Pendimethalin pre-em	0.75+1 HW	75.33	23.72	13.84
Pendimethalin pre-em fb pendimethalin at 30 DATP	0.75+0.75	95.67	23.52	14.57
Oxyflurofen pre-em	0.5	213.33	13.65	50.42
Oxyflurofen pre-em	0.25+1 HW	129.67	18.46	32.95
Oxyflurofen pre-em fb oxyflurofen at 30 DATP	0.25+0.25	231.67	13.26	51.83
Quizalofop + oxyflurofen post-em at 30 DATP	0.050+0.050	173.67	16.58	39.77
Quizalofop + oxyflurofen post-em at 30 DATP	0.075+0.075	101.33	22.13	19.97
Weedy check	-	269.33	7.49	72.79
Weed free check		0.00	27.53	–
LSD (P=0.05)	-	25.65	1.60	–

DATP: Days after transplanting, HW: Hand weeding

replications at the ICAR-Indian Agricultural Research Institute, New Delhi. Soil of the experimental field was sandy loam (*Ustochrept*) slightly alkaline (pH 7.7) with electric conductivity of 0.31 ds/m, low in organic C (0.37 %), medium in available K (260 kg/ha) and low in available P (9.5 kg/ha) and available N (251 kg/ha). Two months old seedlings of onion variety "Pusa Ridhi" were transplanted in the first week of January of 2013 and 2014 at a spacing 15x10cm. The field experiment had ten weed control treatments including pendimetnalin @ 0.75 kg./ha as pre-emergence, pendimetnalin @ 0.75 kg./ha as pre-emergence followed by 1 hand weeding (30 DATP), pendimethalin @ 1.0 kg/ha as pre-emergance followed by pendimetnalin @ 1.0 kg/ha sand mix application at 30 DATP, oxyflurofen @ 0.5kg/ha as pre-emergence, oxyflurofen @ 0.25 Kg/ha followed by 1 hand weeding (30 DATP), oxyflurofen @ 0.25 Kg/ha followed by sequential application of oxyflurofen 0.25 kg/ha as sand mix application at 30 DATP, tank mix post-emergence application of quizalofop (0.050 and 0.075 kg/ha) and oxyflurofen, (0.050 and 0.075 kg/ha), weedfree and weedy check. Herbicides were sprayed treatment wise with knapsack sprayer @ 500 litre spray solution/ha. Observation on weed population was recorded from 0.5m2 area selected randomly at 70 DATP. Observation on crop were recorded as per the standard procedure. Weed index was also calculated by using standard formula given by Gill and Vijay Kumar (1969). The pooled data of the two years experiment are presented in the Table 1.

RESULTS

The dominant weed flora of the experiment site consisted of grasses, sedges and broad leaved weeds. The dominant grasses were *Phalaris minor Avene* ludoviciana and Cynodon dactylon. The dominant broad leaved weeds observed were *Melilotus indica, Rumex dentatus* and *Parthenium hysterophous*. While *Cyperus rotundus* was the lone sedge observed. All weed control treatments caused significant reduction in total weed density as compared to weedy check. The lowest weed population was recorded in the plots were pendimethalin applied @ 0.75 kg/ha as pre-emengance was integrated with one hand weeding at 30 DATP, which however was found at per with sequential application of pendimethalin @ 0.75kg/ha as pre-emergence followed by sandmix application of pendimetnalin @0.75Kg/ha at 30 DATP (Table 1). Weed free situation produced the highest bulb yield owing the complete elimination of weeds Integration of pendimetnalin @ 0.75Kg/ha as pre-emergance supplemented with one hand weeding at 30DATP, sequential application of pendimetnalin @ 0.75 kg/ha as pre-emergence followed by sand mix application (as broad cast) of pendimethalin @ 0.75 kg/ha and tank mix post –emergence application of quizalofop (0.050 and 0.075 kg/ha) and oxyflurofen (0.050 and 0.075 kg/ha) at 30 DATP were found equally effective in increasing the bulb yield. While the lowest bulb yield (7.49 ton/ha) was recorded in unwedded plot due to severe weed competition.

CONCLUSION

Integration of pre-emergence application of pendimethalin at 1.0 kg/ha followed by one hand weeding at 30 days after transplanting of onion could be recommended for effective weed management in onion transplanted in *rabi* season.

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Influence of glyphosate on *Orobanche aegyptiaca* and growth and yield of Indian mustard

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Rapeseed-mustard (*Brassica spp*.) is a major group among oilseed crops in the world being cultivated in 53 countries across the six continents (Goyal *et al.*, 2006), with India ranking third in area (6.70 m ha) and production (7.96 m t) in the world. But, productivity of rapeseed- mustard in India (1188 kg/ha) is very less as compared to world's productivity (1856 kg/ha). Indian mustard (*Brassica juncea* L.) alone is grown on about 75-80% of total area (6.70 m ha) under rapeseed- mustard crops. Mustard crop in about 0.25 m ha area of South-Western Haryana is severely infested by a parasitic weed, *Orobanche aegyptiaca*. It can cause a reduction in the crop yield from 0-100%, depending on the infestation. So, the scientific management of *Orobanche aegyptiaca* in Indian mustard is necessary to improve/ maintain the productivity of the crop. Keeping these points in view, the present investigation was carried out to find the best practices to control *Orobanche aegyptiaca* along with better growth and yield of Indian mustard.

METHODOLOGY

A field experiment was conducted at CCS Haryana Agricultural University (RRS, Bawal, Rewari) in *Rabi* 2014- 15

Table 1. *Orobanche* control,dry matter accumulation, grain yield and economics of mustard as influenced by different weed control treatments

Treatment	*Orobanche* control (%)	Dry matter accumulation/ plant (g)	Grain yield (kg/ha)	Net returns (Rs/ha)
Neem cake 400 kg/ha at sowing	11.1 (10.0)	54.38	1537	10182
Neem cake 400 kg/ha at sowing followed by foliar spray of glyphosate at 20 and 40 g/ha + 1.0 % solution of $(NH_4)_2SO_4$ at 25 & 45 DAS, respectively	50.5 (58.3)	67.07	2147	29292
Neem cake 400 kg/ha at sowing followed by foliar spray of glyphosate at 25 and 50 g/ha + 1.0 % solution of $(NH_4)_2SO_4$ at 25 & 45 DAS, respectively	60.7 (75.0)	69.30	2238	32148
Neem cake 400 kg/ha followed by soil application of metalaxyl 0.2 % at 25 DAS	19.9 (16.7)	56.72	1567	9623
Neem cake 400 kg/ha followed bypendimethalin (PPI) at 0.75 kg/ha followed by soil application of metalaxyl 0.2 % at 25 DAS	25.4 (20.0)	58.46	1694	13349
Neem cake 400 kg/ha at sowing followed by soil application of metalaxyl 0.2 % at 25 DAS followed by foliar spray of glyphosate at 40 g/ha at 45 DAS	32.9 (30.0)	60.76	1782	16367
Foliar spray of glyphosate at 25 and 50 g/ha + 1.0 % solution of $(NH_4)_2SO_4$ at 25-30 DAS & 55 DAS, respectively	75.2 (93.3)	74.91	2426	46430
Foliar spray of glyphosate at 25 and 50 g/ha at 25-30 DAS & 55 DAS, respectively (Recommended practice)	76.2 (91.7)	73.20	2308	42776
125 % of recommended fertilizer (N & P) + foliar spray of glyphosate at 25 and 50 g/ha + 1.0 % solution of $(NH_4)_2SO_4$ at 25 DAS & 55 DAS, respectively	85.7 (98.3)	82.84	2648	52805
Hand pulling of *Orobanche* shoots at 45, 65 & 85 DAS, respectively	11.1 (10.0)	53.41	1519	7003
Weedy check	0 (0)	48.72	1403	14321
CD (P = 0.05)	21.3	11.18	225	-

Original data on *Orobanche* controlwere subjected to arc sin transformation and presented in parentheses located at 28.1º N, 76.5º E and at an altitude of 266 m to examine the effects of different treatments on *Orobanche aegyptiaca* and growth and yield of mustard. Soil of the experimental field was sandy and found low in organic carbon and nitrogen, medium in available phosphorus and potassium and neutral in reaction. The experiment was conducted using randomized block design, comprising of 11 treatments with different combinations of glyphosate, neem cake, pendimethalin, metalaxyl and fertilizer dose along with hand pulling and weedy check, replicated thrice. The variety RH 0749 of mustard crop was sown @ 5 kg/ha by pora method with the help of hand drawn plough keeping row to row distance of 45 cm and 15 cm between plants within the row on 25 October, 2014. The recommended doses of nitrogen (80 kg N/ha) and phosphorus (30 kg P_2O_5/ha) were applied in all the treatments except one, in which 125% of the recommended doses were applied. Data on control of Orobanche, dry matter accumulation, yieldand economics of mustard were recorded and analysed.

RESULTS

Perusal of data revealed that different treatments significantly influenced the Orobanche control as well as the growth and yield of mustard. Application of treatment T9 provided 98.3% control of Orobanche till harvest of mustard crop which was statistically at par with T7 (93.3%) and T8 (91.7%) and significantly higher than other treatments. This might be due to the combined effect of two doses of glyphosate, addition of 1.0% $(NH_4)_2SO_4$ and 25% extra nitrogen and phosphorus. Increasing the application of nitrogen in mustard increased the control of Orobanche in T9 over T8 probably because of detrimental effect of the nitrogenous fertilizers on the Orobanche infestation. Dry matter accumulation at harvest was recorded higher in T9 (82.84 g/plant) which was statistically at par with treatments T7 (74.91 g/plant) and T8 (73.20 g/plant), but was significantly superior over remaining treatments. Grain yield (2648 kg/ha) was found higher in treatment T9 which was statistically at par with T7 (2426 kg/ha) and significantly superior over other treatments. However, dry matter accumulation and grain yield were observed lowest under T11 i.e. weedy check. The combined effect of higher dose of fertilizers and maximum control of Orobanche in treatment T9 provided ideal conditions for growth of mustard crop resulting in higher dry matter accumulation and grain yield. Maximum net returns were also obtained under treatment T9 which might be due to higher grain yield which resulted in higher net returns.

CONCLUSION

The application of 125% of recommended fertilizer (N & P) + foliar spray of glyphosate at 25 and 50 g/ha + 1.0% solution of $(NH_4)_2SO_4$ at 25 DAS & 55 DAS, respectively provided maximum control of *Orobanche* upto harvest and thus resulted in higher dry matter accumulation, grain yield and net returns. Use of neem cake, pendimethalin and metalaxyl either alone or in combination with glyphosate proved ineffective to inhibit *Orobanche* germination.

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Biotic and abiotic stress management through protected cultivation for seed spices under changing climate scenario

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Seed spices are categorized as "High value low volume crops". Rajasthan and Gujarat have emerged as "Seed Spice Bowl" and together contribute more than 80 per cent of the total seed spices production in the country. Almost all the seed spices are winter season crops (*rabi*) need cool weather conditions for better growth and development. However, frost leads to major damage to these crops. These crops are very tender and sensitive to abiotic and biotic factors mainly seed, soil and air born fungal diseases and insects which may damage whole crop at any stage depending on weather parameters.Frost at post flowering stage causes heavy yield loss due to mortality of tender inflorescence. Among biotic factors mainly *Fusarium* wilt and *Alternaria* blight reduce the yield in most of seed spices. All kind of protected technologies may not be economical and suitable to the various groups of farmers in India, because of their very high initial, running and maintenance cost, but some protected technologies are low cost, simple and highly profitable for Indian farmers for production of different high value seed spices crops and nursery raising in profitable agri-business models (Singh *et al.,* 2016).

METHODOLOGY

Different protected structures like plastic sheet / insect proof net/ shed net covered walk in tunnels were designed and tested for biotic and abiotic stress management in seed spices. Other technologies like nursery raising, transplanting, drip fertigation in major and minor seed spices, off season production of leafy coriander and fenugreek were tested at NRCSS farm Tabiji, Ajmer.

RESULTS

Temporary plastic walls for protection of seed spices against frost: Frost occurs mostly during end of the year or at start of the year, when cold period is at the peak (midDecember to mid January) and the crop is at its flowering stage. To manage this condition, barriers needed to block the cold wave over the crop canopy. Rather, low cost technologies like expanding of plastic walls of 1-1.5 m height depending upon crop height from the field surface in the northern direction efficiently blocks the flow of cold waves and thus reduces the loss caused by frost significantly. A 35-50 micrometer thick transparent plastic sheet is suitable for crating artificial temporary walls in the field. These walls can be laid parallel if the field is large leaving a distance of 10-15 meters. Single wall in the north south direction will reduced the chances of cold wave movement along the wall laid in north west direction. Transparent plastic covered walk in tunnel technology for seed spices cultivation: Transparent plastic covered temporary walk-in –tunnel is also suitable and effective for seed spice cultivation up to a limited extent. Plastic sheet of 150-200 micrometer thickness is laid a semi-circle shape with ½ inch GI pipes fitted on the iron made plates fixed in the field at a distance of 2.5-3.0 meter and the height of these walk-in-tunnels is six feet at the centre. This types of structure provides protection not only against biotic and abiotic stresses but also results in vernalization, as it induces early flowering compared to normal open field crop. A crop advancement of 10-15 days was observed for flowering as well as maturity. This technique is actually very low of cost and feasible for crops like coriander, ajwain and cumin, where heavy losses are reported due to abiotc factors. management. Insect proof net covered walk in tunnel technology for seed spices cultivation:The technique of insect proof net covered temporary walk-in –tunnels are as same as above, the only difference is that the basic covering material used is UV stabilized nylon net of 40 mesh. This provides a more open type micro-climate compared to plastic covered as the temperate difference between the outer and inner structure is not much due to free air movement through the holes of the net mesh. The basic advantage of the technology is prevention against hail storms and insects. B. Off season coriander/ fenugreek cultivation under Shade net houses /Walk In Tunnels for leafy vegetable purpose. Shade net houses and walk In tunnels:These nets are available in different shading intensities ranging from 25% to 90%. Leafy seed spices are recommended to be grown under shade nets whose growth are significantly enhanced compared to open conditions when sunlight is strong. *C. Mulching* (Plastic mulching for seed spice cultivation): It is an effective practice to restrict weed growth, conserve moisture and reduce the effect of soil borne diseases through soil solarisation. Transparent polyethylene mulch raises the soil temperature.

CONCLUSION

The overall view of the aspect to introduce protected system of cultivation in seed spices seems to be potential enough in the coming days. The above mentioned technologies have higher scope in hi-tech cultivation of seed spices. The scenario of climate change may force to shift to these climate resilient practices in future.

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Ammonia volatilization in rice under different temperature regimes

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Ammonia volatilization is the major process through which nitrogen losses from soil takes place under increasing temperature scenarios. Large amount of NH_3 emission not only causes environmental problems but also the nutrient losses which lead to economic losses by increasing the cost of production. Rice is the most extensively grown cereal crop in India but excessive use of N fertilizer in the agriculture leads to low nitrogen use efficiency and lower net returns to the farmers. Thus this study was conducted to evaluate the effect of high temperature on ammonia volatilization and yield under different N levels in rice crop. The four different temperature viz. Ambient temperature (T1), Temperature Gradient Tunnel (TGT) Control (T2), plus 3° C (T3) and plus 5° C (T4) and four different levels of nitrogen viz. 0, 90, 120 and 150 kg/ha in combinations were taken as the experimental treatments. Results showed that phenological length, plant height and leaf area was increased significantly in TGT as compared to the ambient temperature. As the nitrogen levels increases, photosynthetic rate was also increases during all the growth stages and highest photosynthetic rate (23%) was observed at N150 as compared to N120 at anthesis. Grain weight/plant, total grain weight, total biomass, number of tiller and number of spike were found maximum in TGT with harvest index up to 0.45. In all the treatments, nitrogen levels enhanced the N content in leaves, stem and gain. Chlorophyll content was found highest (57% increase) at anthesis in N150 as compared to N120. The NH_3 volatilization directly depends on the fertilizer application and was emitted effectively upto the 6th day from the date of fertilizer application. The rate of NH_3 volatilization enhanced with the increase dose of N application and it was observed maximum at N150 as compared to without N level.

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Bio-efficacy of new-generation herbicide combinations on weed growth, yield and economics of greengram (*Vigna radiata* L.)

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Greengram is the third important pulse crop of India in terms of area 3.55 millon ha and production 1.82 million tonnes (Singh *et al*., 2015). It serves as a vital source of vegetable protein (19.1-28.3 %) and vitamins. Weed infestation is one of the major constraints in greengram cultivation and causes 50 to 90 % yield loss (Kumar *et al*., 2006). Being a short statured crop it is invaded by a large number of fast growing weeds at initial stage. In greengram hand weeding effective in controlling the weeds but unavailability of labor and continuous rainfall in rainy season does not permit it to operate timely. It is also time consuming and costly. Therefore chemical control of weed forms an excellent alternative to

Table 1. Bio-efficacy of new-generation herbicide combinations on weed growth, yield and economics of greengram

Treatments	WCE (%)	WI (%)	Pods/ plant	Seed yield (kg/ha)	Net returns (Rs/ha)	B: C
Pendimethalin 30% EC 1.0 kg/ha PRE	34.47	60.68	7.70	426	13052	1.65
Pendimethalin 30% EC 1.0 kg/ha as PRE fb imazethapyr 10% SL 75g/ha as PRE	60.89	16.02	9.33	912	48445	3.23
Early POST (12-15 DAS)						
Imazethapyr 10% SL 75g/ha	50.12	31.67	8.60	742	41275	3.05
Chlorimuron ethyl 25% WP 9g/ha	33.75	79.37	4.00	224	-3023	0.85
Quizalofopethyl 5% EC 50g/ha+imazethapyr 10% SL 75 g/ha	70.15	7.18	10.00	1008	55662	3.55
Imazethapyr 35%+imazamox 35% WG 70g/ha	60.62	17.12	9.23	900	46783	3.09
Propaquizafop 2.5% 50 g/ha+ imazethapyr 3.75 % ME 75g/ha	61.18	15.29	9.40	920	48291	3.15
Haloxyfop-p-methyl 10.8% EC 135 g/ha+imazethapyr 10% SL 75g/ha	70.69	5.25	10.00	1029	56892	3.56
Cycloxydim 20% EC 80 g/ha+ imazethapyr 10% SL 75g/ha	49.51	32.14	8.50	737	38447	2.84
Hand weeding at 20 and 40 DAS	97.92	0.00	10.27	1086	54982	2.94
Unweeded control	0.00	60.87	7.60	425	14592	1.79
SEm±	-	-	0.17	28	840	-
CD (P=0.05)	-	-	0.51	82	2437	-

manual as well as mechanical weeding and provide weed-free environment from emergence up to 30– 35 days. Also manual or spraying of recommended pre-emergence herbicide is some time difficult in rainy season for efficient weed control. Keeping these points in view, a field experiment was under taken to find out the most effective early post-emergence herbicidal treatment for getting higher yield in greengram.

METHODOLOGY

The field experiment was conducted during *kharif*, 2015 in sandy loam soil having pH 7.4 at College Farm. The experiment was laid out in randomized block design with three replications. MGG- 295 was used as a test variety. The crop was sown on 15th July, 2015at a spacing of 30 cm x 10 cm and fertilized with 20:40:30 kgN,P_2O_5 and K_2O/ha. The treatment comprising eleven treatments viz. T_1: pendimethalin 30% EC 1.0 kg/haas pre-emergence, T_2:pendimethalin 30%EC 1.0 kg/ha as pre-emergence followed by imazethapyr 10% SL 75 g/ha as post-emergence (at 2-4 leaf stage), T_3:imazethapyr 10% SL 75 g/haat 12-15 DAS as early post-emergence, T_4:chlorimuron ethyl 25% WP 9 g/haat 12-15 DAS as early post-emergence, T_5:quizalofop ethyl 5% EC 50 g/ha+imazethapyr 10% SL 75 g/ha at 12-15 DAS as early post-emergence, T_6: imazethapyr 35% + imazamox 35% WG 70 g/ha at 12-15 DAS as early post-emergence, T_7: propaquizafop 2.5% 50 g/ha+imazethapyr 3.75% ME 75 g/ha at 12-15 DAS as early post-emergence, T_8: haloxyfop-p-methyl 10.8% EC 135 g/ha+imazethapyr 10% SL 75 g/ha at 12-15 DAS as early post-emergence, T_9: cycloxydim 20% EC 80 g/ha + imazethapyr 10% SL 75 g/ha at 12-15 DAS as early post-emergence, T_{10}: hand weeding at 20 and 40 DAS and T_{11}:Unweeded control. All the herbicides were applied with knap sack sprayer fitted with flat-fan nozzle. All plant protection measures were carried out to raise a good crop. The data on weed growth, yield attributes, seed yield were recorded and economics of treatments were worked out.

RESULTS

A significantly higher weed control efficiency and significantlylower weed index were recorded with hand weeding at 20 and 40 days after sowing followed by haloxyfop-p-methyl 10.8% EC 135 g/ha + imazethapyr 10% SL 75 g/ha at 12-15 DAS g and quizalofop ethyl 5% EC 50 g/ha +imazethapyr 10% SL 75 g/ha at 12-15 days after sowing as early post-emergence at harvest. The yield attributes and yield viz. number of pods/plant, and seed yield were significantly superior with hand weeding at 20 and 40 days after sowing which was on par with haloxyfop-p-methyl 10.8% EC 135 g/ha+imazethapyr 10% SL 75 g/ha at 12-15 days after sowing and quizalofop ethyl 5% EC 50 g/ha+imazethapyr 10% SL 75 g/ha at 12-15 days after sowing as early post- emergence. Though hand weeding at 20 and 40 DAS gave higher yield, net returns and benefit: costwere significantly higher with haloxyfop-p-methyl 10.8 % EC 135 g/haimazethapyr 10% SL 75 g/ha at 12-15 DAS and quizalofop ethyl 5% EC 50 g/ha + imazethapyr 10% SL 75 g/ha at 12-15 DAS as early post-emergence due to more cost of cultivation.

CONCLUSION

From the above study, it can be concluded that combinations of haloxyfop-p- methyl 10.8 % EC 135 g/ha + imazethapyr 10% SL 75 g/ha and quizalofop ethyl 5 % EC 50 g/ha+imazethapyr 10 % SL 75 g/ha at 12-15 DAS as early post- emergence can be recommended for Southern Zone of Telangana State for getting higher yields, net returns and benefit: cost in greengram during *kharif* season.

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Integrated weed management in guar

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India is the leading producer of guar and guar gum in the world. It share around 80 % production of world, rest of major production comes from Pakistan. In India Rajasthan is leading producer of the guar seed and guar gum. It contributes around 70 % production of India. Haryana, Gujarat and Punjab are other Guar producing states in India.The weed infestation is a serious problem in *kharif* season, which reduces the yield of guar crop and the manual weeding is very expensive due to less availability of labour which ultimately finding for suitable herbicide for weed management.

METHODOLOGY

A field trial was conducted during Kharif-2015 at Krishi Vigyan Kendra, Chomu (Tankarda) Farm and farmers' fields (5 locations). Three different treatments were taken in On Farm Testing. Various treatments are:One hand weeding 40 days after sowing (Farmers Practice). (1) Application of Pendimethalin 1.0 kg a.i./ha. before sowing (Recommended Practice) (2) Application of Imazethaypr 40 gm a.i./ha. (15-20 days after sowing).

RESULTS

Results observed that yield (1.75 t/ha) was recorded the highest with application of Imazethypr 40 gm a.i./ha. (15-20 days after sowing), yield increased (20.69%), net return (50,400 Rs/ha.) and BCR (3.57) and followed by application of Pendimethalin 1.0 kg a.i./ha. in case of yield (1.63 t/ha), yield increased (12.07%), net return (45,800 Rs/ha) and BCR (3.39). Because application of Imazethaypr 40 gm/ha gave good result due to less weed infestation and this herbicide is effective for weed control.

CONCLUSION

The results concluded that the application of Imazethypr 40 gm a.i./ha. (15-20 DAS) was found very effective and feasible for enhancing the grain yield and found economically viable.

Table 1. Effect of Integrated Weed Management on yield and economics (pooled of 3 trials)

Technology Option	Yield (t/ha)	Yield increased (%)	Net Return (Rs/ha)	B:C Ratio
One hand weeding 40 DAS (FP)	1.45	—	37,000	2.76
Pendamethalin 1.0 kg a.i./ha (before sowing) (Recommended Practice)	1.63	12.07	45,800	3.39
Imazethapyr 40 gm a.i./ha (15-20 DAS)	1.75	20.69	50,400	3.57

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Adaptations to climate change: use of polymer hydrogel to mitigate biotic stress in Linseed (*Linum usitatissimum*)

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Linseed (*Linum usitatissimum* L.) is one of the *rabi* oil seed crop of India. It is basically an industrial crop, cultivated for its seeds and fiber. It occupies an important position in India for its technical grade oil producing ability. It is cultivated in India an area of 292 thousand ha with a production of 141.7 thousand tonnes and a productivity of 484 kg/ha(Anon., 2014). Rajasthan is the highest producer of linseed in India. In Karnataka, Linseed is grown over an area of 0.06 lakh ha with a production of 0.02 lakh tonnes and productivity of 329 kg/ha (Anon., 2014). Karnataka is eighth largest grower of linseed after Madhya Pradesh, Chhattisgarh, Maharashtra, Uttar Pradesh, Jharkhand, Bihar and Orissa. Linseed production and productivity in India are very low, mainly due to its cultivation in residual moisture during *rabi* season where the crop experiences moisture stress at one or the other stages. Recently the rainfall pattern in the country especially in Karnataka is varying and characterized by frequent droughts, which affected crop growth and development which in turn witnesses with wide fluctuation in productivity due to erratic rainfall distribution and less availability of nutrients. The low productivity is mainly due to the crop growing under rainfed conditions on poor fertility soils with non-availability of cultivars under moisture and nutrient stress situations. Identification of best agronomic practices suited to moisture and nutrient stress conditions are vital to the farmers of this region. Hence, the hydrogel along with FYM, Vermicompost and gypsum were evaluated under the influence of moisture and nutrient management practices in linseed.

METHODOLOGY

The field experiment was conducted for two successive *rabi* season of 2013-14 to 2014-15 under rainfed condition at Main Agricultural Research Station, Raichur, Karnataka, India to find out impact of polymer hydrogel to mitigate biotic stress in linseed to achieve higher productivity and profitability geographically the experiment place is located in North Eastern Dry Zone (Zone-2) of Karnataka State, which falls between 16^o 15' N latitude and 77^o 20' E longitude with an altitude of 389 metersabove mean sea level.The soil of the experimental site belongs to medium black with clay loam texture having 0.50 per cent of organic carbon, 187 kg/ha available nitrogen, 27.33 kg/ha available phosphorus and 142.33 kg.ha^{-1} available potassium with 8.70 pH. The potential linseed variety,NL-115 was used with nine treatments. The experiment was laid out incompletely randomized block design with three replications. The observations were recorded on growth, yield attributes and yield. Costs and returns were computed based on the prevailing market prices. Finally the results wereanalyzed with suitable statistical analysis.

RESULTS

Two years pooled data reviled that, among the different organic amendments and moisture conservation practices, application of hydrogel @ 2.5 kg/ha along with vermicompost @1 t/ha recorded significantly highest plant height (57 cm), number of branches/plant (7.19). Number of capsules/plant (69.44) and 1000 seed weight (8.58 gm) as compared to all other treatments (Table 1). Significantly lower growth and yield parameters were observed in no mulching treatment (40 cm, 3.28, 40.35 and 5.76 gm, respectively). Significantly higher seed yield of linseed was recorded in the treatmentapplication of hydrogel @ 2.5 kg/ha along with Vermicompost @1 t/ha as compared to rest of the treatments in both the years of experimentation. Pooled data of two year showed that hydrogel @ 2.5 kg/ha along with Vermicompost @1 t/ha recorded significantly higher seed yield of Linseed (832 kg/ha)and produced 59 % higher yield over control (100 % NPK only) (491 kg/ha). However which was on par with FYM 1.0 t/ha + hydrogel 2.56 kg/ha (782 kg/ha).The higher seed yield in hydrogel @ 2.5 kg/ha along with Vermicompost @1 t/ha may be due to higher growth and yield attributes of linseed observed the treatment as well as higher moisture retention and its utilization during the requirement. There is strong interaction between nutrient source and moisture availability for crop yield. Application of nutrients facilitates root growth, which can extract soil moisture from deeper layers and moisture conservation practices ensured the better availability of moisture to the plants. Furthermore, supply of nutrients facilitates early development of canopy that covers the soil and intercepts more solar radiation and thereby reduces the evaporation component of the evapo-transpiration.

CONCLUSION

The results of two - year experiment clearly indicated that adoption of moisture conservation techniques like use of polymer hydrogel and supply of nutrients through organics like FYM, Vermicompost, gypsum to linseed are proved to be best ones in Vertisols of Semi-arid Tropics of Karnataka for obtaining higher yield and monetary returns besides having higher production sustainability of linseed.

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Study of effective weed control methods in chickpea

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Commercial chickpea (*Cicer arietinum* L.) production has recently begun in India. The seed size and quality are important factors that influence crop profitability. Interest in chickpea has increased in recent years due to its high economic valve. Chickpea has been shown to consistently provide a nitrogen (N) benefit to spring wheat grown in rotation in northern Great plains (Miller *et al.*, 2002). In addition to the N benefit, Chickpea has also been shown to provide a break in the disease cycle of cereal pathogen in wheat grown in northern regions of Australia. (Felton *et al.*,1998). In general, compared with other pulses, chickpea develops relatively slowly when plants are young and it has an open canopy architecture and low stature (Amor and Francisco, 1987; Knights, 1991), reducing its ability to compete with weeds. Therefore weeds are a constraint to chickpea production resulting in harvesting difficulties, reduced yield and economic returns. Weed control is essential for maximum seed yield and seed quality. Several studies have indicated that effective weed control may increase chickpea yield by 17-105 %.. Hence the present experiment was conducted to screen the most effective weed control measure in chickpea.

METHODOLOGY

The study was conducted at Agriculture Research Station, Badnapur during *rabi* 2008. The experiment was laid out in randomized block design with three replications. It includes twelve treatments *viz.*, weedy check, Hand weeding twice 25-30 days after sowing and 50-55 days after sowing, Quizalofop-ethyl 40 g/ha post emergence at 20 days after sowing, Quizalofop-ethyl 40 g/ha post emergence at 30 days after sowing, Quizalofop-ethyl 50 g/ha post emergence at 20 days after sowing, Quizalofop-ethyl 50 g/ha post emergence at 30 days after sowing, Imazethapyr 25 g/ha post emergence at 20 days after sowing, Imazethapyr 25 g/ha post emergence at 30 days after sowing, Imazethapyr 40 g/ha post emergence at 20 days after sowing, Imazethapyr 40 g/ha post emergence at 30 days after sowing, Chlorimuron-ethyl 4 g/ha post emergence at 20 days after sowing, Chlorimuron-ethyl 4 g/ha post emergence at 30 days after sowing The experiment was sown on 10.11.2008 and plot size was 3.6 x 4.0 sq.m. The spraying of weedicides was done as per the treatments. The data was analyzed with standard statistical methods.

RESULTS

Data pertaining to the chickpea yield is presented in table 1. Results revealed that significantly higher grain yield of chickpea (1913 kg/ha) was observed in hand weeding twice at 25-30 and 50-55 days after sowing (T_2) over weedy check (T_1) (1440 Kg/ha), however it was on par with the application of Quizalofop – ethyl 40 g/ ha POE at 20 DAS(T_3), Imazethapyr 40 g/ha POE at 20 DAS (T_9), Quizalofop – ethyl 50 g/ ha POE at 20 DAS (T_5) and Imazethapyr 25 g / ha POE at 20 DAS (T_7). Imazethapyr 40 g/ ha POE at 30 DAS (T_{10}).

CONCLUSION

Based on present investigation, it can be concluded that to

Table 1. Grain yield (kg/ha) of Chickpea as influenced by different herbicides

Treatment	Treatment Detail	Grain yield (kg/ha)
T_1	Weedy check	1440
T_2	Hand weeding twice 25- 30 and 50-55 DAS	1913
T_3	Quizalofop – ethyl 40 g/ ha POE at 20 DAS	1903
T_4	Quizalofop – ethyl 40 g/ ha POE at 30 DAS	1698
T_5	Quizalofop – ethyl 50 g/ ha POE at 20 DAS	1852
T_6	Quizalofop – ethyl 50 g/ ha POE at 30 DAS	1715
T_7	Imazethapyr 25 g / ha POE at 20 DAS	1835
T_8	Imazethapyr 25 g / ha POE at 30 DAS	1680
T_9	Imazethapyr 40 g / ha POE at 20 DAS	1886
T_{10}	Imazethapyr 40 g/ ha POE at 30 DAS	1821
T_{11}	Chlorimuron-ethyl 4 g/ ha POE at 20 DAS	1732
T_{12}	Chlorimuron-ethyl 4 g/ ha POE at 30 DAS	1715
	CD (P=0.05)	192.36

harvest maximum yield in Chickpea the effective weed control method is Hand weeding twice 25- 30 and 50-55 days after sowing.

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Integrated weed management in wheat (*Triticum aestivum*)

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Wheat (*Triticum aestivum* L.) is an unique and most important grain crop both in regards to its antiquity and its use as source of human food. Wheat serves as a staple food for about one billion people in as many as 43 countries of the world. Wheat suffers badly due to infestation of wide variety of grasses and broad leaf weeds. Unchecked weed growth reduces the wheat yield on an average, more than 66% due to mixed population of weeds in wheat has been observed by (Singh and Singh 2005). In Maharashtra, pendimethalin and 2,4-D are widely used herbicides in wheat crop for control of weeds. Metsulfuron methyl herbicide is promising and most effective against broad leaf weeds as well as *Asphodelustenuifolius* in wheat (Vala, 2000). In Kolhapur region general monocot and dicot weeds are predominant in wheat, and there is meager information available on 2, 4-D herbicide against control of these weeds. Now there is an option to control these monocot weed species in wheat by utilization of herbicide like oxyfluorfen as pre-emergences and there is a need to check this possibility in Kolhapur region. Therefore, the present investigation entitled "Integrated Weed Management in wheat" (*Triticum aestivum* L.).

METHODOLOGY

The field experiment was conducted at post graduate research farm, College of Agriculture, Kolhapur during the *rabi* season of 2009-10. The experiment was laid out in randomized block design with eight treatments viz. Weedy check (T_1), Weed free check (T_2), Pendimethalin @ 1.0 kg a.i./ha as PE + one hoeing at 30 DAS (T_3), Oxyfluorfen @ 0.1 kg a.i./ha as PE + hoeing at 30 DAS (T_4), Pendimethalin @ 1.0 kg a.i./ha as PE + 2.4 – D (Na salt) @ 1.0 kg a.i./ha as PoE at 30 DAS (T_5), Hand weeding at 15 DAS + 2, 4-D (Na salt) @ 1.0 kg a.i./ha as PoE at 30 DAS (T_6), One hoeing at 15 DAS + Hand weeding at 30 DAS (T_7) and One hand weeding at 15 DAS + Metsulfuron methyl @ 6 g a.i./ha as PoE at 30 DAS (T_8) and replicated three times. Post emergence application was done 30 days after sowing. Crop was fertilized with 120 kg N, 60 kg P_2O_5 and 40 kg K_2O/ha. The herbicides were applied with manually operated knapsack sprayer.

RESULTS

The major weeds observed in the experimental field included*Phalaris minor, Brachiaria eruciformis, Cynodondactylon, Cyperusrotundus* among the monocots and *Commelina bengalensis, Partheniumhysterophorus, Protulacaoleraceae, Lactucaruncinata, Sonchusarvensis, Sonchusoleracious, Euphorbia thymifolia and Amaranthus polygamus* were dicots.Weedy check treatment recorded significantly higher dry matter as compared to rest of the treatments. However, weed free check treatment recorded lowest dry matter of weeds and pendimethalin (PE) 1.0 kg a.i./ha + 2,4 –D 1 kg/ha (Na Salt) PoE at 30 DAS recorded significantly higher dry matter than the herbicidal and cultural treatmentsdue to effectively control the weed. Weed free check treatment recorded highest weed control efficiency (97.42%) than the rest of the treatments followed by pendimethalin (PE) 1.0 kg a.i./ha + one hoeing at 30 DAS (91.86%). Weedy check treatment recorded higher weed index (56.29%) than rest of the treatments. However, pendimethalin (PE) 1.0 kg a.i./ha + one hoeing at 30 DAS recorded lowest weed index (13.94%) followed by one hoeing at 15 DAS + one hand weeding at 30 DAS. Thus the integrated approach of applying pendimethalin (PE) 1.0 kg a.i./ha + one hoeing at 30 DAS, one hoeing at 15 DAS + one hand weeding at 30 DAS was superior for controlling weeds. Effectively control of monocot and dicot weeds due to integrated approach. The results are in accordance with the findings of Jat *et al.,*(2004). Maximum number of spikelets/spike (17.67/spike), grains/spike (40.0/spike) and 1000 grain weight (37.51 g) was observed in weed free check and it was significantly superior over rest of the treatments. It was followed by pendimethalin (PE) 1.0 kg a.i./ha+ one hoeing at 30 DAS. The weed free check recorded significantly higher grain yield (3030 kg /ha) and straw yield (3480 kg/ha) more than rest of the treatments. It was followed by Pendimethalin (PE) 1.0 kg a.i./ha+ one hoeing at 30 DAS, one hoeing at 15 DAS + one hand weeding at 30 DAS, one hand weeding at 15 DAS + MSM 6 g a.i./haat 30 DAS, one hand weeding at 15 DAS + 2,4–D (Na) Salt PoE 1 kg a.i./ha at 30 DAS (Pendimethalin (PE)1.0 kg a.i./ha + 2,4 –D (Na Salt) PoE 1 kg a.i./ha at 30 DAS and Oxyfluorfen (PE) 0.1 kg a.i./ha + one hoeing at 30 DAS, and significantly superior over weedy check treatment. The per cent reduction in grain yield of wheat under weedy check treatment was 43.72% over weed free check treatment. Due to effective controlling the weed in earlier growth stage enhance growth and yield attributing character ultimately increased yield

CONCLUSION

It is concluded that integrated weed management in wheat with pre emergence application of pendimethalin @ 1.0 kg a.i./ha + one hoeing at 30 DAS recorded minimum weed in-

Table 1. Effect of integrated weed management treatments on weed dry matter, weed control efficiency, weed index, yield attributes and yield of wheat crop

Treatments	Weed dry matter (t/ha)	Weed control efficiency (%)	Weed index (%)	Spikelets/ spike	Grains/ spike	1000-grain weight (g)	Grain yield (kg/ha)	Straw yield (kg/ha)
T_1 -Weedy check	0.777	0.00	56.29	11.0	33.29	33.29	1326	1758
T_2 -Weed free check	0.020	97.42	0.00	17.67	37.51	37.51	3033	3480
T_3 -Pendimethalin (PE) 1.0 kg a.i./ha+ one hoeing at 30 DAS	0.063	91.86	13.94	15.67	36.84	36.84	2631	2954
T_4 -Oxyfluorfen (PE) 0.1 kg a.i./ha + one hoeing at 30 DAS	0.080	89.70	20.47	14.33	36.02	36.02	2412	2757
T_5 -Pendimethalin (PE)1.0 kg a.i./ha + 2,4 –D (Na Salt) PoE 1 kg a.i./ha at 30 DAS	0.083	89.55	19.32	14.33	35.12	35.12	2417	2721
T_6 -One hand weeding 15 DAS + 2,4–D (Na) Salt PoE 1 kg a.i./ha 30 DAS	0.073	90.57	19.41	14.67	36.17	36.17	2444	2824
T_7 -One hoeing at 15 DAS + one hand weeding at 30 DAS	0.070	90.99	16.28	15.33	36.73	36.73	2539	2884
T_8-One hand weeding at 15 DAS + MSM 6 g a.i./ha at 30 DAS	0.072	90.74	17.21	15.33	36.22	36.22	25.11	2859
S.Em±	0.020	-	-	0.53	0.42	0.42	1.20	139
CD (P=0.05)	0.061	-	-	1.59	1.26	1.26	3.63	422

tensity, weed dry matter and weed index, maximum weed control efficiency and yield as compared with all other treatments.

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Effect of weed management practices on potato in NEH region of India

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Potato (*Solanum tuberosum* L.) is widely cultivated in the north eastern hill region of India under rainfed ecosystem. There are several constraints in potato production, of which weeds are the severe biotic constraint and cause more reduction in productivity of potato. Due to heavy rainfall, weed poses a serious problem for cultivation of potato in north eastern hills region. Weed emergence is directly related to the intensity of rainfall to wet the soil horizons. Different flushes of weed come out at different time depending upon the soil moisture. Weeds not only compete with crop plants for nutrients, soil moisture, space and sunlight but also serve as an alternative hosts for several insect pest and diseases (Yadav *et al.,* 2014). Keeping these points in view, an investigation was undertaken to study the effect weed management practices on productivity of potato in the rainfed region.

METHODOLOGY

A field experiment was conducted under AICRP on potato during consecutive summer season of 2013 and 2014 at ICAR-Central Potato Research Station, Shillong. The soil was sandy loam in the texture with acidic reaction, moderately fertile, being high in organic carbon and medium in available nitrogen while low in available phosphorus and high in available potassium. The trial was laid out in randomized block design, replicated fourth, with 7 treatments. The crop was planted during the first week of March and harvested in the month of July. The recommended dose of fertilizer for this region @ 140: 120: 60 kg N, P_2O_5 and K_2O/ha, respectively. Half dose of nitrogen and full dose of P and K were applied at the time of planting, whereas remaining N was given at earthing up stages. *Kufri Jyoti* was taken as the potato variety for this experiment. The other recommended package of practices was followed as per recommendation of crop in the region. The weed counts were subjected to square root transformation (“x+0.5) to normalize the distribution. Weed control efficiency and weed index were also worked out to assess the efficiency of different weed control treatments. The calculated values of the treatments and error variance ratio were compared with Fisher and Yates F table at 5% level of significance.

RESULTS

The data presented in the (Table 1) revealed that the lowest yield was recorded under weedy check during the investigation. The pooled data over years revealed that the maximum potato tuber yields were recorded in the weed free check followed by herbicide Metribuzin @ 0.75 kg/ha as pre-emergence. The highest weed index was recorded for weedy check than other treatments which indicate that reduction in crop yield by 51.5% due to presence of weeds in comparison with weed-free check. The range of weed control efficiency of different weed management practices varied between 23.4 and

Table 1. Effect of weed management practices on productivity of potato (Pooled over two years)

Treatment	Yield (t/ha)	Weed index (%)	Weed control efficiency (%)	Net return (Rs. x10^3)
Weedy check	10.0	51.5	0.0	47.0
Weed free	20.6	0.0	99.8	174.1
Hand weeding at 30 days and weed free upto maturity	17.7	13.8	93.0	134.9
Hand weeding at 40 days and weed free upto maturity	16.7	18.7	71.8	124.1
Hand weeding at 50 days and weed free upto maturity	16.1	21.6	23.4	119.4
Herbicides (Metribuzin @ 0.75 kg/ha) pre-emergence	19.6	4.8	99.2	187.3
Herbicides (Metribuzin @ 0.75 kg/ha) as post emergence at 10% of plant emergence	18.8	8.6	99.5	175.3
SEm±	0.4	-	-	-
CD (P=0.05)	1.1	-	-	-

99.8%. The maximum weed control efficiency was observed under weed free treatment followed by hand weeding after 30 days of planting and weed free upto maturity. This may be due to negligible dry weight of weeds in weed free treatment. Date presented in Table 1 shown that the maximum net return was found through application of metribuzin @ 0.75 kg/ha as a pre emergence followed by application of herbicide Metribuzin @ 0.75 kg/ha as post emergence at 10% of plant emergence. Although the weed free plot has the highest productivity of potato but maintaining the field weed free throughout the crop season incurred the highest labour cost, consequently net profit was reduced as compare to other treatment.

CONCLUSION

It may be concluded that application of metribuzin @ 0.75 kg/ha as a pre emergence is recommended for controlling the weeds and maximising the profitability of farmers through cultivation of potato in rainfed condition of Meghalaya.

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Bio-efficacy of imazethapyr in rainfed green gram

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Pulses are inseparable ingredients of vegetarian diet, and one of the cheapest weapons for combating the malnutrition problem by supplying dietary protein to the people. India, contributes 27.65% to the global pulse production and holds 35.2% of the world's pulse acreage. Inspite of being the largest producer in the world, our country has to import pulses to the tune of two million tonnes every year to meet its domestic requirement, the increment in the production being not able to maintain the pace with population growth (Chaturvedi and Ali, 2002). Among the grain legumes, greengram can be grown throughout the year, however, cultivation in rainy season is the common practice under rainfed situation. One of the major constraints in greengram production is weed competition. The loss of greengram yield due to weeds ranges from 65.4 per cent to 79.0% (Shuaib, 2001; Dungarwal *et al.* 2003). Imazethapyr is an imidazolinone herbicides applied as pre-emergence and early-post emergence for control of annual grass, broad-leaf weeds and perennial sedges in pulses. It is being a broad spectrum herbicide found superior against all types of weeds. Since work on optimization of its dosage as

Table 1. Effects of different weed management practices on performance of greengram (Pooled data of two years)

Treatment	Weed dry weight at 60 DAS (g/m^2)	Weed control efficiency at 60 DAS(%)	Weed index (%)	Total dry matter production of greengram at harvest (g/plant)	Seed yield (kg/ha)	Haulm yield (kg/ha)
T_1 - Imazethapyr 10 % SL 500 ml/ha	13.70	72.11	44.42	12.4	645	1467
T_2 - Imazethapyr 10 % SL 625 ml/ha	11.04	78.13	28.60	14.2	804	1674
T_3 - Imazethapyr 10 % SL 750 ml/ha	8.70	82.11	17.01	14.4	925	1876
T_4 - Imazethapyr 10 % SL 500 ml/ha +Adjuvant	12.80	74.56	31.07	13.1	782	1678
T_5- Imazethapyr 10 % SL 625 ml/ha+ Adjuvant	10.76	78.43	17.75	14.3	920	1903
T_6 - Imazethapyr 10 % SL 750 ml/l + Adjuvant	7.80	84.16	8.63	14.7	1015	2013
T_7 - Quizalofop - Ethyl 5 % EC @1000 ml/ha	12.00	76.17	31.01	13.0	785	1756
T_8 - Standrad check (2 IC+2HW)	6.44	87.22	4.17	15.4	1057	2213
T_9 - Weedy check	53.60	-	51.78	6.3	567	1345
T_{10} - Weed free	1.48	97.80	-	15.1	1108	1924
SEm±	4.74	4.28	1.79	0.8	72	81
CD (P=0.05)	9.99	9.03	4.30	2.5	191	209

early post emergence herbicides is a need of the hour. Further, during rainy season applied herbicide formulation subjected in to losses because of rainfall in such situation usage of adjuvant is the novel option to achieve desirable efficacy of the applied herbicide and work on these aspects are meager. Hence, an attempt was been made to evaluate the efficacy of imazethapyr at varied dosage.

METHODOLOGY

A field experiment was conducted to study the bio-efficacy of early post emergence herbicide Imazethapyr at various dosage in comparison with and Quizalofop-Ethyl 5% EC @1000 ml/ha, standard check and weed free check against weeds in greengram and the impact different weeds management on growth and yield of greengram cultivar Nirmal was carried out at Main Agriculture Research Station Farm, University of Agricultural Sciences, Dharwad Karnataka during the *kharif* season 2012 and 2013. The experiment was laid out in randomized complete block design having three replications. Herbicides application was done using a Knapsack sprayer equipped with a Flat-fan nozzle. The crop was raised under rainfed condition with recommended package of practices for the Northern Transitional Zone of Karnataka. The total rainfall received during the crop growth was 148.4 and 40.5 mm in 7 and 2 rainy days during 2009-10, 2010-11, respectively.

RESULTS

From the perusal of the Table 1 it was noticed that, significantly higher seed (1057) and haulm (2213 kg/ha) yields of greengram was observed with standard check (2 IC+2HW) on account of excellent performance of greengram crop under two hand weeding coupled with one inter cultivation which might have created good root proliferation due to proper soil loosening. However, among the herbicidal treatments application of Imazethapyr 10% SL 750 ml/l + Adjuvant recorded significantly lower weed dry weight (7.80), higher weed control efficiency (84.16%), lower weed index (8.63%) and higher total dry matter production of greengram at harvest (14.17 g/plant) as a resultant of higher weed control efficiency of the applied herbicide performance of the greengram was excellent when compared to rest of the treatments under investigation and was reflected by registering significantly higher seed (1015 kg/ha) and haulm (2013 kg/ha) yields of greengram. Superior yield attributing characters and effective weed control contributed to higher yields under higher doses of early post emergence application of Imazethapyr 10% SL 750 ml/ha + Adjuvant @ 2.0 ml/l of water.

CONCLUSION

From the current study it was noticed observed that, application of imazethapyr at 750 ml/ha + 2ml adjuvant per liter of water found superior in managing weeds of rainfed greengram by recording significantly superior weed control efficiency, higher growth, yield attributes, seed and stover yield.

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Integrated weed management in *rabi* fennel

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Fennel is export oriented low volume but high value cash crop of arid and semi arid regions of country. It is mainly cultivated for its seed, which have pleasing fragrance and pleasant aromatic taste act as a stimulant and carminative. Fennel (*Foeniculum vulgare* Mill.) generally takes longer time for germination and also has slow initial growth which often leads to heavy infestation of weeds. If not controlled timely, these weeds adversely affect the growth and cause huge losses in yields. Therefore, weed management is one of the most crucial factors in realizing optimum yields. Manual weeding is the common practice in fennel to keep the weeds under check. However, timely availability of labourers and higher costs involved are the major constraints in effective weed management in fennel. Suitable alternatives involving herbicide use is the need of the hour for effective and efficient control of weeds in fennel to ensure optimum yields and reduce the dependence on manual labour. Therefore, use of herbicide as pre or post emergence with cultural practices for weed management is emerged as a best alternative to sustain the productivity in fennel with minimum soil and air pollution.

METHODOLOGY

A field experiment was conducted during *rabi* season of three consecutive years 2012-13, 2013-14 and 2014-15 at Seed Spice Research Station, S.D. Agricultural University, Jagudan. The soil was loamy sand in texture, neutral in soil reaction, with low in organic carbon, medium in available phosphorus and potash. The treatments consisted best combinations of physical and chemical as well as alone viz., T_1: Two H.W.+ I.C. at 20 and 40 DAS, T_2: Pendimethalin @ 1.0 kg/ha as PE followed by H.W. + I.C. at 30 DAS, T_3: Oxadiargyl @ 100 g/ha as PE followed by H.W. + I.C. at 30 DAS, T_4: Oxadiargyl @ 100 g/ha as PoE at 20 DAS, T_5: Pendimethalin @ 1.0 kg/ha as PE + Oxadiargyl @ 100 g/ha as PoE at 20 DAS, T_6: Oxyfluorfen @ 100 g/ha as PE followed by H.W. + I.C. at 30 DAS, T_7: Oxyfluorfen @ 100 g/ha as PoE at 20 DAS, T_8: Pendimethalin @ 1.0 kg/ha as PE + Oxyfluorfen @ 100 g/ha as PoE at 20 DAS, T_9: Weed free up to 45 DAS and T_{10}: Unweeded control replicated thrice in laid out in RBD. The seeds were sown manually at about 4-5 cm depth in furrows at 45 cm row spacing and covered properly with the soil, using seed rate 5 kg/ha. All the weed count data were recorded at 20, 40 and 60 DAS, whereas dry weight of weeds was recorded at harvest.

RESULTS

Growth and yield attributing characters as well as seed yield were affected significantly by different weed control

Table 1. Growth, yield and quality attributes, seed yield, weed dynamics and economics of fennel as influenced by different weed control treatments (pooled data).

Treatment	Plant height (cm)	No. of umballates/ umbel	No. of seeds/ umballate	Seed yield (kg/ha)	Dry weight of weed (kg/ha)	BCR
T1 : Hand weeding and IC at 20 and 40 DAS	164.2	33.2	37.4	1621	145	2.27
T2 : Pendimethalin @ 1.0 kg /ha as PE + I.C. followed by H.W. at 30 DAS	155.9	32.9	35.0	1637	152	2.38
T3 : Oxadiargyl @ 100 g/ha as PE+ I.C. followed by H.W. at 30 DAS	154.4	33.0	35.8	1525	159	2.07
T4 : Oxadiargyl @ 100 g/ha as PoE at 20 DAS	127.0	20.9	21.7	903	758	0.95
T5: Pendimethalin @ 1.0 kg /ha as PE + Oxadiargyl @ 100 g/ha as PoE at 20 DAS	154.8	32.1	35.1	1611	408	2.32
T6 : Oxyfluorfen @ 100 g /ha as PE + I.C. followed by H.W. at 30 DAS	142.1	17.4	22.7	818	576	0.74
T7 : Oxyfluorfen @100 g/ha as PoE at 20 DAS	117.6	15.4	21.7	492	1090	0.13
T8 : Pendimethalin @ 1.0 kg /ha as PE + Oxyfluorfen @ 100 g/ha as PoE at 20 DAS	143.3	29.4	31.9	1414	545	2.08
T9 : Weed free up to 45 DAS	166.5	34.4	37.0	1661	133	2.19
T10 :Unweeded control	93.5	10.1	18.4	265	1566	0.38 (-)
CD (P=0.05)	12.6	2.8	2.9	139	48.0	

methods, except quality character on pooled basis (Table 1). Crop kept weed free up to 45 DAS recorded significantly higher plant height, number of branches and umbels/plant, number of umballates/umbel, seeds/umballate as well as test weight and was remained at par with treatments Hand weeding followed by IC at 20 and 40 DAS (T1), Pendimethalin @ 1.0 kg/ha as PE + I.C. followed by H.W. at 30 DAS (T2), Oxadiargyl @ 100 g/ha as PE + I.C. followed by H.W. at 30 DAS (T3) and Pendimethalin @ 1.0 kg/ha as PE + Oxadiargyl @ 100 g/ha as PoE at 20 DAS (T5), except in case of test weight where it was also at par with Pendimethalin @ 1.0 kg /ha as PE + Oxyfluorfen @ 100 g/ha as PoE at 20 DAS (T8). All these characters were found significantly minimum under unweeded control treatment (T10). Similar observations in fennel due to weed treatments were earlier reported by Meena and Mehta (2009). Treatment weed free up to 45 DAS (T9) recorded significantly lower dry weight of weeds, but remained statistically at par with T1,T2 and T3,whereas it was maximum recorded with unweeded control.

Treatment weed free up to 45 DAS (T9) recorded significantly higher fennel yield and remained at par with the treatments T2, T1, T3 and T5 and were recorded significantly higher seed yield over rest of the treatments. Higher yield under weed free crop condition might be minimized the competition between crop and weed for resources i.e. light, water, nutrient *etc*. The lowest yield was accrued with the treatment unweeded control on pooled basis. Pendimethalin @ 1.0 kg/ ha as PE + I.C. followed by H.W. at 30 DAS (T2) recorded higher BCR (2.38). Which was closely followed by treatments T5 (Pendimethalin @ 1.0 kg /ha as PE + Oxadiargyl @ 100 g/ha as PoE at 20 DAS), T1 (I.C and H.W. at 25 and 40 DAS) and T9 (weed free up to 45 DAS) recorded BCR values of 2.32,2.27 and 2.19, respectively (Table 1). The results are in conformity with Thakral (2007) on fennel crop.

CONCLUSION

For obtaining the maximum net return and income/rupees investment with higher yield, apply pendimethalin @1.0 kg/ ha as pre emergence and interculturing followed by hand weeding at 30 DAS.

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Weed management in greengram (*Vigna radiata*)

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Greengram (*Vigna radiata*) is one of the major pulse crops in India which is cultivated in arid and semi-arid region. Being a rainfed *kharif* crop, weed infestation is one of the most important factor of low productivity besides other constraints. Yield losses in mungbean due to weeds have been estimated to range between 30-50% (Kumar *et al.,* 2004). Herbicides in isolation, however, are unable to control complete weed infestation because of their selective kill. Their use can be made more effective if one or two herbicides were mixed together to control diversified weed flora.

METHODOLOGY

A field experiment was conducted during three consecutive *kharif* season of 2013, 2014 and 2015 at Research farm of Agriculture Research Station, Swami Keshwanand Rajasthan Agricultural University, Bikaner. Ten weed control treatments comprising of viz. pendamethalin 1000 g/ha (PE), imazethapyr 50g/ha, imazethapyr 70 g/ha, pendamethalin + imazethapyr 800 g/ha, 900 g/ha and 1000 g/ha, imazethapyr + imazemox 60 g/ha & 70 g/ha, two hand weeding at 20 & 40 DAS and weedy check were evaluated in randomized block design with three replications. The soil of experimental site was loamy sand having 0.08% organic carbon, 8.22 pH, 78, 22 and 210 kg/ha available N, P and K, respectively.

RESULTS

The density and dry weight of both broad leaf and grassy weeds were significantly reduced by all weed control treat-

Table 1. Effect of weed management on weed count, weed dry weight and yield of greengram (Pooled data of three years)

Treatment	Weed Count/m²			WDW	Seed yield
	Broad leaved	Grassy	Total	(g/m²)	(kg/ha)
Pendimethalin 1.0 kg	5.80	0.88	5.83	33.36	784
Imazethapyr 50g	3.28	2.155	3.87	12.00	761
Imazethapyr 70 g	2.94	1.665	3.31	3.40	766
Pendimethalin + Imazethapyr 800g	2.08	0.71	1.90	0.78	892
Pendimethalin + Imazethapyr 900g	1.65	0.71	1.65	0.45	907
Pendimethalin + Imazethapyr 1000g	0.90	0.71	0.90	0.96	885
Imazethapyr + Imazemox 60g	2.65	1.05	2.78	5.91	784
Imazethapyr + Imazemox 70g	1.74	0.71	1.74	0.75	786
Weed Free	0.78	0.71	0.78	0.00	986
Weedy Check	8.08	2.51	8.43	54.69	637
SEm±	0.23	0.105	0.22	2.09	41
CD	0.66	0.305	0.65	6.25	122

ments compared to weedy check, however, two hand weeding recorded lowest broad leaved, grassy and total weeds compared to rest of the weed control treatments (Table 1). Among the different herbicidal treatments, pre-emergence application of pendimethalin + imazethapyr 1000g as pre sown was found effective in reducing the density and dry weight of both broad leaf and grassy weeds followed by its lower dose (pendimethalin + imazethapyr 800 and 900g/ha). Application of pendimethalin 1.0 kg/ha as pre sown was found effective against grassy weeds, however, application of imazethapyr 50 g/ha and imazethapyr 70 g/ha were found at par with each other and these treatments significantly reduced the density of broad leaf weeds as comparison to weedy check. Among different treatments, pendimethalin + imazethapyr 800g/ha recorded higher seed yield over weedy check and was at par with its upper doses and two hand weeding. The reduced crop weed competition caused significant increase in growth characters and yield ultimately led to higher seed yield of greengram. The crop plant faced stress which ultimately affected their growth, development and yield.

CONCLUSION

All weed control treatments are almost equally important in controlling weeds and improving crop yield. Pendamethalin + imazethapyr 800 g/ha was superior most with respect to yield.

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Moisture regimes induced variation in some physiological and agronomical attributes of safflower (*Carthamus tinctorius*)

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Water deficit is the most critical limiting factor for growth and yield of safflower in scarcity zone of Maharashtra. Safflower is an important oilseed crop of post rainy season, cultivated mainly on stored soil moisture. Previous results on irrigated safflower showed remarkable yield increase with higher biological yield. Hence, an experiment was conducted at DFRS, Solapur to evaluate the effect of irrigation through drip on physiological and agronomical characters of different safflower genotypes. The main plot treatments consisted of three irrigation regimes *viz.* drip irrigation at 60% of CPE (I_1), 80% of CPE (I_2) and 100% CPE (I_3) and subplot consisted of three varieties and three different geometries *viz*, SSF 708 X 45x20 cm, SSF-748 X 45x20 cm, GMU 6878 X 45x20 cm, GMU 6878 X 30x20 cm and GMU 6878X 30 x15 cm. Irrigation was given at three growth stages *viz*, rosette termination, branching and 50% flowering. The results showed that, higher values of RLWC (80.95%) were noticed under I_3, i.e. 100% of CPE and the chlorophyll reading was also observed under the same regime (I_3). Significantly higher total dry matter/plant was noticed in SSF-748 and at 100% of CPE at all the physiological growth stages. Higher LAI was recorded under I3 and by SSF-748 at the end of each growth stage and *var*. SSF-708 was second in order. Significantly higher total number of capitula/plant (28.37 and 32.0 g) and total seed weight per plant (34.27 and 38.94 g) had followed the similar trend under irrigation regimes and variety x spacing, respectively. The data on yield attributes were also found influenced significantly due to different treatments. Higher seed yield (25.64 q/ha) with the HI of 26.01% was recorded under Safflower variety SSF-748 sown at 45x20 cm and irrigated at 100% of CPE. The yield attributing characters *viz*. plant height, number of branches and volume weight followed the similar trend.

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Impact of weed spectrum and its management under different seeding rate in dry-direct sown rice (*Oryza sativa* L.)

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The need to intensify rice production through double and triple cropping and the hike in wage rate accelerated switching of rice crop establishment from transplanted to direct sown rice (DSR). Direct seeding offers several advantages like faster and easier establishment, less drudgery, earlier crop maturity, more efficient water use, and higher tolerance to water deficit. In spite of its advantages, DSR have failed to gain popularity among farmers because the adoption and sustainability of DSR is threatened by heavy weed infestation and poor crop establishment (Mahajan *et al*., 2013). As a result, farmers often resort to costly practice of increasing the seeding rate for DSR by 2–3 times. So, new varieties suitable for DSR needs to be identified which can compete with weeds at optimum seeding rate. Again, manual weeding two to three times in a season by engaging up-to 190 person days ha^1 is a common practice to manage weeds in DSR by rice farmers (Roder, 2001). This involves huge cost in weed control. Low-dosage high-efficacy post-emergent herbicides having broad spectrum of weed control are expected to be an intervention to suppress the weeds during critical period of crop-weed competition up-to 35-40 days of crop emergence. Hence, the present investigation was undertaken to study the weed spectrum and the efficacy of different low-dose post emergent herbicides/ herbicide mixtures for managing broad spectrum of weeds under varying seed rate in dry-direct sown rice with new variety CR Dhan 304 along with existing variety Naveen as check.

METHODOLOGY

The field experiment was carried out during the wet seasons of 2014 and 2015 at the Institute Farm to compare new variety, CR Dhan 304 with Naveen (check) for weed competitiveness in response to different seeding rates and herbicide application. The experiment was laid out in a split-split plot design with two rice varieties [Naveen and CR Dhan 304] in main plots, four seeding rates [20, 30, 40 and 50 kg/ha] in subplots and three weed control treatments [azimsulfuron (35 g/ha) , azimsulfuron + bispyribac sodium (22+25 g/ha) and weedy check] in sub-sub plots. Weed density and biomass (dry weight basis) were recorded at 60 days after emergence (DAE). Grain yield of rice was recorded at harvest at 14% moisture content in seed. Weed control efficiency (%) was computed using the formula given below. The data collected on weed density, weed biomass, yield parameters, etc., were analyzed using ANOVA.

$$WCE = \left[{(x-y)}\big/{x} \right] \times 100$$

RESULTS

Echinochloa colona was the most predominant weed species in weedy plots followed by *Leptochloa chinensis, Cyperus difformis, Fimbristylis miliacea* and *Sphenoclea zeylanica*. The grassy weeds constituted 57% of the total weed population in weedy plots followed by sedges (24%) and broadleaved weeds (19%). Results revealed that application of azimsulfuron+ bispyribac sodium at 15 days after emergence (DAE) controlled the weeds effectively with lowest weed biomass (10.6 g/m^2) and weed control efficiency (WCE) of 88%. The weed population and biomass were significantly reduced with increasing seed rates from 20 to 50 kg/ha. Significantly higher grain yield was recorded at 50 kg/ha over 20-30 kg/ha, however, seed rate at 40 and 50 kg/ha did not register any significant difference in yields. Among the varieties, CR Dhan 304 produced relatively higher grain yield (5.32 t/ha) than Naveen (5.17 t/ha), but it was at par. Application of azimsulfuron + bispyribac sodium produced highest yield (5.57 t/ha). There was 49% reduction in grain yield due to weed completion in weedy check plots over azimsulfuron + bispyribac sodium treated plots.

CONCLUSION

The results suggest that the sowing with 40 kg seeds/ha provides better crop establishment of dry direct-sown rice (D-DSR). Application of azimsulfuron + bispyribac sodium shows broad spectrum of weed control and these management practices may be recommended for higher productivity of dry direct-sown rice (D-DSR) during wet seasons.

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Herbicidal potential of Triasulfuron on associated weeds of transplanted rice

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Rice occupies a pivotal place in Indian agriculture and it contributes to 15 per cent of annual GDP. The productivity of rice in India is quite low due to many biotic and abiotic factors. One of such factor is weeds problem. Weeds compete with crop for nutrients, water, light and space. It has been estimated that without weed control, the yield loss can be as high as 90% (Ferrero and Tinarelli, 2007). Manual weed control is very costly so there is a need of chemical control. Triasulfuron, a post emergence herbicide has been reported speedy and effective control of broad leaf weeds in rice. Under or over dose of herbicide is not desirable as under dose may be less effective and facilitate development of resistance in weeds, while over dose may result in phytotoxicity. This study was conducted to find out the optimum dose of triasulfuron 20% WG for the control of associated weeds in transplanted rice.

METHODOLOGY

A field experiment was conducted during *kharif* season of 2014 in E-5 block of N.E. Borlaug Crop Research Centre of G. B. Pant University of Agriculture and Technology, Pantnagar (Uttarakhand) to evaluatethe effect of different rates of triasulfuron on the performance of transplanted rice (*Oryza sativa* L.) and associated weeds. Treatments consisted of triasulfuron in three different rates i.e. 8, 10 and 12 g/ha, ethoxysulfuron at 15 g/ha, metsulfuron methyl at 4 g/ha, 2,4-D at 500 g/ha, weed free and untreated check. Experiment was laid out in Randomised Block Design with 8 treatments and 3 replications. Normal package and practice was practiced for successful raising of the crop.

RESULTS

The data pertaining to weeds dynamics, crop dry matter

Table 1. Effect of triasulfuron on weed dynamics, crop dry-matter and grain yield

Treatment	Total Weed population/m^2	Total weed dry matter (g/m^2)	Weed control efficiency (%)	Crop dry matter (g/m^2)	Grain yield (kg/ha)
Triasulfuron 20 WG @ 8 g/ha	7.15 (50.7)	8.72 (92.0)	44.7	801.2	4808
Triasulfuron 20 WG @ 10 g/ha	6.16 (37.3)	8.22 (71.6)	55.2	830.0	5384
Triasulfuron 20 WG @ 12g/ha	5.61 (30.7)	8.10 (65.1)	60.9	851.3	5786
Metsulfuron methyl 20 WG @ 4 g/ha	7.46 (54.7)	8.91 (104)	37.5	783.0	4417
Ethoxysulfuron 15 WDG @ 15 g/ha	6.16 (37.3)	8.46 (87.7)	47.3	815.4	5043
2,4-D @ 500 g/ha	7.46 (54.7)	8.50 (91.8)	44.8	792.6	4707
Weed free	1.00(0.0)	1.00 (0.0)	100.0	1045.5	6513
Weedy check	10.50 (109.3)	12.27 (166.5)	0.0	470.3	2705
S.Em ±	0.26	0.18	-	2.5	57
CD at 5%	0.98	0.55	-	7.6	173

and grain yield is presented in Table 1. All the weed control treatments caused significant reduction in the weed population at harvest as compared to weedy check. Triasulfuron at 12 g/ha proved most efficient in controlling weeds, which was at par with ethoxysulfuron at 15 g/ha and triasulfuron 10 g/ha. Similar findings have been reported by Saha, 2006. In case of total weed dry matter at harvest, the lowest dry matter of weeds was recorded with triasulfuron at 12 g/ha, which was at par with triasulfuron at 10 g/ha, ethoxysulfuron at 15 g/ha and 2, 4-D at 500 g /ha.Among the different rates of triasulfuron and other herbicides, the maximum weed control efficiency was observed with triasulfuron at 12 g/ha, which was closely followed by application of triasulfuron at 10 g/ha , ethoxysulfuron at 15 g/ha, triasulfuron at 8 g/ha and 2,4-D at 500 g/ha .The lowest weed control efficiency was recorded with metsulfuron methyl at 4 g/ha at harvest. Among the plots treated with different rates of triasulfuron and other herbicides, the highest crop dry matter was produced by triasulfuron at 12 g/ha .None of the herbicidal treatments could accumulate crop dry matter equal to application of triasulfuron at 12 g/ha. Triasulfuron at 12 g/ha produced the maximum grain yield of rice which was significantly higher than all other treatments while the lowest grain yield was observed in metsulfuron methyl at 4 g/ha. The grain yield of rice being low in triasulfuron at 8 g/ha and was at par with 2, 4-D at 500 g/ha. Sreedevi *et al*. (2007) observed that the lower dosage of triasulfuron @ 0.006 kg a.i/ha was not effective, while it's higher doses @ 0.009 and 0.012 kg a.i/ha were effective and recorded higher grain yields.

CONCLUSION

On the basis of present investigation, it may be concluded that application of triasulfuron at 12 g/ha is most effective for control weeds and for getting higher yield of transplanted rice.

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Effect of weed management practices on weeds, yield and economics of dry direct - seeded rice (*Oryza sativa*) grown under graded fertilizer levels

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Rice is the staple food for more than half of the human population, and as such plays an important role in ensuring food security all over the world (Khush, 2005). Rice is grown mostly under puddled submerged conditions which results in very low water use efficiency besides ecological consequences such as emission of greenhouse gases. Repeated puddling of soil damages soil structure andcan negatively affect the growth and yield of succeeding upland crops in rotation.With the global water crisis looming large due to increasing alternate demands for water, it has become imperative to develop technologies that produce rice using lower quantities of water (Bouman, 2001). Dry direct - seeded rice (Dry DSR) is one such cost effective technology that has been developed to raise rice crop with reduced water and labour requirement besides improving physical structure of soil and reducing methane emission. Weed infestation in dry direct - seeded rice fields remains the single largest constraint limiting the crop productivity. A direct - seeded rice crop generally lacks a 'head start' over weeds due to dry tillage, absence of flooding and alternate wetting and drying conditions making it particularly vulnerable to weed competition during early part of its growth (Rao *et al*., 2007). Manual weeding is an effective tool in managing weeds in direct - seeded rice but has limited practicability owing to economic factors. Thus managing weeds through use of herbicides offer easy, quick, economical and reliable alternative to manual weeding. The pre-emergence herbicide application offers control of first flush of weeds but has little effect on second flush of weeds that appear later. Thus the sequential application of pre-emergence and post-emergence herbicides offers a better option for managing weeds in the direct - seeded rice crop.Thus the present study was undertaken to evaluate the efficacy of sequential application of pre-emergence and post-emergence herbicides as compared to their application alone in direct - seeded rice crop raised under graded fertility levels.

METHODOLOGY

The field experiment was conducted at the Experimental Farm of CSKHPKV, Rice and Wheat Research Centre, Malan during the *kharif* seasons of 2014 and 2015. The soil of the experimental site was silty clay loam in texture, acidic in reaction (pH 6.0), low in organic carbon (0.54) and available nitrogen (275.4 kg/ha), high in available phosphorus (27.4 kg/ha) and medium in available potassium (218.4 kg/ha). The experiment was laid out in split plot with three fertilizer levels in main plot and five weed management practices in sub plot. Fertility levels tested include 75%, 100% and 125% of recommended dose (60:30:30) while weed management practices included pre-emergence application of butachlor 1.5 kg/ha, post emergence application of bispyribac sodium 0.025 kg/ha, sequential application of butachlor 1.5 kg/ha (pre-emergence) and bispyribac sodium 0.025 kg/ha (post-emergence) and application of both herbicides followed by hand weeding at 55 days after sowing (DAS).Newly released rice variety Him PalamDhan 1 (HPR 2656) was dry seeded in the second week of June during both the years by using a seed rate of 60 kg/ha at 20 cm row spacing. Butachlor (sprayed within 3 days of sowing) and bispyribac sodium (sprayed at 25 DAS)were sprayed with knap sack sprayer fitted with flat fan nozzle using a spray volume of 750 litre/ha. Fertilizer doses, as per treatments, were applied using urea, single super phosphate and muriate of potash.

RESULTS

Among different weed management practices, significantly lowest weed count (grassy weeds, broad leaved weeds and total) and weed biomass was recorded when sequential application of pre-emergence (butachlor) and post emergence (bispyribac sodium) herbicides was followed by single hand weeding at 55 DAS while significantly highest values of these parameters were recorded in weedy check (Table 1). Weed count of grassy weeds, total weed count and weed biomass did not vary significantly between the pre-emergence application of butachlor and post-emergence application of bispyribac sodium through number of broad leaved weeds were significantly lower with post-emergence application of

Table 1. Effect of graded fertilizer doses and weed management practices on weeds, yield and economics of direct dry seeded rice (pooled data of two years)

Treatment	Grain yield (t/ha)	Weed count (No. /m^2)			Weed biomass at heading (g/m^2)	Net return (Rs/ha)	B:C ratio
		Grassy weeds	Broadleaved weeds	Total at heading			
F_1 -75% RD (45:22.5:22.5)	2.42	6.74 (51.9)*	6.43 (51.2)	9.59 (103.1)	8.12 (80.9)	20315	0.80
F_2 - 100% RD (60:30:30)	2.77	6.64 (49.6)	6.54 (52.7)	9.50 (102.3)	7.68 (71.7)	26260	1.01
F_3 - 125% RD (75:37.5:37.5)	2.81	7.11 (57.0)	6.69 (56.7)	10.02 (113.7)	8.15 (82.9)	26523	0.99
SEm±	0.06	0.28	0.15	0.32	0.20		
CD (P = 0.05)	0.18	NS	NS	NS	NS		
Butachlor 1.5 kg/ha - PRE	2.60	7.18 (52.3)	7.54 (62.6)	10.57 (114.9)	8.99 (84.0)	25694	1.09
Bispyribacsodium 0.025 kg/ha - POST	2.66	7.66 (60.9)	6.41 (47.0)	10.26 (107.9)	8.50 (74.8)	25888	1.05
Butachlor 1.5 kg/ha PRE *fb* Bispyribacsodium 0.025 kg/ha POST	3.14	4.84 (24.0)	5.15 (31.6)	7.20 (55.6)	5.23 (28.1)	33096	1.26
Butachlor 1.5 kg/ha PRE *fb* Bispyribacsodium 0.025 kg/ha POST *fb* 1 HW (55 DAS)	3.27	4.06 (16.5)	3.96 (18.8)	5.85 (35.3)	3.33 (11.3)	27550	0.80
Weedy check	1.66	10.42 (110.5)	9.71 (107.7)	14.63 (218.2)	13.87 (194.4)	9588	0.44
SEm±	0.05	0.25	0.24	0.40	0.29		
CD (P = 0.05)	0.13	0.72	0.68	1.14	0.84		

RD: Recommended dose: PRE: Pre – emergence application (1-3 DAS); POST: Post-Emergence application (25 DAS); HW: hand weeding;*fb*: followed by*Analysis done after square root transformation, figures in parentheses are the means of original values

bispyribac sodium. However both these treatments were significantly inferior to the treatment in which both these herbicides were sequentially applied. This better efficacy of sequential application in controlling weeds as compared to the single application of either pre- or post-emergence herbicide was due to the better control of both the flushes of weeds that emerge immediately after sowing and those emerging after 15-20 days after sowing. Significantly highest grain yield was recorded when the crop was fertilized with 125% of recommended fertilizer through it was at par with the yield obtained with the application of recommended dose. This higher yield was due to the higher panicle weight as well as test weight recorded with higher fertilizer application. Weed management practices also had a significant influence on the yield and yield attributes with significantly lowest yield recorded from weedy check. Significantly highest grain yield was recorded when sequential application of both pre- and post-emergence herbicides was followed by one hand weeding though it was at par with treatment in which only herbicides (pre and post-emergence) were applied. Application of either pre-emergence herbicide or post-emergence herbicide alone gave yields that were at par with each other but significantly lower than their sequential application. This higher yield obtained with sequential application of herbicides was mainly due to significantly higher panicle number/m^2 as well as panicle weight. This sequential application of herbicides gives season long effective weed control, especially during the critical stages of crop-weed competition. The net return increased with increasing fertilizer application with highest value reported with the application of 125% of recommended dose though it was only slightly higher than the net return obtained with the recommended fertilizer application. However the B:C ratio was higher with the application of recommended fertilizer. All the weed management practices gave higher net return as well as B:C ratio compared to the weedy check. Sequential application of herbicides gave higher net return as well as B:C ratio as compared to the sole application of either pre- or post-emergence herbicides. Inclusion of hand weeding in the herbicide treatments considerably lowered the B:C ratio because of higher labour cost involved in hand weeding.

CONCLUSION

From the above study it can be concluded that weeds in direct dry seeded rice can effectively be controlled by sequential application of herbicides involving pre – emergence application of butachlor (1.50 kg/ha) followed by post – emergence application of bispyribac sodium (0.025 kg/ha). Also the direct dry seeded crop should not be fertilized with higher fertilizer dose and only recommended dose should be added.

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Effect of post emergence herbicides on weed flora and weed density in soybean

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Soybean is an important oilseed crop and playing a vital role in sustaining the oilseed production in India over the past few years. In the different constraints, the weed management assumes the major importance for increasing the productivity of soybean. Hand weeding is widely practiced for eliminating the weeds, though it is costly and time consuming. Hence, chemical weed control has become the potential tools for curbing the weed menace since last two decades. Several herbicide viz., fluchloralin, pendimethalin, alachlor and metalachlor, were in use for controlling weeds associated in soybean but these have not been found much effective in controlling all sort of weeds. Presently, imazethapyr is a very effective post emergence herbicide for controlling most of the grassy and broad leaf weeds in soybean but its efficacy has not been tested.withcombine application of Quizalofop-p-ethyl+Chlorimuron ethyl for wide spectrum weed control in soybean in different parts of the country including Jabalpur.

METHEDOLOGY

A field experiment was conducted during *kharif* season of 2015,at the Research Farm, Department of Agronomy, Jawaharlal Nehru KrishiVishwaVidyalaya, Jabalpur (M.P.) to study the efficacy of different post emergence herbicides on soybean varieties (*Glycine max* L.). The present experiment was carried out on clayey soil which was medium in organic carbon (0.65 %), available nitrogen (352 kg/ha) and phosphorus (16.60 kg/ha) but high in potassium (335 kg/ha) and neutral in reaction (7.2). The investigation was aimed to study the efficacy of herbicides as applied post-emergence for weed control in different soybean varieties and to determine eco-

Table 1. Influence of varieties and weed control treatments on the weed density (m^2) dry weight and weed control efficiency

Treatment	Total weed density (m^2)	Total weed dry weight (m^2)	Weed control efficiency %
Variety			
V_1- JS 20-29	48.03	56.67	39.00
V_2-JS 20-34	52.12	65.24	30.44
V_3 - JS 20-69	51.42	60.97	34.90
CD (P=0.05)	2.56	1.52	–
Weed control treatment			
W_1- Imazethapyr@100 g/ha	46.9	55.97	40.32
W_2 - Quizalofop-p-ethyl @50 g/ha	54.75	62.44	33.40
W_3-Chlorimuron ethyl @ 9g/ha	47.85	60.72	35.20
W_4-Quizalofop-p-ethyl + Chlorimuron ethyl @ (50+9)g/ha	31.88	32.88	64.0
W_5 - Weedy-check (Control)	64.49	93.79	–
CD (P=0.05)	2.45	3.21	

nomic viability of treatments. The experimental area has the natural weed flora comprising of grassy as well as broad leave weeds. 15 treatments comprised three (main plot treatments) variety JS 20-29,JS 20-69 and JS 20-34 and 5 (sub plot treatments) weed control treatments Imazethapyr, Quizalofop-p-ethyl, Chlorimuron ethyland Quizalofop-p-ethyl +Chlorimuron ethyl and weedy check were laid out in Split Plot Design with three replications.

RESULTS

In weedy check treatment the total weed population was significantly higher than all the herbicidal treatments, Quizalofop-p-ethyl +Chlorimuron ethyl (50+9)g/ha, Imazethapyr 100g/ha,Quizalofop-p-ethyl 50g/ha and Chlorimuron ethyl 9g/ha. The weed menace was minimum under the combination of Quizalofop-p-ethyl +Chlorimuron ethyl (50+9)g/ha as post emergence for controlled broad leaf and grassy leaves weeds and it was most effective to reduced all weed flora. The weed biomass had highest in the variety JS 20-34 the number of weeds more is this variety because it was less height and the minimum weed biomass variety JS 20-29 because it is spreading type variety (Table 1). Both seed and stover yields were significantly higher under all the treatments receiving weed control measure than weedy check plots. Maximum seed yield of soybean was recorded under combination of Quizalofop-p-ethyl + Chlorimuron ethyl (50+9)g/ha aspost emergence over all the all the treatments.

CONCLUSION

The combination of Quizalofop-p-ethyl +Chlorimuron ethyl (50+9)g/ha as post emergence for controlled broad leaf and grassy leaves weeds and it was most effective to reduced all weed flora and gave maximum yield .

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Efficacy of pre and post emergence herbicides in Maize

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Maize (*Zea mays* L.) being one of the most important cereals and has attained a commercial crop status and has scope to increase the present maize yields. Management of weeds is considered to be an important factor for achieving higher productivity. Yield loss occurs up to 33% to complete crop failure due to weed competition in maize. Rout *et al.* (1996) revealed that weeds cause enormous damage upto 30 to 50 per cent in maize crop. Due to increased cost and non availability of labour in required quantity timely for hand weeding, role of herbicide is significant preposition. Herbicides not only control the weeds timely and effectively but also offer great scope for minimizing the cost of weed control irrespective of the situation. The conventional method of weed control (hoeing/ hand weeding) are very laborious, expensive and time consuming and needs to be often repeated at different intervals. Frequent rainfall during rainfed cropping season does not permit manual and mechanical methods of weeding at the appropriate time. Use of pre and post emergence application of herbicides would make herbicidal weed control more acceptable to farmers which will not change the existing agronomic practices but will allow for complete control of weeds. Pre emergence and post emergence herbicides will be an ideal means for controlling the weeds in view of economics and effectiveness in maize. The present investigation was therefore planned with a objective to study the efficacy of pre and post emergence herbicides and its effect on weed flora, growth and yield of maize.

METHODOLOGY

The field experiment was conducted during *Kharif* season of the year 2015-2016 at the research farm of Agronomy Department, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola(M.S.) in Randomized Block Design with three replication having eight different treatments of weed management including weed Free (T_1), Weedy check (T_2), 2,4-D sodium salt 0.80 kg /ha PoE 30 DAS (T_3), 2,4-D sodium salt 1.20 kg /ha PoE 30 DAS(T_4), Atrazine 1 kg /ha PE(T_5), Atrazine 0.50 kg /ha fb 2,4-D sodium salt @ 0.5 Kg POE 30 DAS (T_6),

Table 1. Weed population, weed dry matter, weed control efficiency, weed index at harvest, yield and economics of maize as affected by different weed control treatments

Treatment	Total Weed population (m^2)	Weed Dry Matter (g/m^2)	Weed Control Efficiency (%)	Weed Index (%)	Grain weight cob^{-1} (g)	Grain Yield (t/ha)	NMR (/ha)	B:C Ratio
T_1 : Weed Free	2.80	2.33	96.51	—	84.73	4.75	48769	2.87
T_2 : Weedy check	12.24	11.91	—	57.40	48.59	2.02	16144	1.83
T_3 : 2,4-D sodium salt 0.80 kg /ha PoE 30 DAS	8.05	7.65	58.92	28.41	58.47	3.40	35014	2.72
T_4 : 2,4-D sodium salt 1.20 kg /ha PoE 30 DAS	7.70	7.39	61.70	27.30	60.93	3.45	35753	2.74
T_5 : Atrazine 1 kg /ha PE	6.36	5.90	75.67	24.10	72.81	3.60	37765	2.82
T_6 : Atrazine 0.50 kg /ha fb 2,4-D sodium salt @ 0.5 Kg POE 30 DAS	5.90	5.35	80.09	13.50	75.10	4.11	44658	3.11
T_7 : Pendimethalin 1.0/ha PE	7.56	7.02	65.39	24.82	64.69	3.57	35874	2.67
T_8 : Atrazine 0.50 kg + Pendimethalin 0.50 Kg /ha PE	6.70	6.34	71.95	23.98	68.51	3.61	36982	2.75
CD (P= 0.05)	0.79	0.56	-	-	8.01	0.52	6958	–

Pendimethalin 1.0/ha PE(T_7) and Atrazine 0.50 kg + Pendimethalin 0.50 Kg ./ha PE(T_8). The soil of the experimental field was black and clayey in texture and slightly alkaline in reaction, low in nitrogen, medium in phosphorous and fairly rich in potash. The maize variety Maharaja was sown at the spacing of 60x30 cm on 21st June 2015 with recommended dose of fertilizer 120:60:30 NPK Kg ha^{-1}.

RESULTS

The major weed flora during *kharif* season in experimental field was composed of *xanthium strumarium, celosia argentea, tridax procumbens, phyllanthus niruri, euphorbia geniculata, euphorbia hirta, alternanathera triandra parthenium hysterophorus, digera arvensis, cynodon dactylon, cyperus rotundus, amaranthis viridis, dinebra arabica, panicum spp commelina benghalensis, etc. B*oth broad and narrow leaved weeds were observed but dominance of broad leaved weeds was observed in entire field. The data presented in Table 1 indicated that, the weed control treatments significantly reduced the weed population and weed biomass when compared with unweeded control. The sequential application of atrazine 0.50 kg/ha fb 2,4-D sodium salt @ 0.5 Kg PoE 30 DAS followed by atrazine 1 kg/ha PE and atrazine 0.50 kg + pendimethalin 0.50 Kg/ha PE showed superiority in minimizing the total weed population and weed dry matter at harvest. Weed control efficiency of maize was significantly influenced by weed management treatments, where all the treatments resulted in increase of weed control efficiency over the weedy check. Among the herbicides highest weed control efficiency and less weed index was recorded in atrazine 0.50 kg/ha fb 2, 4-D sodium salt 0.5 Kg PoE 30. This may be due to better control of weeds in response to sequencial application of pre and post emergence herbicides. As indicated in the Table 1, it was noticed that grain weight per cob and grain yield was found maximum in weed free treatment (4.75 t/ha) while among the pre and post herbicidal treatments application of atrazine 0.50 kg/ha fb 2, 4-D sodium salt 0.5 Kg PoE 30 DAS recorded higher grain yield (4.11 t/ha) which was closely followed by atrazine 0.50 kg + pendimethalin 0.50 Kg/ha PE and atrazine 1 kg/ha PE. It may be due to better control of weeds initially by pre emergence spray and after that late emerging weeds are controlled by post emergence herbicides .Similar results were reported earlier by Sharma (2007) and Waliya *et al*. (2009). The net monetary returns was found maximum under weed free treatment followed by atrazine 0.50 kg/ha fb 2, 4-D sodium salt 0.5 Kg PoE 30 DAS and atrazine 1 kg/ha PE while the maximum B:C ratio was found in atrazine 0.50 kg/ha fb 2,4-D sodium salt 0.5 Kg PoE 30 DAS (3.11) than weed free treatment (2.87). This might be due to the higher cost of cultivation in weed free treatment. Similar result was obtained by Shantveerayya and Agasimani (2011).

CONCLUSION

Sequential application of pre and post emergence herbicides i:e, atrazine 0.50 kg /ha fb 2,4-D sodium salt 0.5 Kg PoE 30 DAS proves better in controlling weeds and found economical compare to conventional weed management practice .

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On farm assessment of ready mix herbicide combinations for broad spectrum weed control in wheat

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Wheat (*Triticum aestivum* L.) is an important winter cereal of Madhya Pradesh and Gwalior district as well. In Madhya Pradesh, it is grown in 4.89 million hectare area with the production of 17.48 million tone (Agri. Stat., 2013). Through the production and productivity of wheat have increased in Madhya Pradesh during the last five years, but productivity levels are still low in Madhya Pradesh as compared to other wheat growing states in the country. There are many factors which affect the yield of the wheat but weed infestation is one of the most serious causes of low yields of irrigated wheat.Weeds are considered as major bottlenecks in realizing potential yield of wheat. Uncontrolled weeds are reported to cause up to 66 % reduction in wheat grain yield (Kumar *etal.,* 2011). Chemical weed control is a preferred practice due to scarce and costly labour as well as lesser feasibility of mechanical or manual weedingin wheat crop sown with narrower spacing. Farmers in Gwalior district usually apply 2,4- D for the control of weeds in wheat crop which has been found promising against broad leaved weeds but it was not found effective against grassy weeds in wheat crop viz.*Phalaris minor, Avenaludoviciana* and *Poaannua*. This problem was surfaced up in participatory rural appraisal survey of the K.V.K. adopted villages viz. *Badkisarai, Amrol* and *Kunarpur* in Bhitarwar and Morar blocks respectively of Gwalior district.Hence the present investigation was carried out to evaluate the efficacy of ready mix herbicide combinations for broad spectrum weed control in wheat on farmer's fields.

METHODOLOGY

A framers led field experiment was conducted during *rabi*seasons of the year 2014-15 and 2015-16 in K.V.K. adopted villages viz. *Kunarpur* in Morar block and *Badkisarai* and *Amrol* in Bhitarwar blocks of the district.The soil of the experimental plots was clay loam in texture, moderately alkaline in reaction (pH 7.8-8.4), low in organic carbon(0.48%) and available nitrogen (210kg/ha), medium in available phosphorous (15.5kg/ha) and high in potassium (336 kg/ha). The experiment was conducted in a single replicated trial on 10 farmers fields having 1000m^2 area each broad spectrum herbicide assessed and farmers practice(2,4 D@ 500g/ha). Wheat variety GW 273 and Raj 4037 were sown in lines 20 cm apart by using double chamber seed cum fertilizer seed drill with 100 kg/ha seed rate during last week of November and first week of December during both the year. Recommended dose of fertilizers (120 Kg N, 60Kg P_2O_5 and 40Kg K_2O) was uniformly applied to all the three weed control treatments viz. farmers practice (2,4-D @ 500g/ha), clodinofop + metsulfuron (60+2g/ha),sulfosulfuron + metsulfuron (30+2g/ha) all applied at 30-35 DAS stage. Full dose of phosphorous and potassium and half dose of nitrogen were applied basal at the time of sowing and rest of nitrogen in two equal splits was top dressed at first and second irrigation stage during both the crop seasons. The herbicides were sprayed with knapsack sprayer fitted with flat fan nozzle using spray volume of 500 litres/ha. Observations on weed composition and dry matter were recorded from the random quadrates of 0.25 m^2 in each plots at 60DAS stage of the crop.

RESULTS

Application of clodinofop + metsulfuron (60+2g/ha) gave significant reduction in total weed dry weight and weed counts overfarmer's practice (2,4-D @ 500g/ha) at 60 DAS stage of wheat crop (Table 1) as it reduces the stand of both grassy and broad leaved weeds. The application of sulfosulfuron+metsulfuron (30+2g/ha) gave similar effect over mixed weed flora during both the seasons of farmers led field experimentations. This may be because it also has broad spectrum effect on weed species in wheat fields, however comparatively low performance was observed due to its fewer efficacies to control *Phalaris minor*, *Avenaludoviciana* and *Poaannua*. The highest total weed density and weed dry weight was recorded under farmers practice. Application of clodinofop+metsulfuron (60+2g/ha) gave highest WCE (83 and 82.6%) during both the years of investigation followed by application of sulfosulfuron + metsulfuron (30+2g/ha). Application of clodinofop+metsulfuron (60+2g/ha) resulted in significantly highest grain yield of wheat over farmer's practice(21.4 & 22.4%, respectively) and sulfosulfuron + metsulfuron (30+2g/ha) during both the year (Table 1). Both the ready mix herbicide combinations were observed significantly superior over farmers practice during both the year, due to less crop weed competition for nutrients, water, space and light. This in turns might have resulted in greater photosynthesis besides larger sink and stronger reproductive phase.

CONCLUSION

On the basis of two years farmers led field assessment of ready mix herbicide combinations for weed control in wheat, it may be concluded that post emergence application of clodinofop + metsulfuron (60+2g/ha) at 30-35 DAS could be a effective weed control practice for realizing higher productivity of wheat crop under mixed weed flora having higher population of *Phalarisminor*and*Avenaludoviciana*in rice-wheat cropping system.

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Integrated weed management in ginger (*Zingiber officinale*)

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Ginger is important spice crop of India and accounts for 45% of the world's ginger production. Ginger crop is highly susceptible to weed competition especially in the initial stages of crop growth. Reports on integrated weed management involving manual, mulch and chemical method of weed control is lacking, hence, an effort was made with an objective to find out effect of weed control measures on productivity and profitability of ginger.

METHODOLOGY

A field experiment was conducted at Birsa Agricultural University, Ranchi during *Kharif* season of 2014-15 and 2015-16. The experiment was laid out in Randomized Block design with three replications. The treatments comprised of pendimethalin @ 1.5 kg/ha after planting but before mulching (T1), oxyfluorfen @ 0.20 kg/ha after planting but before mulching (T2), T_1+ 1 hand weeding before mulching (T3), T_{2+} 1 hand weeding before mulching (T4), glyphosate 0.80 kg/ha just before emergence of sprouts of ginger (T5), glyphosate 0.80 kg/ha + pendimethalin 1.5 kg/ha just before emergence of sprouts of ginger (T6), glyphosate 0.80 kg/ha + oxyfluorfen 0.2 kg/ha just before emergence of sprouts of ginger (T7), Hand weedings at 25 and 50 DAS (T8) and un-weeded control (T9). The experimental soil was low in nitrogen (125 kg/

Table 1. Effect of weed control methods on weed control efficiency, yield and economics of ginger

Treatment	Weed control efficiency (%)		Yield (t/ha) (Rs./ha)	Cost of cultivation	Net return (Rs/ha)	B:C ratio
	30 DAS	75 DAS				
Pendimethalin	52.77	53.28	9.99	207627	191873	0.92
Oxyfluorfen	76.20	76.70	16.65	206755	459135	2.22
Pendimethalin *fb* hand weeding	88.08	87.45	23.49	210284	729300	3.47
Oxyfluorfen *fb* hand weeding	87.85	87.59	22.63	209411	695714	3.32
Glyphosate	67.68	67.50	15.29	205659	406008	1.97
Glyphosate + pendimethalin	72.70	73.06	15.68	208359	418933	2.01
Glyphosate + oxyfluorfen	90.11	90.10	28.99	207486	952230	4.59
Hand weeding (2)	89.24	89.12	24.75	213427	776478	3.64
Un-weeded control	0.00	0.00	3.49	204573	-64858	-0.32
SEm±			2.26		90376	0.44
CD (P=0.05)			6.77		270917	1.31

ha) and phosphorus (19 kg/ha) but medium in potash (187 kg/ha). The pH of soil was 6.2 having organic carbon 0.34%. The crop was sown on 27.06.14 and 16.06.15 during first and second year.

RESULTS

Pooled data revealed that grassy, broad leaved weeds and sedges as well as total weeds and their dry matter accumulation were significantly controlled by glyphosate 0.80 kg/ha + oxyfluorfen 0.2 kg/ha applied just before emergence of sprouts of ginger having highest weed control efficiency (90%) as it controlled weeds effectively than rest of the treatments (Table 1). This treatment was similar to hand weeding at 25 and 50 DAS recorded maximum ginger rhizome yield (29 t/ha), net return (Rs. 9, 52,230 /-) and B:C ratio (4.59). This may be due to efficiently control of weeds during all the stages of crop growth as well as substantial reduction in labour requirement with the use of herbicides resulted reduced cost of cultivation than hand weeding.

CONCLUSION

From the two years findings it can be inferred that glyphosate 0.80 kg/ha + oxyfluorfen 0.2 kg/ha applied just before emergence of sprouts of ginger was more effective in controlling weeds of ginger and producing maximum ginger rhizome yield, net return and B:C ratio.

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Estimation of genetic parameters of muskmelon germplasm for water stress under greenhouse

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Drought is one of the most important abiotic stresses which causes greater yield loss (15 to 60%) and plant growth than any other single biotic or abiotic factor worldwide. Therefore a study of drought tolerance was conducted in greenhouse under different water regimes.

METHODOLOGY

The aim of this study was to obtain information on the genetic variability and heritability of root and shoot characters that could be used as selection criteria under seedling stage in relation to drought tolerance. All the 40 germplasm accessions of muskmelon were sown in perforated polythene bags of 110 cm length x 20 cm diameter dimension in two replications at 30^0C temperature for studying root and shoot traits. Each polythene bag was filled with light textured sandy soils and saturated with ¼ MS liquid media water to get sufficient soil moisture for dibbing two seeds each bag in March, 2013 on 05/03/2013. One bag was used for one genotype in each replication. At initial stage, no stress was imposed till germination of seeds. Stress was created by different levels of irrigation per day (50 ml, 25 ml and 0 ml) in different sets after germination of seeds.

RESULTS

By growing plants under different levels of water stress, non- water stress NS (50 ml irrigation water), moderate water stress S_1 (25 ml irrigation water), and severe water stress S_2 (no irrigation water) were imposed till 35 days old seedlings. After 35 days, the bottoms of polythene bags were cut opened and whole bags were immersed in water. The sandy soil present in the polythene bags were washed without disturbing the root system. Then observations were recorded. There was significant difference among root-shoot traits in normal and water stress conditions. High GCV, PCV and high heritability associated with high GA was observed for root dry weight, root shoot ratio by weight, root shoot ratio by length and shoot length in all the three water regimes under greenhouse condition. This indicated that these traits were predominantly governed by additive gene action, therefore fixable and hence would respond to artificial selection.

CONCLUSION

High GCV, PCV and high heritability associated with high GA for characters like root dry weight, root shoot ratio by weight, root shoot ratio by length and shoot length in all the three water regimes indicated that these traits were predominantly governed by additive gene action, therefore fixable and hence would respond to artificial selection.

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Effects of combined application of propaquizafop and imazethapyr on agronomic indices, weed growth and yield of soybean

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Weeds infestation is one the major constraints in the cultivation of soybean.If weeds are not controlled during critical period of crop-weed competition, there is identical reduction in the yield of soybean to the tune of 58 to 85 %, depending upon the types and intensity of weeds(Kewat *et al.*, 2000).Imazethapyr is reported very effective post emergence herbicide for controlling grassy and some broad leaf weeds in soybean but its efficacy has not been tested with propaquizafop for wide spectrum weed control in soybean. Therefore, a comprehensive field study was under taken to find out the suitable dose of propaquizafop and imazethapyr mixture for effective control of weeds in soybean.

METHODOLOGY

A field experiment was conducted during *Kharif* seasons 2013 at Live stock Farm, JNKVV, Jabalpur, to evaluate the efficacy of propaquizafop and imazethapyr mixture against weeds in soybean. Nine treatments comprising of five doses of propaquizafop and imazethapyr mixture (47+66, 50+70, 53+74, 56+78 and 100+140 g/ha), alone application of propaquizafop 75 g/ha and imazethapyr 100 g/ha, hand weeding twice (20 and 40 DAS) including weedy check, were laidout in randomized block design with three replications. Soybean variety JS 97-52 was grownin the experimental field with recommended package of practices. Fertilizers were applied uniformly through urea, single super phosphate and muriate of potash at the rate 20,60 and 20 kg N, P, and K/ha, respectively. Theobservations on weed growth, at 30 days after application and yield attributing traits and yield were recorded at harvest. The different agronomic indices weeds

Table 1. Effect of different weed control treatments on density, dry weight of weeds, yield and various agronomic indices of soybean

Treatment	Weed density (No./m^2)	Weed dry matter (g/m^2)	Seed yield (t/ha)	HaulmYield (t/ha)	HEI	CRI
1 ropaquizafop+Imazethapyr (47+66 g/ha)	10.63 (112.47)	13.51 (182.08)	1.52	3.31	115.35	3.15
2. ropaquizafop+Imazethapyr (50+70 g/ha)	9.56 (90.80)	12.46 (154.68)	1.65	3.61	175.00	4.05
3. Propaquizafop+Imazethapyr (53+74 g/ha)	8.65 (74.37)	10.74 (114.94)	2.16	4.29	431.04	6.67
4.Propaquizafop+Imazethapyr (56+78 g/ha)	7.27 (52.40)	9.50 (89.69)	2.18	4.31	562.83	8.60
5.Propaquizafop+Imazethapyr (100+140 g/ha)	4.95 (24.0)	6.37 (40.13)	2.19	4.32	1270.14	19.30
6.Propaquizafop (75 g/ha)	11.08 (122.18)	14.11 (198.48)	1.35	3.09	67.18	2.66
7. Imazethapyr (100 g/ha)	9.65 (92.67)	13.44 (180.00)	1.59	3.21	133.53	3.17
8.Hand weeding (20&40 DAS)	4.53 (20.0)	1.78 (2.67)	2.21	4.31	-	-
9. Weedy check	16.46 (270.33)	21.61 (466.45)	1.05	2.87	0.00	1.00
LSD (P = 0.05)	0.40	0.55	0.13	0.37	-	-

*Values in parentheses are original.
HEI = Herbicide efficiency index, CRI = Crop resistance index,

have been determined as suggested by Awan *et al.* (2015).

RESULTS

Weed density and weed biomass was higher under weedy check plots (Table 1). Among the herbicidal treatments, the reduction in weed density and weed biomass was higher when propaquizafop and imazethapyr mixture was applied at 53+74, 56+78 and 100+140 g/ha and proved significantly superior over weedy check, other mixtures including check herbicides propaquizafop 75 g/ha and imazethapyr 100 g/ha applied alone. However, none of the herbicidal treatments excelled the hand weeding twice which curbed the weed growth to the maximum extent (99.42 %). The unchecked weed growth throughout the season caused 52.48 % reduction in yield of soybean. But yield reduction was arrested appreciably (2.26 to 0.90%) when propaquizafop was applied along with imazethapyr at 53+74 or at higher dose (56+78 to 100+140g/ha). Seed and haulm yields of soybean were minimum under weedy check plots but these increased under propaquizafop and imazethapyr mixture applied at 53+74 g/ha and at par to higher doses of propaquizafop and imazethapyr mixture (56+78 and 100+140 g/ha) including hand weeding twice. All agronomic indices like HEI, CRI had inferior values. When propaquizafop + imazethapyr mixture was applied at the lowest dose (47+66 g/ha). But these indices were improved identically corresponding increase in application rates (47+66 to 100+140 g/ha). However, these indices had lower values when propaquizfop (75 g/ha) and imazethapyr (100 g/ha) was applied alone in soybean.

CONCLUSION

Post-emergence application of propaquizafop and imazethapyr mixture at the rate of 53+74 g/ha was most effective for curbing weed growth and improving seed yield of soybean whithout any phytotoxic effect on crop plants..

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Chemical weed management in baby corn (*Zea mays*)

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Maize (*Zea mays* L.) is the third most important cereal crop in the world following wheat and rice. It has been cultivated for centuries as a grain crop and more recently as a vegetable crop, such as baby corn and sweet corn. Maize used as a vegetable is known as "baby corn". Baby corn is the young, finger-length fresh maize ear harvested within 2 or 3 days of silk emergence but prior to fertilization. Hundred gram of baby corn contains 89.1% moisture, 0.2 g fat, 1.9 g protein, 8.2 mg carbohydrate, 0.06 g ash, 28.0 mg calcium, 86.0 mg phosphorus and 11.0 mg of ascorbic acid. Attention is now being paid to explore its potential in India for earning foreign exchange besides higher economic returns to the farmers. In India, baby corn is emerging as a potential remunerative crop among the progressive farmers.

Baby corn (*Zea mays* L.) cultivation provides tremendous avenues for crop diversification, crop intensification, value addition and revenue generation. Being relatively a new introduction to the domain of study. Manual weeding though very effective in controlling weeds, very often is cumbersome, labour intensive, expensive and time consuming. With the advancement in technology, number of herbicides are now available which can be used effectively and economically. Many herbicides were found effective for controlling weeds in common maize.

OBJECIVES

1. To evaluate the different chemical weed management practices in baby corn.

2. To workout the economics of weed management

METHODOLOGY

A field experiment was conducted during *kharif,* 2014 at IFS farm, Main Agricultural Research Station (MARS), Raichur. The soil of the experimental site was deep black soil with pH of 8.10, 246 kg/ha available N, 35 kg/ha available P_2O_5 and 295 kg/ha available K_2O. The experiment was laid out Randomised Block Design with three replications and eleven treatments. The baby corn genotype used was "CPB-472" which is a hybrid. The special character of the genotype is that it doesn't require detasselling. The crop was sown on 10/07/2014 with a spacing of 45 cm × 20 cm and first harvest was done on 04/09/2014 and subsequent harvesting of baby corn was carried out up to a week on alternate days. The study involves the application of atrazine 50 WP @ 1.0 kg a.i/ha as PRE application, alachlor 50 EC @ 1.0 kg a.i/ha as PRE application and pendimethalin 38.7 CS @ 1.0 kg a.i/ha as PRE application and combination of these three herbicides as PRE application and followed by 2, 4-D as post emergence application at 25 DAS.

RESULTS AND DISCUSSION

Effect on weed control efficiency

The results showed that significantly higher weed control efficiency (82.54%) was recorded in atrazine 50 WP @ 0.5 kg a.i/ha + pendimethalin 38.7 CS @ 0.5 kg a.i/ha as PRE application and was followed by atrazine 50 WP @ 1.0 kg a.i/ha as PRE application fb 2, 4-D Sodium salt 80 WP @ 1.0 kg a.i/ha as POE application at 25 DAS (79.28 %) and it was on par with atrazine 50 WP @ 1.0 kg a.i/ha as PRE application (77.05%) This might be due to the combination of both the chemicals which were found to be more effective in suppressing the weed density as well as weed dry matter. These results corroborate with the findings of Saini and Angiras (1998) and Pandey *et al.* (2002).

Effect on yield

The highest green cob yield and stalk yield (11.91 t and 30.59 t/ha, respectively) were recorded in weed free check and atrazine 50 WP @ 0.5 kg a.i/ha + pendimethalin 38.7 CS @ 0.5 kg a.i/ha as PRE application (10.98 t/ha and 28.83 t/ha respectively) was on par with it. This might be due to the application of herbicide which resulted in reduced crop weed competition and creating good environment for better growth of plant resulting in higher yield of baby corn. Weedy check recorded significantly lower green cob yield (6.31 t/ha) due to severe weed competition with baby corn which resulted in stunted growth and lower yield. Similar result was also reported by Sinha *et al.* (2005).

Table 1. Weed control efficiency (WCE), yield and economics in baby corn as influenced by chemical weed management

Tr. No.	Treatment	WCE (%)	Green cob yield (t ha^{-1})	Green Stalk yield (t ha^{-1})	Gross returns (Rs ha^{-1})	Net returns (Rs. ha^{-1})	BC ratio
T_1	Atrazine 50 WP @ 1.0 kg a.i. ha^{-1} as PRE application	77.05	9.77	27.53	1,74,124	1,30,845	4.02
T_2	Alachlor 50 EC @ 1.0 kg a.i. ha^{-1} as PRE application	47.01	7.99	24.54	1,44,329	1,01,530	3.37
T_3	Pendimethalin 38.7 CS @ 1.0 kg a.i. ha^{-1} as PRE application	68.82	8.91	26.45	1,60,037	1,16,247	3.65
T_4	Atrazine 50 WP @ 0.5 kg a.i. ha^{-1} + alachlor 50 EC @ 0.5 kg a.i. ha^{-1} as PRE application	63.06	8.59	26.04	1,54,849	1,11,810	3.60
T_5	Atrazine 50 WP @ 0.5 kg a.i. ha^{-1} + pendimethalin 38.7 CS @ 0.5 kg a.i ha^{-1} as PRE application	82.54	10.98	28.83	1,93,497	1,49,963	4.44
T_6	Alachlor 50 EC @ 0.5 kg a.i. ha^{-1} + pendimethalin 38.7 CS @ 0.5 kg a.i. ha^{-1} as PRE application	61.21	8.44	25.72	1,52,317	1,09,022	3.52
T_7	Atrazine 50 WP @ 1.0 kg a.i. ha^{-1} as PRE application fb 2, 4-D Sodium salt 80 WP @ 1.0 kg a.i. ha^{-1} as POE application at 25 DAS	79.28	10.34	27.93	1,83,008	1,38,829	4.14
T_8	Alachlor 50 EC @ 1.0 kg a.i. ha^{-1} as PRE application fb 2,4-D Sodium salt 80 WP @ 1.0 kg a.i. ha^{-1} as POE application at 25 DAS	54.80	8.29	25.29	1,49,583	1,05,884	3.42
T_9	Pendimethalin 38.7 CS @ 1.0 kg a.i. ha^{-1} as PRE application fb 2, 4-D Sodium salt 80 WP @ 1.0 kg a.i. ha^{-1} as POE application at 25 DAS	70.48	9.24	27.08	1,65,608	1,20,918	3.71
T_{10}	Weed free check	100.00	11.91	30.59	2,09,164	1,55,145	3.87
T_{11}	Weedy check	0.00	6.31	22.16	1,16,881	74,862	2.78
	S.Em.±	0.90	0.32	0.79	-	5,081	0.11
	C.D. at 5%	2.65	0.95	2.33	-	14,988	0.33

WP : Wettable Powder EC : Emulsifiable Concentrate CS:Capsular Suspension fb: followed by
DAS : Days After Sowing PRE : Pre-emergence POE : Post-emergence
*Figures in parentheses indicate original values Total weed count (x) data were transformed to $(x+0.5)^{1/2}$

Economics

Weed free check recorded higher gross returns (‘ 2,09,164/ha) and it was followed by atrazine 50 WP @ 0.5 kg a.i/ha[1] + pendimethalin 38.7 CS @ 0.5 kg a.i/ha as PRE application, atrazine 50 WP @ 1.0 kg a.i/ha as PRE application fb 2, 4-D Sodium salt 80 WP @ 1.0 kg a.i/ha[1] as POE application at 25 DAS. While, lower gross returns was recorded in weedy check (Rs.1,16,881/ha).

Significantly higher net returns (‘ 1,55,145 ha^{-1}) was recorded in weed free check which was on par with atrazine 50 WP @ 0.5 kg a.i. ha^{-1} + pendimethalin 38.7 CS @ 0.5 kg a.i ha^{-1} as PRE application. Significantly a lower (‘ 74,862 ha^{-1}) net return was recorded in weedy check (T_{11}). This result was also reported by Pandey *et al.* (2002).

The benefit cost ratio as influenced by different weed control treatments was significant and followed similar trend to that of net returns except weed free check. Benefit cost ratio was significantly higher in atrazine 50 WP @ 0.5 kg a.i. ha^{-1} + pendimethalin 38.7 CS @ 0.5 kg a.i. ha^{-1} as PRE application (4.44) and it was on par with atrazine 50 WP @ 1.0 kg a.i. ha^{-1} as PRE application fb 2, 4-D Sodium salt 80 WP @ 1.0 kg a.i. ha^{-1} as POE application at 25 DAS. The lowest B:C ratio was recorded in weedy check (2.78) and among herbicide treatments alachlor 50 EC @ 1.0 kg a.i. ha^{-1} as PRE application (T_2) recorded lower B:C ratio. Similar results were also reported by Malla Reddy *et al.* (2012).

CONCLUSION

Tank mix application of atrazine 50 WP @ 0.5 kg a.i/ha + pendimethalin 38.7 CS @ 0.5 kg a.i/ha as PRE application was found to be best treatment for effective control of weeds, yield and economics. The next best treatment was atrazine 50 WP @ 1.0 kg a.i/ha as PRE application fb 2, 4-D Sodium salt 80 WP @ 1.0 kg a.i/ha as POE application at 25 DAS.

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Weed and nitrogen management in Indian mustard [*Brassica juncea* (L.) Czern and Coss.]

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Rapeseed and mustard is the second major oilseed crop after groundnut in India, accounting nearly 25-30% of total oilseeds production. As an irrigated crop in north-west India, the crop suffers more from weed competition at the early growth stagewith both grassy and broad leaved weeds under unweeded condition and causes yield reduction to the extent of 68% as compared to weed free condition (Degra *et al.*, 2011). Moreover, competition of weeds with crop plant causes severe nutrition deprivation in general (Roshdy *et al.*, 2008) and nitrogenous fertilizer in particular on small, marginal and rocky areas of tribal dominated population. Increasing wages, back breaking due to manual weeding, scarcity of labour at peak periodsand high cost involvement compelled scientists to search other feasible and economically viable alternativemeasures to manage the weed below the economic threshold level to harness the yield potential of this crop. Adequate nitrogen dose enhances the yield by influencing a variety of growth and yield parameters and also provides lush green colour of the crop canopy and concurrently increasing the competitive ability of the crop. Considering these facts a field experiment was carried out to find out the most effective weed management practice and nitrogen levels in Indian mustard.

METHODOLOGY

A field experiment was conducted during *rabi* 2014-2015 on clay loam soil of Instructional farm, Rajasthan College of Agriculture, Udaipur. The soil of the experimental field was alkaline in reaction, medium in N and P and high in K. The experiment involved 15 treatment combinations consisted of 5 weed management practices (pendimethalin 0.75 kg/ha as pre emergence, oxadiargyl 0.09 kg/ha as pre emergence, quizalofop-ethyl 0.05 kg/ha25 days after sowing (DAS), hand weeding 25 DAS and weedy check) and 3 nitrogen levels (45, 60 and 75 kg/ha). Indian mustard variety BIO-902 (*Pusa Jaikisan*) was sown with seed rate of 2.5 kg/ha on 2nd November, 2014 at 30 cm × 10 cm spacing using package of practices available for Sub-Humid Southern Plain and Aravalli Hills'' of Rajasthan. Herbicides were sprayed with knapsack sprayer fitted with flat fan nozzle using 500 litres of water per hectare. Observations on various parameters were taken using standard procedures.

RESULTS

In the experimental sites,predominant monocot and dicot weeds were*Cynodon dactylon, Cyperus rotundus, Phalaris minor, Asphodelus tenuifolius,Anagallis arvensis, Chenopodium murale, Chenopodium album, Convolvulus arvensis, Fumaria parviflora* and *Melilotus indica.* Among the weed management treatments, one hand weeding 25 DAS resulted in minimum density of monocot, dicot and total weeds at 60 DAS compared to rest of the treatments which was followed by oxadiargyl 0.09 kg/ha and pendimethalin 0.75 kg/ha. However, one hand weeding and oxadiargyl 0.09 kg/hatreatments were found statistically at par in reducing weed dry matter at 60 DAS.The highest weed control efficiency (WCE) at60 DAS (76.35%) was recorded under one hand weeding treatment closely followed by oxadiargyl 0.09 kg/ha (74.11%) in this regard.Also,one hand weeding at 25 DAS and oxadiargyl 0.09 kg/ha were found statistically at par with respect to seed and stover yields. These results seems to be due to the fact that both these treatments provided better environment to the crop for luxuriant growth and later on the crop itself acted as smoother crop and curbed the growth of weeds beneath the crop coverage.Application 75 kg N/ha increased dry matter oftotal weeds at 60 DAS compared to 45 kg N/ha.Seed andstoveryields of the crop increased with each level of nitrogen application from 45 kg/ha to 75 kg/ha which is the manifestation of significant increase in yield attributes. It was well emphasized that application of 75 kg N/ha markedly improved overall growth of the crop in terms of dry matter/plant by virtue of its impact on morphological and photosynthetic components. The improvement in these growth parameters results competitive ability of crop with unwanted plants. This reflects great availability of nutrients and metabolites for different biosynthesis process of growth and development of both vegetative (source) and reproductive (sink) part. Economic evaluation of the treatments revealed maximum net returns and B-C ratio (₹ 67136 /haand 3.05, respectively) with pre emergence application of oxadiargyl 0.09 kg/ha followed by one hand weeding 25 DAS (65757 /haand 2.76, respectively). Among the nitrogen levels the maximum net returns (61333 /ha) and B-C ratio (2.75) were recorded under application of 75 kg N/hadue to higher seed and stover yields with comparatively less additional cost of nitrogen under this treatment.

Table 1. Effect of weed management and nitrogen levels in Indian mustard

Treatment	Seed yield (t/ha)	Stover yield (t/ha)	Net returns (/ha)	B-C ratio	*Weed density/m^2 at 60 DAS	Weed dry matter at 60 DAS (kg/ha)
Weed Management						
Pendimethalin 0.75 kg/ha	1.85	4.84	52860	2.45	8.24(67)	200.09
Oxadiargyl 0.09 kg/ha	2.23	5.46	67136	3.05	7.99(63)	141.59
Quizalofop-ethyl 0.05 kg/ha	1.66	4.51	44913	2.04	11.65(135)	431.79
One Hand weeding 25 DAS	2.24	5.59	65757	2.76	5.52(30)	129.43
Weedy Check	1.31	4.00	33661	1.68	14.43(208)	549.62
LSD (P=0.05)	0.21	0.51	8155	0.37	0.35	29.06
Nitrogen levels (kg/ha)						
45	1.61	4.35	43263	1.97	9.43(99)	269.16
60	1.89	4.94	54000	2.46	9.57(101)	295.26
75	2.08	5.35	61333	2.75	9.69(103)	307.09
LSD(P=0.05)	0.16	0.39	6317	0.29	NS	22.51

(*) figures in parenthesis are original values, *= Transformed values $\sqrt{(x + 0.5)}$

CONCLUSION

Pre-emergence application of oxadiargyl 0.09 kg/hainIndian mustard recorded the highest net returns and B-C ratio with greater seed yield comparable to one hand weeding. It is found that oxadiargyl 0.09 kg/hacould be the alternative option of costly hand weeding practice in gaining higher yield in Indian mustard. Among the N treatments, application of 75 kg N/ha recorded the maximum net returns (61333 /ha) and B-C ratio (2.75) with higher seed yield.

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Integrated weed management in safflower (*Carthamus tinctorius*)

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A field experiment was conducted at research farm, department of Agronomy, at Indira Gandhi Krishi Vishwavidyalaya, Raipur during *kharif* season 2014. Fourteen treatments comprised of either alone or different combinations of herbicides (pre and post emergence) and 1 and 2 hand hoeing at 25 and 25&45 DAS including one standard check untreated control. The experiment was laid out in randomized block design replicated thrice. Experimental field was dominated by *Medicago denticulata, Chenopodium album* and *Cyperus iria* whereas, *Medicago denticulate* was the dominating among the weeds. The results of experiments indicated that weed density, weed dry weight and weed control efficiency were significantly influenced by different weed control treatments pendimethalin 30 EC @ 1 kg/ha + 2 hand hoeing at 25 and 45 DAS showed good performance with minimum weed dry weight, highest weed control efficiency and lowest weed index. However, pendimethalin 37.8 EC @ 1 kg/ha+ 2 hand hoeing at 25 and 45 DAS and hand hoeing at 25 and 45 DAS were also found effective in controlling broad leaved weeds and sedges. Pendimethalin 30 EC @ 1 kg/ha + 2 hand hoeing at 25 and 45 DAS recorded significantly highest yield but pendimethalin 37.8 EC @ 1 kg/ha + 2 hand hoeing at 25 and 45 DAS and hand hoeing at 25 and 45 DAS were also better performing treatments in terms of yield.

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Weed growth and yield performance of wheat as influenced by weed control treatments under peninsular Indian conditions

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Wheat [*Triticum aestivum* (L.)] is one of the most important food grain crops in the world regarded as the "king of cereals". India ranks first in area (31.0 million hectares) and second in production (93.80 million tons) of wheat in the world with an average productivity of 3025 kg/ ha(Anonymous, 2015). Weed incidence is one of the major barrier responsible for the low productivity of wheat in India. The short stature of new dwarf varieties of wheat coupled with high fertilizer and irrigation requirement creates favourable ecological conditions for heavy weed infestation. According to Chauhan *et al.* (1997), the maximum yield loss in wheat (33%) was caused by weeds alone. In wheat, manual and mechanical weed control measures are rather difficult due to its narrow row spacing. Further, labour scarcity and high labour wages makes it highly uneconomical. Herbicides offer most ideal, practical, effective and economical means of reducing early weed-crop competition. However, a single application of a pre-emergence or post-emergence herbicide is often inadequate for satisfactory weed control due to a wide range of weed flora and varying periodicity of weed germination, implying the need for sequential application. A bulk of the weed research conducted is confined to North Indian conditions where wheat is the major *rabi* crop. Hence, to test the efficacy of some pre-emergence (pendimethalin, metribuzin) and post-emergence (2,4-D and metsulfuron-methyl) herbicides, alone and in sequence under the peninsular Indian conditions, the present experiment was planned.

METHODOLOGY

An experiment was conducted during *Rabi* season of 2014 at a farmer's field in Muttagi village, Vijayapura district under Northern Dry Zone of Karnataka. The soil of the experimental field was clayey in texture, low in available nitrogen and medium in available phosphorus and potash and slightly alkaline in reaction with pH 8.10 and EC 0.35 dS/m. Two pre-emergence (pendimethalin 30% EC @ 1 kg a.i./haand metribuzin 70% WP @ 175 g a.i./ha) and post-emergence (2,4-D 80 % WP @ 2 kg a.i./haand metsulfuron-methyl 20% WP @ 4 g a.i./ha)) herbicides were applied singly (T_1, T_4, T_7 and T_8) and in sequence (T_2, T_3, T_5 and T_6) and were compared with weedy check and weed free check. Totally 10 treatments were tested in randomized block design with three replications. The wheat variety 'UAS-304' was sown at 22.5 cm row spacing at 150 kg seed per hectare on November 6, 2014

Table 1. Effect of different weed control practices on wheat productivity, profitability and weed growth at harvest

Treatment	Total weed dry weight (kg/ha)	Weed control efficiency (%)	Grain yield (kg/ha)	Net return (Rs/ha)	Weed Index (%)
T_1 : Pendimethalin *fb* 1 IC	140.9	69.81	4029	51704	7.34
T_2 : Pendimethalin *fb* 2,4-D	90.3	80.65	4145	53807	4.71
T_3 : Pendimethalin *fb* MM	84.0	81.96	4174	54953	4.04
T_4 : Metribuzin *fb* 1 IC	145.4	68.87	3362	39994	22.61
T_5 : Metribuzin *fb* 2,4-D	104.3	77.64	3391	40464	22.04
T_6 : Metribuzin *fb* MM	91.7	80.35	3420	41599	21.28
T_7 : 2,4-D	133.3	71.44	3870	50603	10.91
T_8 : MM	124.9	73.25	3913	51494	9.91
T_9 : Weed free check	0.0	100.00	4348	57424	0.00
T_{10} : Weedy check	466.7	0.00	3257	40871	25.04
SEm±	7.0	1.43	131	2504	2.98
CD (P=0.05)	20.8	4.24	389	7439	8.85

Note : IC = Intercultivation, MM = Metsulfuron-methyl, *fb* = followed by and harvested on March 1, 2015. Pendimethalin and metribuzin were sprayed at 1 DAS (days after sowing) and 2,4-D and metsulfuron-methyl at 25 DAS with a spray volume of 750 l/ha. All the experimental data were statistically analyzed and critical difference was worked out as per standard statistical procedure.

RESULTS

The data pertaining to effect of different weed control treatments on wheat productivity, profitability and weed growth at harvestare presented in Table 1.Total weed dry weight at harvest was significantly lower in the treatment T_3 : pendimethalin @ 1 kg a.i./ha*fb* metsulfuron-methyl @ 4 g a.i./ha (84.0 kg/ha) which was at par with T_2 : pendimethalin @ 1 kg a.i./ha*fb* 2,4-D @ 2 kg a.i./ha, T_6 : metribuzin @ 175 g a.i./ha*fb* metsulfuron-methyl @ 4 g a.i./ha and T_5 : metribuzin @ 175 g a.i./ha*fb* 2,4-D @ 2 kg a.i./ha. A similar trend was also found in case of weed control efficiency at harvest. Maximum grain yield and net returns was recorded under weed free check (4348 kg/haand Rs 57,424 resp.) which was at par with the treatments T_3 : pendimethalin @ 1 kg a.i./ha*fb* metsulfuron-methyl @ 4 g a.i./ha, T_2 : pendimethalin @ 1 kg a.i./ha *fb* 2,4-D @ 2 kg a.i./haand T_1 : pendimethalin @ 1 kg a.i./ha*fb* one intercultivation at 30 DAS. Weed index, which is a measure of yield reduction due to weed competition, was significantly higher in weedy check (25.04 %). Significantly lower weed index was recorded with T_3 (4.04%)which was at par with the treatments T_2, T_1, T_8 and T_7. Pre-emergence application of metribuzin @ 175 g a.i./ hawas phytotoxic to wheat crop.

CONCLUSION

It may be inferred that, among all the weed control treatments, performance of wheat crop was superiorin the treatments,pendimethalin @ 1 kg a.i./ha *fb* metsulfuron methyl @ 4 g a.i./ha, pendimethalin @ 1 kg a.i./ha *fb* 2,4-D @ 2 kg a.i./ha and pendimethalin @ 1 kg a.i./ha *fb* one intercultivation at 30 DAS which resulted in lower weed dry weight and weed index and higher weed control efficiency, grain yield and net returns. Hence sequential application of herbicides may be a solution to the persistent weed problems in wheat crop under peninsular Indian conditions.

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Effect of weed management practices on weed biomass and fodder productivity of cowpea (*Vigna unguiculata*)

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ABSTRACT

Despite of world largest milk producing country, the productivity of Indian livestock is very poor compared to developed countries mainly due to shortage of green and dry fodder. At present, the country faces a net deficit of 35.6 % green fodder, 10.95 % dry crop residue and 44 % concentrate feed ingredient (IGFRI Vision, 2050). The scarcity of fodder in the country is mainly due to less area allocated to fodder crops and poor resource management. Out of several factors causing low yield, weed management in forages is very important for higher and quality forage production (Ghosh *et al*, 2016 and Palsaniya *et al*, 2015). Cowpea is an important legume fodder crop in arid, semi arid and hub-humid regions of the country whose productivity is far below its potential yield mainly due to poor weed management. Therefore present weed management study was planned for reducing weed competition and enhancing fodder productivity of cowpea.

METHODOLOGY

A field experiment was conducted at the Central Research Farm of Indian Grassland and Fodder Research Institute, Jhansi during *kharif* 2015. The soil of experimental site is sandy loam in texture and slightly acidic in reaction (pH 6.30). The soil was high in organic carbon (1.06 %) and low in avail-

Table 1. Effect of weed management practices on weed biomass and yield of fodder cowpea

Treatment	Yield (t/ha)		Weed dry matter at harvest (g/m^2)	Weed index of GFY (%)	WCE at harvest (%)
	Green Fodder	Dry Fodder			
Imazethapyr @0.1 kg a.i./ha (PE)	27.18	5.13	27.4 (1.54)*	9.59	70.91
Imazethapyr @0.1 kg a.i./ha (PE) + Wheel Hoe at 20 DAS	29.25	5.37	23.4 (1.38)*	2.71	75.16
Weed Free	30.07	5.51	0.00 (0.30)	-	100.0
Weedy check	18.31	3.55	94.2 (1.95)*	39.08	-
Sem$\pm$	1.91	0.41	0.02		
CD (P=0.05)	5.91	1.26	0.07		

*Figures given in parenthesis are (X+2) log transformed

able nitrogen (190.67kg/ha) and medium in available P (16.57 kg/ha) and K (208.3 kg/ha) with a EC of 0.11. The experiment was laid out in randomized block design with five replications. The treatments consisted of four weed management practices, *viz.* weedy check (control), weed free, Imazethapyr @0.1 kg a.i./ha as pre-emergence and Imazethapyr @0.1 kg a.i./ha as pre-emergence + wheel hoe at 15 DAS. Field was prepared with a disc plough followed by two pass of a disc harrow and planking in the last to have a uniform seed bed of fine tilth. The crop was sowed on 15th July with a seed rate of 35 kg/ha and 30 cm row to row distance was kept for proper growth. The treatment was imposed as per technical programme. The observation on weed and crop was recorded on different stages of the crop. The crop was harvested at 50 % days to flowering. The statistical analysis of data was done as per procedure suggested by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

The experimental results given in Table 1 showed that application imazethapyr @0.1 kg a.i as pre- emergence+ Wheel hoe (20 DAS) in fodder cowpea recorded lower values of total weed dry matter (23.4 g/m^2) at harvest, weed index of green fodder yield (2.71 %) over weedy check and Imazethapyr alone. Respective treatment recorded 75.16 % more weed control over weedy check. Effective control of grassy and sedges weeds in early stages by application of imazethapyr and some broad weeds through wheel hoe might resulted lower weed biomass in fodder cowpea. Likewise application of imazethapyr @0.1 kg a.i./ha as pre-emergence+ wheel hoe (20 DAS) being at par with weed free and imazethapyr @0.1 kg a.i as pre- emergence alone recorded significantly higher green fodder (29.25 t/ha) and dry matter yields (5.37 t/ha) over weedy check (18.31 and 3.55 t/ha, GFY & DMY, respectively). Timely control of weeds provided better environment to fodder cowpea for space, light and nutrients led to higher green and dry fodder yield of cowpea. Similar results were also reported by Washnik *et al*. (2014).

CONCLUSION

On the basis of one year experimentation, it can be concluded that application of imazethapyr @0.1 kg a.i./ha as PE + Wheel hoe at 20 DAS could be adopted for realizing higher productivity of fodder cowpea with minimum weed competition.

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Efficacy of fenoxaprop-p-ethyl and penoxsulam on weed flora in transplanted summer rice with special emphasis on grasses

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In transplanted summer rice, *Echinochloa crusgalli, E. glabrescens, Panicum sp., Cyperus difformis,C. iria, Marsilea minuta, Jussiaea repens,Alternanthera sessilis, A. philoxeroides, Commelina sp.*are foundto be the major weeds in West Bengal. The grassy weeds *E.glabrescens* and *E. crusgalli* have been recorded to be severe in rice under rice – rice cropping system causing considerable yield loss (Duary*et al*., 2013). Farmershave expressed their concern on the problem caused by the weed in nursery as well as main field. As the weed has mimicry with rice, sometimes farmers are compelled to discard nursery bed owing to severe infestation of *Echinochloa*species.Thus to manage the weeds herbicide is the only viable and economic option. A few herbicides have been tested and recommended for management of *Echinochloa sp.*Therefore, the present investigation wasundertaken to find out the effect of fenoxaprop-p-ethyl (Rice Star)and penoxsulam (Granite)on weed growth with special emphasis on grasses and productivity of transplanted summer rice.

METHODOLOGY

Field experiment was conducted at farmer's field of Borah village (E 87^{0}47.5772, N 23^{0}42.4002, elevation 34 m) of district Birbhum, West Bengal, India during the summer season of 2016.Eight treatments comprising of three doses of fenoxaprop-p-ethyl (Rice Star 6.9 EC)at 80, 90 and 100 g/ha at 20 DAT, three doses of penoxsulam(Granite 24 SC) at 20, 22.5 and 25 g/ha at 20 DAT, hand weeding twice at 20 and 40 DATand weedy check were assigned in a Randomized Block Design replicated thrice.The rice variety '*PAN 5010*' was used in the present experiment. All the agronomic practices were followed as per recommendations.

RESULTS

The experimental field was infested with eight species out of which *Echinochloa crusgalli, E. glabrescens* and *Panicum sp.* among the grasses, *Cyperus difformis* among the sedges and *Jussiaearepens* and *Alternantheraphiloxeroides* among the broad leaved were the predominant weeds. No phytotoxicity was noticed on rice crop due to the application of fenoxaprop-p-ethyl at any of the doses applied at 20 DAT. Application of fenoxaprop-p-ethylboth at 90 and 100 g/ha and higher dose of penoxsulam (25g/ha) effectively reduced grassy weeds in rice. But application of penoxsulam at 25g/ha at 20 DATresulted in a significantly lowerdensity as well as dry weight of total weedsand was comparable with hand weeding twice. Both the herbicides with all the doses of application tested in the present experiment recorded signifi-

Table 1. Effect of treatments on density and dry weight of weeds and grain yield of rice

Treatment	Weed density (no./m^2) at 50 DAT		Weed dry matter (g/m^2) at 50 DAT		Grain yield
	Grasses	Total weeds	Grasses	Total weeds	(kg/ha)
Fenoxaprop-p-ethyl at 80 g/ha at 20 DAT	2.97 (8.33)	4.30 (18.00)	2.69 (6.76)	3.34 (10.66)	5197
Fenoxaprop-p-ethyl at 90 g/ha at 20 DAT	0.71 (0.00)	3.00 (8.50)	0.71 (0.00)	1.70 (2.41)	5333
Fenoxaprop-p-ethyl at 100 g/ha at 20 DAT	0.71 (0.00)	3.00 (8.50)	0.71 (0.00)	1.55 (1.91)	5783
Penoxsulam at 20g/ha at 20 DAT	2.27 (4.67)	2.80 (7.33)	1.10 (0.71)	1.61 (2.08)	5378
Penoxsulam at 22.5g/ha at 20 DAT	2.12 (4.00)	2.55 (6.00)	1.03 (0.56)	1.23 (1.01)	5647
Penoxsulam at 25g/ha at 20 DAT	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	6167
Hand weeding at 20, 40 DAT	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	6186
Weedy check	5.46 (29.33)	6.52 (42.00)	4.83 (22.80)	5.45 (29.20)	4944
CD (P=0.05)	0.29	0.38	0.20	0.19	753

*****Values in parentheses are original. Data transformed to square root transformation cantly higher grain yield over the untreated control. This was due to effective management of weeds, which facilitated better growth of crop which ultimately increased the grain yield. The highest grain yield was obtained where hand weeding was done twice at20 and 40 DAT. Application of penoxsulam both at 22.5 and 25 g/ha at 20 DAT and fenoxaprop-p-ethyl at 100 g/ha at 20 DAT were statistically at par with hand weeding twice in respect to the grain yield of rice.

CONCLUSION

From the experimental study it may be concluded that fenoxaprop-p-ethyl at 100 g/ha at 20 DATand penoxsulamat 22.5 to 25 g/ha provided excellent control of grassy weeds in transplanted summer rice. However, penoxsulamat 22.5 to 25 g/ha also provided higher weed control of broad spectrum weeds and registered higher grain yield of summer rice.

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Seed bank dynamics and emergence pattern of weeds as influenced by different tillage systems in wheat

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Soil weed seed bank is a general term which is used for viable weed seeds existing in the soil. Changes in tillage intensity can lead to shifts in weed species and densities with increased incidence of perennial and some annual monocot weeds (Blackshaw *et al*., 2001). The vertical weed seed distribution in a soil profile as affected by tillage practices which further influences weed seed germination affecting the microclimate surrounding the seeds. Study of seed bank dynamics can help in better understanding of the communities of the most important weed species; thus a better and more efficient weed management strategies can be ascertained.Factors affecting germination and emergence of weed seeds are complex under natural conditions and poorly understood, especially for zero tillage systems in India. Tillage systems, residue retention and cover crop are some of the important factors that affect weed seed germination and emergence in zero tillage. Therefore, the present study was carried out to study theseed bank dynamics and emergence pattern of weeds in zero and conventional tillage systemsin wheat.

METHODOLOGY

A field experiment was initiated in 2012 at research farm of ICAR-Directorate of Weed Research, Jabalpur, M.P., India (23°14’8.51"N and 79°58’4.88" E). The soil of the experimental site was classified as typic chromusterts with sandy loam texture, 0.48% organic C, 238 kg/ha available N, 16.4 kg/ha available P and 340 kg/ha available K. The study compared four tillage systems, conventional tillage (CT), conventional tillage with residue incorporation (CT+RI), zero tillage with residue retention (ZT+RR) and zero tillage without residue (ZT) in a thrice replicated randomized block design. Data presented here of wheat crop for the same treatments were collected in the *Rabi* season of 2015-16. Weed emergence was recorded in all plots from threequadrates of 50×50 cm at 30, 60 and 90 days after sowing (DAS), and expressed as seedling emergence m^{-2}. A naturally occurring seed bank was recorded by taking three soil cores (10 cm in diameter) of three different depths (0-2, 2-5 and 5-10 cm) per plot before sowing.

RESULTS

Data on weed emergence pattern was taken at 30, 60 and 90 days. Major weeds were *Medicago polymorpha, Chenopodium album, Avena ludocviciana.* Other weedswere *Rumex dentatus, Sonchus oleracious, Dinebra retroflexa, Lathyrus*

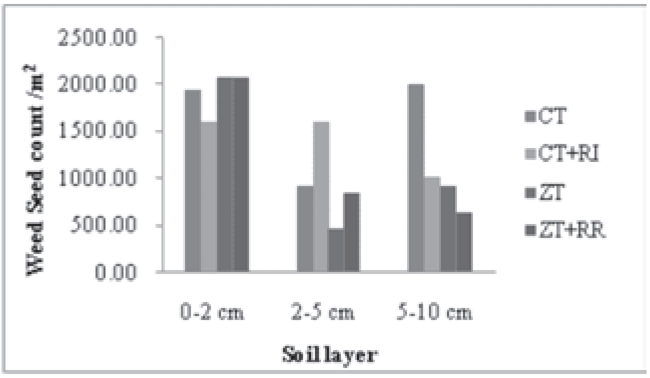

Fig. A

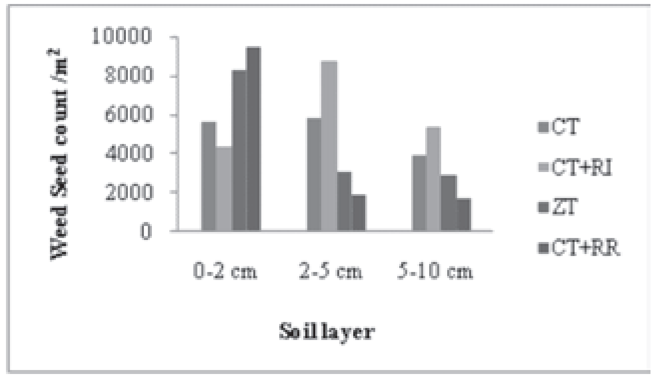

Fig. B

Fig 1. Vertical seed distribution of broad leaved (A) and narrow leaved weeds (B) in different tillage system

aphaca, Brachiaria eruciformis, Echinochloa colona, Digitaria sanguinalis and Phalaris minor. In zero tillage practices weed were dominant at all the stages of observation than conventional tillage practice. *Echinochloa colona, Digitaria sanguinalis* and *Brachiaria eruciformis* were only found at 90 DAS.*Avena ludoviciana* wasdominated in the zero tillage practice. High emergence rate of *Avenaludoviciana*occur under ZT systems may be due to light stimulation and the absence of physical obstacles to emergence. *Echinochloa, Digitaria* and *Brachiaria* are generally *Kharif* weedsbut came at 90 DAS in wheat may be due to the high temperature during the period of this year. Soilweed seed bank study showed that upper soil layer (0-2 cm) had higher number of broad leaved weed seeds in all the tillage system i.e. CT, ZT and ZT+RR except CT+RI. But in case of narrow leaved weed seeds, higher number was noticedunder CT and ZT+RR system. At 2-5 cm layer, higher number of broad leaved weed seeds wasfound in CT+RI and lowest in ZT system. Narrow leavedweeds were higher in CT and CT+RI and lowest in ZT and ZT+RR system. At lower (5-10 cm) layer,number of broad and narrow leaved weeds was higher in CT+R and lowest in the ZT+R system (Fig 1).There was a variation in the proportion of weed seeds in the surface layer between CT and ZT. This suggests that a lesser proportion of weeds will be prone to desiccation and predation in CT than ZT.

CONCLUSION

The results suggest that, zero tillage systems could favour the emergence of many weed species which could become major problem in ZT systems. Management of weed seed bank through stale seedbed technique and control of weeds before seed setting may need to be exposing to control weeds in such situations. On the other hand, CT systems may encourage the weed seed bank in lower layer which may persist by inducing dormancy in weed seeds.

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Design and optimization of border and check basin in slopping land for improving irrigation efficiency

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In India surface irrigation is considered one of the most common and important irrigation methods, and will remain as one of the most extensive methods used for irrigation. However, it is a well known fact that efficiencies with surface irrigation methods tend to be low due to different losses occurring in the field. Thus, optimal designing and management of these systems, for increasing irrigation efficiency and reducing water losses, is essential. One potential for improving the efficiency and performance of surface irrigation methods lies in the use of simulation models to simulate and predict irrigation performance. Several models have been developed by the researchers for simulating flow in surface irrigation. One of the most commonly used models SIRMOD (Walker, 1998), has seen wide use and evaluation throughout the world particularly by researchers and has been shown to offer potential for increasing surface irrigation efficiency (Faulkner *et al*., 1998). The SIRMOD model adequately describes water infiltrated depth under experimental site conditions for the different surface irrigation methods. Some workers have validated SIRMOD model under clay loam soil conditions, and indicated that there were good relationships between the predicted and measured infiltration depths. This study aims to validate SIRMOD model for border and basin irrigation methods and optimize the design of border and check basin in slopping land.

METHODOLOGY

To optimize the design of border and check basin irrigation in the slopping land, field dimensions, slope and soil information were collected from 3 blocks of langha watershed of Dehradun which were irrigated by gravity fed water conveyance system. Surface irrigation system software SIRMOD developed by Utah State University was used for the study. The SIRMOD software was validated using the recommended dimensions of border and check basin given for different soils in the different parts of India (Yadav, 1982). After validating the SIRMOD, it was used to design optimum size of border and check basin for different dimensions soils and for high slope conditions of langha watershed. The selection of a particular dimension as optimum was decided based on the efficiency estimated by SIRMOD. The length of the field was varied between 20-30 m and 30-70 m for sandy loam and clay loam soil respectively for design of border and check basin at higher slope (1-2%). However the width was fixed as 15 m as most of the farmers maintained same width of the field in all the 3 blocks. The average discharge of risers in all the 3 blocks for irrigating the fields was 10 lps.

RESULTS

The SIRMOD model was validated using the recommended dimensions of border and check basin for different soils (Yadav, 1982) and it was found that the application efficiency, storage efficiency and distribution efficiency estimated by the model were more than 80% for all the recommended dimensions, slope and discharge. After validating the model, optimum size of border and check basin for different

Table 1. Optimum dimensions in Slopping land based on SIRMOD Simulation

Soil type	Length (m)	Width (m)	Discharge (lps)	Slope (%)
Basin Irrigation				
Sandy loam	20	15	5-6	1-2
Sandy Loam	30	15	8	1-2
Border irrigation				
Sandy Loam	40	15	10	0.5-1.5
Clay Loam	50-70	15	10	0.5-1.0

soil and slope conditions of langha watershed were simulated using SIRMOD model. The selection of optimum design was based on the maximum efficiencies. The SIRMOD simulation results showed that in sandy loam soil, application efficiency, required efficiency and distribution efficiency at 20 m length and slope of 1-2%, the efficiencies varied between 70-80%. The optimum discharge for 20 m and 30 m length for higher slopes were 5-6 lps and 8 lps. Similarly for border irrigation, the optimum length and slopes in sandy loam and clay loam soil were 40 m and 50-70 m and 0.5-1.5% and 0.5-1% respectively. It was also found that increase in the length in sandy loam soil above 50m and increase in the slope in clay loam soil above 1% reduced the storage and distribution efficiency.

CONCLUSION

Based on the simulation, the optimum dimension of border and check basin for sandy loam and clay loam soil were decided in slopping land for which all the efficiencies i.e application, required and distribution efficiency varied between 70-80%. SIRMOD proved to be a good tool for predicting the water distribution along the gravity fed irrigated field under border and basin irrigation in slopping land. The model could be a helpful tool for irrigation practitioners to design the border and check basin irrigation in flat and slopping land for proper on farm water management.

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Effect of weed control practices on productivity of mustard

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Brassica juncea is the oldest cultivated amphidiploid and originated from *B. rapa* and *B. nigra.* India has 6.7 million hectares area with 8.0 million tonnes production and 1188 kg /ha productivity. mustard is exclusively grown under irrigated conditions, problem of weeds poses a serious threat to its potential production. Among the factors responsible for the low productivity of the mustard, poor weed control ranges from 10-58 per cent yield loss. The most noxious weeds in oilseed rape include wild mustard (*Sinapis arvensis* L.), wild oat (*Avena fatua* L.) and green foxtail (*Setaria viridis* L.). The most common weeds of rape and mustard crop are *Chenopodium album, Lathyrus spp.*, *Melilotus indica*, *Cirsium arvense*, *Cyperus rotundus* and *Fumaria parviflora.* The critical period of crop weed competition in rapeseed-mustard is 15-40 days and weeds cause alarming decline in crop production ranging from 15-30 per cent to a total failure yield depending on weed flora, its intensity, stage, nature and duration of the crop weed competition. The crop is infested with both grasses and broad-leaved weeds, which pose a serious competition during early period of crop growth. Weed competition not only decreases the mustard crop yield but also reduced its quality and market value. In the present study, new post emergence herbicides were tried at different levels and compared with recommended treatments to find out the most effective and safe method of weed control in mustard.

METHODOLOGY

A field experiment was conducted on clay loam soils, at Instructional Farm, Rajasthan College of Agriculture, Udaipur during *Rabi*, 2014-15 with the objective to find out the suitable method of weed control in mustard. The experiment consisted of 10 treatments *i.e.* weedy check, one hand weeding 20 DAS, two hand weeding 20 and 40 DAS, fenoxaprop-p-ethyl 0.075 kg /ha 10 DAS, fluazifop-p-butyl 0.055 kg /ha 10 DAS, quizalofop-p-ethyl 0.050 kg /ha 30 DAS, fenoxaprop-p-ethyl 0.075 kg /ha 10 DAS + one hoeing 40 DAS, fluazifop-p-butyl 0.055 kg /ha 10 DAS + one hoeing 40 DAS, isoproturon 1.25 kg /ha 30 DAS and weed free check. These treatments were replicated four times in randomized block design. Mustard variety Pusa Jai Kisan (Bio- 902) with seed rate of 3 kg/ha was sown at spacing of 40 cm x 10 cm. The soil of experimental field was clay loam in texture and slightly alkaline in reaction and calcareous in nature. It was medium in available nitrogen, phosphorus and potassium. A uniform dose of 60 kg N and 35 kg P_2O_5 /ha was given through urea and DAP after adjusting the quantity of nitrogen supplied through DAP. As per treatment, fenoxaprop-p-ethyl and fluazifop-p-butyl were applied 10 days after the sowing of crop while quizalofop-p-ethyl and isoproturon were applied 30 days after sowing. These herbicides were sprayed with knapsack sprayer fitted with flat fan nozzle using 500 litres of water per hectare. Hand weeding operations were performed by removing weeds by hand and hand hoe. The crop was irrigated twice at 35 and 70 DAS. The crop was harvested at physiological maturity when plants turned brownish yellow.

RESULTS

The results revealed that among weed control treatments, two hand weeding 20 and 40 DAS, post-emergence application of fluazifop-p-butyl 0.055 kg/ha + hoeing 40 DAS and fenoxaprop-p-ethyl 0.075 kg/ha + hoeing 40 DAS resulted significantly lower weed population and dry matter of monocot, dicot and total weeds and significantly higher weed control efficiency at 60 DAS as compared to other treatments. Integration of post-emergence herbicides with hoeing was found significantly superior in controlling the weed density and dry matter compared to their corresponding application alone. Uptake of N, P and K by weeds at harvest was found significantly lower with all the weed control treatments compared to weedy check. The minimum total uptake of N (0.52 kg /ha), P (0.08 kg /ha) and K (0.49 kg /ha) was recorded with two hand weeding 20 and 40 DAS closely followed by post-emergence application of fluazifop-p-butyl 0.055 kg /ha + hoeing 40 DAS. Weed free treatment recorded the highest plant dry matter, number of siliquae/ plant, seed/ siliqua and test weight closely followed by two hand weeding 20 and 40 DAS. Amongst weed control treatments the maximum seed (1977.25 kg /ha), straw (5783.75 kg /ha) and biological yield (7761.00 kg /ha) were recorded with weed free treatment which was statistically at par with two hand weeding 20 and 40 DAS, post-emergence application of fluazifop-p-butyl 0.055 kg /ha + hoeing 40 DAS and fenoxaprop-p-ethyl 0.075 kg /ha + hoeing 40 DAS. The maximum uptake of total nitrogen (112.61 kg /ha), phosphorus (25.31 kg /ha) and potassium

Table 1. Effect of weed control on yield and harvest index of mustard

Treatment	Yield (kg/ha)			Harvest index (%)
	Seed	Straw	Biological	
Weedy check	1166.75	3943.00	5109.75	22.88
One hand weeding 20 DAS	1655.00	4894.75	6549.75	25.27
Two hand weeding 20 and 40 DAS	1955.25	5568.25	7523.50	26.03
Fenoxaprop-p-ethyl 0.075 kg /ha 10 DAS	1491.00	4694.75	6185.75	24.10
Fluazifop-p-butyl 0.055 kg /ha 10 DAS	1499.25	4700.50	6199.75	24.31
Fluazifop-p-butyl 0.055 kg /ha 10 DAS + one hoeing 40 DAS	1914.00	5222.25	7136.25	26.86
Isoproturon 1.25 kg /ha 30 DAS	1389.50	4557.00	5946.50	23.47
Weed free check	1977.25	5783.75	7761.00	25.48
SEm ±	63.26	161.27	158.31	1.08
CD (P=0.05)	183.58	467.95	459.38	NS

(76.90 kg /ha) by the crop was in weed free check closely followed by two hand weeding 20 and 40 DAS, post-emergence application of fluazifop-p-butyl 0.055 kg /ha and fenoxaprop-p-ethyl 0.075 kg /ha along with hoeing 40 DAS and these treatments were found statistically at par to each other in this regard and the minimum uptake of nutrients being recorded under weedy check with the respective value of 70.11, 16.05 and 51.86 kg /ha. As nutrient uptake by crop is primarily a function of yield and nutrient content. Thus, higher uptake of nutrients by the crop may be due to decreased weed competition and concurrently increased in nutrient availability, better crop growth and higher biomass production coupled with more nutrient content. Both net returns (₹56337 /ha) and benefit-cost ratio (2.69) were obtained maximum under post-emergent fluazifop-p-butyl 0.055 kg /ha + hoeing 40 DAS closely followed by fenoxaprop-p-ethyl 0.075 kg /ha + hoeing 40 DAS with the respective net returns and B-C ratio of ₹55225 /ha and 2.51.

CONCLUSION

It is concluded that two hand weeding 20 and 40 DAS recorded the highest seed yield of mustard 1955.25 kg /ha.

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Integrated weed management in pearlmillet (*Pennisetum glaucum)*

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Pearlmillet [*Pennisetum glaucum* (L.) R. Br. Emend Stuntz] is an important short duration and drought tolerant millet crop for millions of people in tropics, particularly, in Africa and Asia. Heavy weed infestation during rainy season is a major constraint to higher productivity in pearlmillet and cause grain yield loss up to 40% or even more in pearlmillet (Sharma and Jain, 2003). Though hand weeding is the predominant method of weed control in pearlmillet, but labour scarcity during peak rainfall period has made use of herbicides indispensable for timely control of weeds. Keeping this idea in view, the present investigation was carried out.

METHODOLOGY

A field experiment was conducted during *kharif,* 2014 in sandy loam soils of dryland farm at S. V. Agricultural College, Tirupati. The experiment was laid out in randomized block design with ten treatments of weed control comprising of two pre-emergence herbicides (atrazine @ 750 g/ha and oxyflourfen @ 100 g/ha), two post-emergence herbicides (almix @ 8 g/ha and ethoxysulfuron @ 37.5 g/ha) and hand weedings at 20, 30 and 40 DAS. The pre-emergence herbicides were applied alone and in combination with post-emergence herbicides or hand weeding. The observations on weed

Table 1. Effect of weed management practices on weed density at 25 DAS and at harvest and weed dry weight and weed control efficiency

Treatment	Weed density (No./m^2)		Weed dry weight (g/m^2)		Dry matter production (kg/ha)	Grain yield (kg/ha)	B:C Ratio
	25 DAS	At harvest	25 DAS	At harvest			
T-$_1$: PE atrazine @ 750 g/ha	102.32 (10.16)	138.66 (11.81)	26.08 (5.20)	35.52 (6.03)	8919	2289	2.74
T $_2$: PE oxyflourfen @ 100 g/ha	80.33 (9.01)	174.66 (13.23)	20.49 (4.63)	43.73 (6.68)	7313	1860	2.20
T-$_3$: PE atrazine @ 750 g/ha + HW at 30 DAS	105.33 (10.31)	33.66 (5.86)	26.65 (5.25)	8.64 (3.10)	10449	2936	2.82
T-$_4$: PE oxyflourfen @ 100 g/ha + HW at 30 DAS	79.00 (8.94)	161.33 (12.74)	19.86 (4.56)	40.26 (6.42)	7901	2055	1.96
T-$_5$: PE atrazine @ 750 g/ha + PoE almix @ 8 g/ha	102.66 (10.17)	137.66 (11.76)	26.23 (5.21)	34.77 (5.98)	9391	2339	2.65
T-$_6$: PE atrazine @ 750 g/ha + PoE ethoxysulfuron @ 37.5 g/ha	104.33 (10.26)	133.66 (11.60)	26.54 (5.24)	33.71 (5.89)	9459	2398	2.63
T-$_7$: PE oxyflourfen @ 100 g/ha + PoE almix @ 8 g/ha	81.00 (9.04)	165.66 (12.89)	20.48 (4.63)	43.41 (6.66)	7592	1915	2.15
T-$_8$: PE oxyflourfen @100 g/ha + PoE ethoxysulfuron @ 37.5 g/ha	78.33 (8.91)	163.33 (12.81)	19.65 (4.54)	40.62 (6.44)	7606	2007	2.18
T-$_9$: HW twice at 20 and 40 DAS	10.00 (3.30)	32.00 (5.73)	2.53 (1.87)	8.29 (3.04)	10674	2976	2.46
T-$_{10}$:Weedy check	200.00 (14.17)	335.66 (18.33)	48.27 (7.01)	80.84 (9.04)	6151	1595	1.99
SEm±	0.18	0.26	0.07	0.09	285.9	77.5	0.072
CD (P= 0.05)	0.54	0.80	0.22	0.28	849	232	0.21

growth parameters were taken at 25 DAS and at harvest.

RESULTS

The predominant weed species found in the experimental site were sedges like *Cyperus rotundus* L. (30.7%) and *C. iria* L. (17.0%), grasses like *Digitaria sanguinalis* L. (9.8%), *Echinochloa colona* L. (7.5%) and *Celosia argentia* L. (5.2%), broad leaved weeds like *Commelina benghalensis* L. (4.8%) and *Phalaris minor* L. (4.3%). At 25 DAS, the lowest density and dry weight of weeds were recorded with hand weeding (HW) twice at 20 and 40 DAS followed by pre-emergence (PE) application of oxyflourfen alone or in combination with hand weeding at 30 DAS or any post-emergence (PoE) herbicide, which maintained statistical similarity with each other (Table 1). At harvest, the lowest density and dry weight of weeds were observed with HW twice at 20 and 40 DAS, which was on par with PE application of atrazine *fb* HW at 30 DAS. The treatments involving PE application of atrazine alone or in combination with any of the post-emergence herbicide were the next best treatments. Unweeded check recorded the highest dry weight and density of weeds at both the stages of observation. HW twice at 20 and 40 DAS and PE application of atrazine *fb* HW at 30 DAS recorded statistically similar plant height and dry matter production. The treatments involving PE application of oxyflorfen resulted in reduced crop growth. The highest number of panicles/plant and grain yield was recorded with HW twice at 20 and 40 DAS having parity with PE application of atrazine *fb* HW at 30 DAS PE application of atrazine *fb* HW at 30 DAS recorded the highest B:C ratio than all other weed management practices due to its higher productivity and less cost of cultivation.

CONCLUSION

The present study revealed that PoE application of almix and ethoxysulfuron in combination with any of the pre-emergence herbicides did not have any significant effect on weed control and grain yield of pearlmillet. Pre-emergence application of atrazine *fb* hand weeding at 30 DAS resulted in effective control of weeds with increased grain yield and maximum B:C ratio. However, it was comparable with hand weeding twice at 20 and 40 DAS. The choice of weed management practice in pearlmillet may be followed based on availability and cost of labour.

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Weed suppression through inter-cultivation in direct seeded rice

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Direct seeding is gaining momentum in the recent past as it saves time, labour and energy; improves profitability; increases cropping intensity (through reduced turnaround); and avoids arduous operations such as nursery preparation and transplanting (Subbaiah and Balasubramanian, 2000). The change in crop establishment technique from transplanted to direct seeded rice culture, is subjected to greater weed competition than transplanted rice because both weed and crop seeds emerge at the same time resulting in severe yield reduction. Moreover weed menace is a major concern in direct seeded rice. In recent years, deterioration in soil health due to application of chemical fertilizers alone necessitated the judicious combination of organic manure and inorganic fertilizer to improve soil fertility to sustain rice production. To address these problems of weed infestation and low nitrogen use efficiency, the present investigation was undertaken to identify effective and feasible weed and nitrogen management practices for direct seeded rice.

METHODOLOGY

Field experiments were conducted during *Kharif* seasons of 2009 and 2010 at Sam Higginbottom Institute of Agriculture, Technology and Sciences, Allahabad (U.P.). Soil was sandy loam with pH 8.4, 0.54% organic C, and 208.33 N, 15.98 P, and 186.64 K kg/ha. Rice seeds were soaked in water overnight and incubated for 24 hours. Sprouted rice seeds of *Arize* 6444 were sown at 50 kg/ha using a drum seeder at a spacing of 20 cm in unpuddled soil on 10th June during both the years in the experimental field with recommended package of practices. The seeds of companion crop, *Sesbania* (*Sesbania rostrata*), was uniformly broadcasted by hand at a seed rate of 25 kg/ha in respective treatments. A dual crop of

Table 1. Influence of weed management through inter-cultivation on weed growth, weed smothering efficiency and yield of direct seeded rice

Treatment	Weed density (no./m^2)		Weeds dry weight (g/m^2)		Grain yield (t/ha)	WSE (%) 30 DAS
Planting systems with nitrogen level						
Transplanted rice + 100% RDN	6.56	(58.77)	3.70	(15.63)	4.08	
Transplanted rice + 75% RDN	7.37	(71.66)	4.34	(22.21)	3.92	
DSR (Sole) + 100% RDN	14.69	(271.83)	9.22	(105.71)	3.44	
DSR (Sole) + 75% RDN	13.91	(244.60)	8.74	(96.02)	3.26	
DSR + *Sesbania* + 100% RDN	10.94	(136.27)	5.80	(35.27)	4.05	43.23
DSR + *Sesbania* + 75% RDN	10.36	(124.38)	5.21	(28.16)	3.85	32.30
DSR + *Azolla* + 100% RDN	9.325	(105.16)	4.28	(19.69)	3.97	66.57
DSR + *Azolla* + 75% RDN	9.82	(114.05)	4.76	(24.19)	3.81	48.57
CD (P=0.05)	0.49		0.71		S	
Weed management practice						
No weeding	17.29	(319.37)	8.70	(90.74)	2.10	
Pretilachlor plus 0.3 kg a.i./ha at 2 DAS *fb* HW at 45 DAS	6.43	(44.58)	3.78	(15.14)	4.81	
HW twice at 20 and 45 DAS	7.40	(58.58)	4.8	(24.20)	4.47	
CD (P=0.05)	0.31		0.44	S	MF X W	
	S	S	S	S	0.07	

S = Significant at P = 0.05; NS = Non-significant The data were subject of $\sqrt{x+0.5}$ transformation; Figures in parentheses are original values

Azolla (*Azolla microphylla*) was inoculated 15 days after sowing (DAS) at 0.5 t/ha. *Sesbania* and *Azolla* were trampled into the soil manually at 37 DAS. Recommended levels of N, P and K at 150:60:90 kg/ha were applied. Nitrogen 100% (150 kg) and 75% (112.5 kg) were applied as per the treatments. Half at sowing and the remaining dose was applied in two equal splits; one half at tillering and the remaining at panicle initiation stage as top dressing; P and K were applied as basal dressing. The systems of planting with fertility levels were allotted to main plot and weed management practices were allotted to sub plot treatments (Table 1) .The experiment was conducted in split-plot design with three replications. Weed samples were taken at 60 DAS in each plot at four randomly selected spots using a 0.25 m^2 quadrat. The samples were oven-dried at 70 °C for 48 hours, and the dry weight was recorded.

RESULTS

Growing *Sesbania* and *Azolla* as companion crops, followed by manual incorporation at the early stages (37 DAS) effectively reduced the total weed density and weeds dry weight (Table 1). The broad-spectrum weed control achieved with DSR + *Sesbania* + 100% RDN was evident from the drastic reduction in total weed density and weeds dry weight (35 g/m^2). The control of weeds through DSR + *Azolla* + 100% RDN was comparable with DSR + *Sesbania* + 100% RDN in terms of reduced total weed density (105 no./m^2) and weeds dry weight (20 g/m^2). However, the weed smothering efficiency (WSE) was maximum in DSR + *Azolla* + 100% RDN which was 66.57 percent. Higher fertilizer N (100%) along with organic sources (*Sesbania* and *Azolla*) enhanced the yield attributes of rice and consequently resulted in higher grain yield (4.05 t/ha in the DSR + *Sesbania* + 100% RDN and 3.97 t/ha in the DSR + *Azolla* + 100% RDN). This indicates that inter-cultivation practices could lead to moderate weed suppression, resulting in higher nutrient uptake and higher dry matter production. The incorporation of *Sesbania* and *Azolla* resulted in higher uptake of nutrients, which favored the rice crop, and suppressed the weed species.

CONCLUSION

It is concluded that DSR inter-cultivation (either with *Sesbania* or *Azolla*) + 100% N with pretilachlor plus 0.3 kg a.i./ha at 2 DAS *fb* HW at 45 DAS was found better for controlling weeds and improving productivity of direct seeded rice.

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Comparative study of competitiveness of different weedy rice accessions on cultivated rice

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Weedy rice is a serious problem in many rice growing regionsand anticipated to cause huge losses to rice cultivation. It has become significant mainly after the shift from rice transplanting to direct seeding. Different populations of weedy rice exhibit differences in competitive ability and growth patterns. The novelty of our experiment was the attempt to characterize the weedy rice accessions and study their competitiveness as the first step towards formulation of management strategy.

METHODOLOGY

The present study was conducted to differentiate weedy rice accessions collected from hills of Assam (Assam accession 1 [AA1], Assam accession 2 [AA2], Assam accession 3 [AA3]) and coastal Odisha (Odisha accession 1 [OA1], Odisha accession 2 [OA2], Odisha accession 3 [OA3]) in terms of their competing ability grown in presence of cultivated rice, cv. Swarna. Therefore, to simulate the competition,

Table 1. Grain yield of rice (cv. Swarna) as influenced by uprooting of central plants at different stages of plant growth

Treatment	Grain yield (g/plant) Uprooting at 2 weeks	Uprooting at 4 weeks	Uprooting at 6 weeks	Uprooting at 8 weeks	No uprooting
cv. Swarna (Control)	38.7	34.6^{A}	27.9^{A}	20.0^{AB}	18.2^{A}
cv. Swarna (in presence of AA1)	37.1	32.7^{AB}	24.3^{AB}	21.0^{A}	16.4^{AB}
cv. Swarna (in presence of AA2)	36.8	31.5^{B}	25.80^{AB}	21.0^{A}	16.8^{AB}
cv. Swarna (in presence of AA3)	35.3	29.1^{B}	23.0^{AB}	21.0^{A}	15.3^{B}
cv. Swarna (in presence of OA1)	36.5	30.7^{B}	22.6^{B}	18.0^{B}	14.2^{B}
cv. Swarna (in presence of OA2)	34.6	27.3^{BC}	26.9^{A}	20.0^{AB}	15.2^{B}
cv. Swarna (in presence of OA3)	37.3	33.1^{AB}	27.6^{AB}	21.0^{A}	16.4^{AB}
Tukey HSD at 5%	NS	2.88	3.65	2.79	2.80

Abbreviations: AA1, Assam accession 1; AA2, Assam accession 2; AA3, Assam accession 3; OA1, Odisha accession 1; OA2, Odisha accession 2; OA3, Odisha accession 3

weedy rice seeds were sown at the centre of each pot (central plant), covered with a thin layer of soil, and subsequently thinned to one plant immediately after emergence. Four rice seeds (cv. Swarna) were placed equidistant from each other around the weedy rice seeds. Rice seeds (cv. Swarna) were placed at a distance of 10.5 cmfrom weedy rice at the centre. The plant to plant distance between rice seeds (cv. Swarna) was 15 cm as recommended under field condition. Weedy rice plants (central plant) were uprooted at 2, 4, 6 and 8 weeks after emergence (WAE) and plant height, number of tillers, leaf area, number of leaves and shoot biomass were recorded.

RESULTS

The early vegetative growth was significantly higher in Assam accessions, AA1 and AA2. However, OA1 emerged as the most competitive weedy rice accession at later stage, with maximum plant height, tiller number and total biomass (Figs. 1 and 2). Nutrient uptake was also higher in OA1 with respect to cv. Swarna. The highest yield reduction (22%) in cv. Swarna was recorded when grown with OA1 and lowest (7.7%) was recorded with AA2 (Table 1). The results suggest that there was significant difference in competitiveness of cultivated rice, cv. Swarna with different weedy rice accessions in terms of yield and nutrient uptake.

CONCLUSION

The competitiveness depends on the geographic origin, weedy rice biotype and rice cultivar. Therefore, high competitive ability of weedy rice cannot be generalised as it was previously done.

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Yield, weed growth, nutrient uptake and economics of rainfed greengram (*Vigna radiata* L.) under sowing date and weed management practices

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Green gram or mungbean (*Vigna radiata* L.) is the third most important food legumes grown and consumed in India including Odisha comparatively of shorter duration and is a good source of proteins and minerals and its protein quality is similar to or better than other legumes (Samant *et al*., 2013). Greengram is the major pulse crop of Odisha with a total coverage of 0.86 million hectareand area under greengram crop in Angul district is 0.03 million hectare with a productivity of 0.45 t/ha which is at par with state. Integration of one herbicide with one hand-weeding provided better growth, yield attributes and consequently higher yield. Among the various production practices, sowing date is considered as important factors which is having the vast potential to explore the maximum yield (Palsaniya *et al*., 2016). Sowing time is one of the major non-monetary input affecting growth, yield and its contributing characters. When mungbean is grown under rainfed condition, greater rooting depth helps to acquire stored water from various depths to improve stability in grain yield. Weed management practice in greengram not only increase N, P and K uptake by seed and stover of crop but also it decreases the total N, P and K uptake by weeds over weedy check (Komal *et al*., 2015).Therefore, the present investigation was undertaken with the objective of finding suitability of sowing date and weed management practices on crop growth, yield, weed control efficiency, profitability and nutrient uptake inrainfedgreengram.

METHODOLOGY

The field experiment was conducted during rainy (*kharif*) season of 2013 and 2014 at the Instructional farm, Krishi Vigyan Kendra, Angul (20^0.49' N, 85^0.04' E, 300 m above mean sea-level) under rainfed condition in mid central table land zone of Odisha to assess the effect of various sowing date and weed management practices on crop growth, yield, weed control efficiency, profitability and nutrient uptake of greengram (*Vigna radiata* L.). The experiment involved three main plot treatments comprising different sowing dates viz. 20 June, 5 July, 20 July and six weed management practices viz. application of Imazethapyr @ 100 g/ha at 20 DAS; mechanical weeding by finger weeder at 20 DAS; application of Imazethapyr @ 100 g/ha20 DAS *fb* one hand weeding at 40 DAS ; mechanical weeding by finger weeder at 20 DAS *fb* one hand weeding at 40 DAS; hand weeding at 20 DAS *fb* hoeing at 40 DAS, Weedy check as subplots in split-plot design with three replications. Greengram (OBGG 52) was sown with seed rate of 20 kg/ha with plant spacing 30 × 10 cmduring 4th week of June to 3rd week of July and harvested during 4th week of August to 4th week of September in both the year with recommended package of practices. The individual plot size was 5 × 5 m^2. The recommended dose of fertilizer for green gram was 20:40:40 kg/ha N, P and K respectively and all fertilizers were applied as basal. Imazethapyr was sprayed with manually operated knapsack sprayer fitted with a flat-fan nozzle using a spray volume of 500 litres water per hectare. Mechanical weeding was done by finger weeder.

RESULTS

All the weed control treatments significantly reduced both the weed density and weed dry weight as compared to weedy check where maximum weed growth observed during entire crop-growing period. Significant differences in seed yield, stover yield and harvest index were recorded with different sowing date and weed management practices (Table 1). Maximum seed and stover yield was obtained when sown on 20 June, which was statistically at par with 5 July and significantly superior to 20 July sowing due to higher yield attributing characters. The harvest index was highest in 5 July sowing for partitioning of biomass from vegetative to reproduc-

Table 1. Effect of sowing date and weed management practices on yield and economics in greengram. (Pooled data of 2 years)

Treatment	Seed yield (t/ ha)	Stover yield (t/ ha)	Harvest index (%)	Gross return (× 10^3₹/ha)	Net return (× 10^3₹/ha)	Monetary return* (₹/ ha/day)	Benefit: cost ratio
Sowing date							
20 June	1.00	2.56	28.2	49.0	26.1	753.6	2.18
5 July	0.99	2.42	28.9	48.0	24.2	738.3	2.04
20 July	0.91	2.30	28.1	44.5	19.4	684.1	1.75
SEm ±	0.02	0.04	0.31	0.89	0.80	13.62	0.06
CD (P=0.05)	0.07	0.15	NS	3.48	3.12	53.48	0.23
Weed management practice							
Imazethapyr @ 100 g/ ha at 20 DAS	0.99	2.48	28.6	48.3	24.0	743.4	2.03
Mechanical weeding by finger weeder at 20 DAS	0.95	2.36	28.7	46.1	23.3	709.6	2.06
Imazethapyr @ 100 g/ ha20 DAS *fb* one hand weeding at 40 DAS	1.17	2.76	29.7	56.7	30.3	872.1	2.18
Mechanical weeding by finger weeder at 20 DAS *fb* one hand weeding at 40 DAS	1.03	2.62	29.5	53.2	28.3	817.7	2.19
Hand weeding at 20 DAS *fb* hoeing at 40 DAS	0.89	2.20	28.8	43.5	18.8	669.2	1.80
Weedy check	0.71	2.15	25.1	35.1	14.7	540.0	1.70
SEm ±	0.04	0.09	0.46	1.71	1.66	26.30	0.07
CD (P=0.05)	0.10	0.25	1.33	4.94	4.78	75.96	0.20

*Calculated on gross return basis

tive organ. Among the weed management practices, Imazethapyr @ 100 g/ha20 DAS *fb* one hand weeding at 40 DAS produced significantly higher seed, stover yield and harvest index than other treatments due to increased pods/ plant, seeds/pod, better crop growth and reduced crop weed competition. This was followed by mechanical weeding by finger weeder at 20 DAS *fb* one hand weeding at 40 DAS and weedy check plot recorded the lowest seed, stover yield and harvest index due to maximum weed density. The gross return, net return, monetary return and benefit: cost ratio was significantly influenced by sowing date and weed management practices (Table 1). However, significantly higher gross return, net return, monetary return and benefit: cost ratio was obtained on 20 June sowing which was at par with 5 July and significantly higher than 20 July owing to higher seed yield.Among different weed management practices, application of Imazethapyr @ 100 g/ha at 20 DAS *fb* one hand weeding at 40 DAS recorded highest gross return, net return and monetary return which was at par with mechanical weeding by finger weeder at 20 DAS *fb* one hand weeding at 40 DAS and significantly higher than rest of the treatments.Maximum benefit: cost ratio among the weed management practices was recorded under mechanical weeding by finger weeder at 20 DAS *fb* one hand weeding at 40 DAS. The sowing dates did not show any significant difference in N, P and P uptake by both seed and stover of crop. However, early sowing of greengram on 20 June recorded increased N, P and K uptake by both seed and stover of greengram with reduced nutrient depletion by weed in compared to delay sowing on 5 July and 20 July.

CONCLUSION

The study revealed that shifting of sowing from 20 July to 20 June could be effective for better crop growth, weed control, higher yield, yield attributes, nutrient uptake and economics. Imazethapyr @ 100 g/ha at 20 DAS *fb* one hand weeding at 40 DAS found to be economical and efficient in crop growth, yield, weed control and nutrient uptake for timely sown rainfed greengram .

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Weed management influenced on onion bulb crop under fertilizer levels

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Onion (*Allium cepa* L.), locally known as *Dungali* belongs to family alliaceae, is a biennial herbaceous and cross-pollinated winter vegetable. One of the main limiting factors is weed infestation. Due to smaller leaf size and slow growth, onions cannot compete well with weeds. Yield loss due to weed infestation in onion has been recorded to the tune of 40 to 80% (Angiras *et al.*, 2008).Usually farmers do not do weeding early enough to prevent major damages to onion due to shortage of labour.As weeds decrease the profitability of the onion crop, therefore weeds must be controlled well in time.Onionresponds very well to increasing rate of fertilizers due to its' shallow root system and dense population. This study was therefore, conducted to compare the effectiveness of different weed management practices for onion crop under different fertility levels.

METHODOLOGY

Field study was conducted to compare various weed and fertilizer management practices in onion *(Allium cepa* L.*)* at the research farm of Navsari Agricultural University, Navsari, Gujarat during winter season of 2008-09 and 2009-10. The experiment was laid out in Factorial Randomized Block Design (FRBD) design. Plot size was 4×3 m^2. The following thirty treatment combinations consisting of ten treatments of

Table 1. Interaction effect of weed management and fertilizer levels on onion bulb yield (t/ha)

Fertilizer levels	Weed management									
	W_1	W_2	W_3	W_4	W_5	W_6	W_7	W_8	W_9	W_{10}
					2008-09					
F_1	31.47	26.54	35.86	33.34	33.57	36.34	33.10	31.57	33.59	23.60
F_2	27.74	29.67	36.48	36.21	41.24	39.38	36.92	31.27	38.63	23.26
F_3	36.14	36.73	37.03	39.52	43.19	41.04	38.77	36.20	39.92	24.09
CD (P=0.05)	4.50									
					2009-10					
F_1	28.63	25.42	32.80	29.93	31.48	31.24	28.01	26.12	28.92	16.59
F_2	27.91	27.69	32.23	32.48	38.47	36.47	32.13	27.01	36.17	16.17
F_3	34.13	34.02	33.71	35.38	40.09	38.31	35.58	33.92	39.18	17.30
CD (P=0.05)	4.07									
					Pooled					
F_1	30.05	25.98	34.33	31.63	32.52	33.79	30.55	28.84	31.26	20.10
F_2	27.83	28.68	34.35	34.34	39.86	37.93	34.53	29.14	37.40	19.72
F_3	35.14	35.37	35.37	37.45	41.64	39.67	37.17	35.06	39.55	20.70
CD(P=0.05)	2.85									

weed management *viz.*, W1-Pendimethalin 1 kg/ha as pre-emergence, W2-Oxyfluorfen 0.24 kg/ha as pre-emergence, W3-Pendimethalin 1 kg/ha pre-emergence + Fluazifop-p-butyl 0.25 kg/ha at 40 DAT, W4-Oxyfluorfen 0.24 kg/ha pre-emergence + Fluazifop-p-butyl 0.25 kg/ha at 40 DAT, W5-Pendimethalin 1 kg/ha pre-emergence + One hand weeding at 40 DAT, W6-Oxyfluorfen 0.24 kg/ha pre-emergence + One hand weeding at 40 DAT, W7-Hand weeding at 20 DAT + Fluazifop-p-butyl 0.25 kg/ha at 40 DAT, W8-Two hand weeding at 20 and 40 DAT, W9-Weed free control (Hand weeding at 20, 40 and 60 DAT), W10-Weedy check and three treatments of fertilizerlevels*viz.*, F1-75 % RDF (75:37.50:37.50, $N:P_2O_5:K_2O$ kg/ha), F2-100 % RDF (100:50:50, $N:P_2O_5:K_2O$ kg/ha), W3-125 % RDF (125:62.5:62.5, $N:P_2O_5:K_2O$ kg/ha), each replicated three times were included in the trial.The soil was clayey in texture, having 0.59 % organic C, medium in available nitrogen (284kg/ha) and phosphorus (40 kg/ha), fairly rich in available potassium (362 kg/ha) and slightly alkaline in reaction (pH 7.6) with normal electrical conductivity.

RESULTS

The results showed that the highest yield (39.33, 36.60 and 37.97 t/ha, respectively) was recorded with Pendimethalin 1 kg/ha supplement with one hand weeding followed by oxyflourfen 0.24 kg/ha + one hand weeding at 40 DAT and weed free treatments during both the years as well as in pooled analysis, respectively. Yield obtained from weed free treatment was lower due to disturbance of shallow root system by repeated hand weeding, being narrow spacing crop, manual hand weeding also damaged the leaves and plant parts, ultimately reduced the photosynthetic actively of plants. Crop was fertilized with 125 % RDF produce significantly higher bulb yield of 37.3, 34.2 and 35.7, respectively.On pooled basis, the treatment combination of Pendimethalin at 1.0 kg/ha *fb* one hand weeding at 40 DAT and fertilized crop with 125:62.5:62.5 kg NPK/ha recorded higher onion bulb yield over rest of the treatment combinations.

CONCLUSION

The present findings exhibited that pre-emergence application of either pendimethalin at 1.0 kg/ha or oxyfluorfen at 0.24 kg/ha supplemented with one hand weeding at 40 days after transplanting prove efficient weed management strategies. Further, application of fertilizer at 125:62.5:62.5 kg NPK/ha gave higher and profitable onion bulb yield.

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Weed control efficiency and yield of maize as affected by application of pre and post emergence herbicide in sequence

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Weed problem in kharif maize is considered to be an important factor for achieving higher productivity as it is more severe during continuous rains in early stages of maize growth. Weed management by traditional and cultural practices alone is problematic due to too much wetness and high cost involvement. Sequential use of pre and post emergent herbicides at temporal variation may help in avoiding the problem of weeds throughout the maize growth stages.

METHODOLOGY

A field experiment was conducted during *kharif* 2014 at College of Agriculture, Dharwad which is situated at 15^0 29' N latitude, $74^0$59' E longitudes and at an altitude of 689 m above mean sea level and it comes under Northern Transition Zone (Zone-8) of Karnataka. The soil of the experimental site was black clayey soil with pH 7.1, 229 kg available N, 34 kg P_2O_5 and 484 kg K_2O/ha. Treatments comprised of six herbicides namely glyphosate (2.5 kg/ha), paraquat (1 kg/ha), glufosinate ammonium (0.375 kg/ha), saflufenacil (75 g/ha), halosulfuron (90 g/ha) and imazathapyr (75 g/ha) were tried as post emergence (directed spray) in addition to pre-emergence application of atrazine (1 kg/ha) along with atrazine + 2 intercultural + 1 hand weeding, weed free and weedy check. Total nine treatments were tested in randomized block design with three replications. The test variety was 900 M Gold and the crop received a rainfall of 633.5 mm during crop growing period. The weed infestation was predominantly consisted of grassy weeds, broad leaved weeds and sedges. The total weed dry matter at different crop growth stages, crop yield and economics were recorded.

RESULTS

Weed control efficiency (WCE) differed significantly with different weed control methods at various crop growth stages. At 20, 40 and 60 DAS, T_8 (weed free check) was recorded higher WCE than rest of the weed control methods. WCE of treatments normally decreased over time up to application of post emergence herbicides (45 DAS). In the present study, there were no significant differences among herbicide treatments before application of post emergence herbicides, but only weed free check recorded significantly higherWCE. However, with application of post emergence herbicides, T_1 (atrazine @ 1 kg /ha fb glyphosate @ 2.5 kg /ha), T_3 (atrazine @ 1 kg /ha fb glufosinate ammonium @ 0.375 kg /ha), T4 (atrazine @ 1 kg /ha fb saflufenacil @ 75 g /ha) and T_2 (atrazine @ 1 kg /ha fb paraquat @ 1 kg /ha) recorded WCE of 92.1, 91.7, 90.0 and 89.1 percent, respectively which were found on par with each other. It might be due to better control of weeds following exposure to post emergent treatment which might have resulted in lower weed population as well as dry weight of weeds. Significantly lowest weed index (3.79 %) was recorded in T_4 (Atrazine @ 1 kg /ha fb saflufenacil @ 75 g /ha). Yield of maize varied significantly among various weed control treatments. Significantly higher grain yield (84.59 q /ha) was observed in T_8 (weed free check) which was 87.68 per cent higher than weedy check (45.07 q /ha) followed by T_4 (atrazine @ 1 kg /ha fb saflufenacil @ 75 g /ha) that resulted a yield of 81.38 q /ha which was 80.56 per cent higher than the weedy check. The next to it T_2 (Atrazine @ 1 kg /ha fb paraquat @ 1 kg /ha) recorded with grain yield of 70.56 q /ha (56.55 per cent more than weedy check). Significantly higher yields obtained with these treatments might be due to positive association between yield attributing characters *viz.,* cob length (cm), cob girth (cm), test weight (g), grain weight/plant (g), shelling per cent and harvest efficiency as less weed competition and lesser phytotoxicity injury as well as better growth characteristics. The lowest grain yield (45.07 q /ha) was noticed in weedy check (T_9) as a consequence of the highest removal of nutrients and moisture by weeds and severe crop weed competition resulting in poor source-sink relationship with poor yield components. T_8 (weed free check) recorded significantly higher stover yield (114.10 q /ha) which was 71.83 per cent higher over weedy check (66.40 q /ha) and it was on par with T_4 (atrazine @ 1 kg/ha fb saflufenacil @ 75 g/ha) having stover yield 109.80 q /ha (65.36 per cent higher over weedy check). Higher stover yield might be attributed to higher dry matter production and its accumulation in leaves, stem, reproductive parts and also other growth attributes such as plant height, number of leaves, leaf area, leaf area efficiency. Significantly higher B:C ratio

(3.14) was observed with T_4 (atrazine @ 1 kg /ha fb saflufenacil 75 g /ha) followed by T_8 *i.e.* weed free check (2.77). T_2 (atrazine @ 1 kg /ha fb paraquat @ 1 kg /ha) which recorded B: C ratio of 2.68 was the next best treatment. This was due to lower cost of herbicides, higher economic yield and net returns involved. The lowest B: C ratio was recorded with weedy check which might be due to less gross returns as a result of lower yield of maize.

CONCLUSION

Atrazine @ 1 kg/ha fb saflufenacil @ 75 g /ha as directed spray at 45 days after sowing (T_4) is found to be the best weed control method for rainfed maize compared to other herbicides treatments.

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Effect of herbicidal weed control measures on seed yield and quality of fodder cowpea [*Vigna unguiculata* (L.) Walp.]

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The Major problem posses by annual and perennial weeds infestation in *Kharif* cowpea, the potential yield is generally not possible to obtained with weeds. Yield loss in cowpea due to weeds was 12.7-60.0% (Li *et al*., 2004). It has been observed that thehand weeding without application of herbicides is not enough to control weed infestation in *Kharif* cowpea. Objective of the study was to evaluate the effect of herbicide weed control measures on seed yield and quality of fodder cowpea under sandy clay loam soil of Haryana at Karnal.

METHODOLOGY

A field experiment was conducted during *kharif* season at Karnal. There were ten treatments like viz-. Pendimethalin 1.0 kg a.i./ha PE (pre-emergence + 1HW (Hand weeding) at 40 DAS, Pendimethalin 1.0 kg a.i./ha PE, Oxyfluorfen 0.2 kg a.i./ha PE + 1HW at 40 DAS, Oxyfluorfen 0.2 kg a.i./ha PE, Imazethapyr 0.075 kg a.i./ha POE (post-emergence) at 20 DAS + 1HW at 40 DAS, Imazethapyr 0.075 kg a.i./ha POE at 20 DAS, Quizalofop-*p*-ethyl 0.025 kg a.i./ha POE at 20 DAS + 1HW at 40 DAS, Quizalofop 0.025 kg a.i./ha POE at 20 DAS, Weed free and Weedy check were tried in randomized blockdesign with four replications. Cowpea cv 'C-152' was sown on June, 23, 2014 with row distance of 45 cm and seed rate 25 kg/ha. The seeds were kept for standard germination at 25°C for 7 days in rolled towel paper (Between paper method) (ISTA method, 1985).Seedling Vigour Index was determined by the formula.Seedling Vigour Index II = Germination percentage X Seedling dry weight. All the data were statistically analyzed using the analysis of the variance (ANOVA) technique. The critical differences at 0.05% level of probability were calculated to assess the significance between treatments if treatments was significant.

RESULTS

Pendimethalin (1.0 kg a.i./ha) with one hand weeding established its superiority over rest of the herbicides treatments. This could be explained with the fact that Pendimethalin did not allow the emergence and growth of weed seedling particularly of broad leaf weed of reduced cell division and cell elongation (Singh and Angiras, 2004). The extent of increase in seed yield was found 54.69% and 45.04% under Pendimethalin and Imazethapyr respectively, over weedy check. Similar results also obtained by Madukwe *et al*. (2012) in cowpea. Among the herbicidal control measures the maximum seed germination percentage (84.75%) was recorded with application of Pendimethalin 1.0 kg/ha PE one hand weeding at 40 DAS.Among the herbicidal treatments Pendimethalin 1.0 kg a.i./ha PE + 1HW at 40 DAS recorded significantly higher seedling dry weight than weedy check and Quizalofop-*p*-ethyl 0.025 kg a.i./ha POE at 20 DAS. The DW of seedlings increased with the size of the seed obviously indicative of vigour. The Seedling–Vigour Index-II was maximum in weed free and lowest in weedy check. Among the herbicidal treatments Pendimethalin 1.0 kg a.i./ha PE + 1HW

Table 1. Effect of weed removal on seed yield,seed germination (%), seedling dry weight and seedling vigour index

Treatment	Seed yield (kg/ha)	Seed germination (%)	Seedling dry weight (g)	Seedling vigour index II
Pendimethalin 1.0 kg a.i./ha PE + 1HW at 40 DAS	577	84.7	0.60	51.1
Pendimethalin 1.0 kg a.i./ha PE	523	82.2	0.59	48.2
Oxyfluorfen 0.2 kg a.i./ha PE + 1HW at 40 DAS	523	78.7	0.57	45.1
Oxyfluorfen 0.2 kg a.i./ha PE	394	77.7	0.56	43.7
Imazethapyr 0.075 kg a.i./ha POE + 1HW at 40 DAS	541	81.5	0.58	47.3
Imazethapyr 0.075 kg a.i./ha POE	440	81.2	0.57	46.0
Quizalofop-*p*-ethyl 0.025 kg a.i./ha POE + 1HW at 40 DAS	443	79.5	0.55	43.7
Quizalofop-*p*-ethyl 0.025 kg a.i./ha POE	408	79.0	0.53	41.6
Weed Free	655	86.2	0.61	53.0
Weedy Check	373	74.5	0.51	38.2
CD (P=0.05)	79	6.3	0.06	4.2

at 40 DAS recorded maximum Seedling Vigour Index. The Seedling Vigour Index was the indicator of the quality of seed.

CONCLUSION

Based on the study, it can be concluded thatpendimethalin (PE) and imazethapyr (POE)with integration of one hand weeding at 40 days after sowingwere the best herbicides to efficient weed control in forage cowpea.

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Agronomic indices, weed growth and yield of blackgram as affected by propaquizafop + imazethapyr mixture

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Grassy as well as broad leaved weeds competes with the blackgram for growth resources and reduces the blackgram yield to the tune of 49% (Rao and Rao, 2003).Imazethapyr is reported very effective post emergence herbicides for controlling grassy andsome broad leaf weeds in *Kharif* pulses including blackgram. But its efficacy has not been judged in combination with propaquizafop for wide spectrum weed control in blackgram. Therefore, a comprehensive field study was undertaken to find out the suitable dose of propaquizafop and imazethapyr mixture for effective control of weeds in blackgram.

METHODOLOGY

A field experiment was undertaken during *Kharif* season of 2013 at Live Stock Farm, JNKVV, Jabalpur to evaluate the efficacy of propaquizafop and imazethapyr mixture against weeds in blackgram. Nine treatmentscomprising of five doses of propaquizafop and imazethapyr mixture (47+66, 50+70,

Table 1. Effect of different weed control treatments on density, dry weight of weeds yield and various agronomic indices of blackgram

Treatment	Weed density (No./m^2)	Weed dry matter (g/m^2)	Seed yield (t/ha)	Haulm yield (t/ha)	HEI	CRI
1.Propaquizafop+Imazethapyr (47+66 g/ha)	(115.33) 10.76	(215.03) 14.68	1.23	3.82	50.67	2.41
2.Propaquizafop+Imazethapyr (50+70 g/ha)	(94.33) 9.74	(186.25) 13.67	1.34	3.96	84.08	2.92
3.Propaquizafop+Imazethapyr (53+74 g/ha)	(75.33) 8.71	(157) 12.55	1.71	4.33	205.39	3.96
4.Propaquizafop+Imazethapyr (56+78 g/ha)	(55.33) 7.47	(131.68) 11.50	1.72	4.35	247.57	4.74
5.Propaquizafop+Imazethapyr (100 +140 g/ha)	(22.00) 4.74	(72.59) 8.55	1.73	4.36	452.14	8.61
6.Propaquizafop (100 g/ha)	(121.67) 11.05	(186.07) 13.66	1.29	3.84	73.97	2.83
7. Imazethapyr (100 g/ha)	(89.00) 9.46	(185.8) 13.65	1.37	3.98	93.19	2.97
8.Hand weeding (20&40 DAS)	(18.33) 4.34	(1.64) 1.46	1.74	4.41	-	-
9. Weedy check	(257) 16.05	(432.31) 20.80	0.98	3.23	0.00	1.00
SEm±	0.11	0.38	0.00	0.01		
LSD (P = 0.05)	0.34	1.14	0.01	0.02		

*Values in parentheses are original. HEI = Herbicide efficiency index, CRI = Crop resistance index.

53+74, 56+78 and 100+140 g/ha), alone application of propaquizafop 100 g/ha and imazethapyr 100 g/ha, hand weeding twice (20 and 40 DAS) including weedy check, were laidout in randomized block design with three replications. Blackgram variety LBG-20 was grown in the experimental field with recommended package of practices. Fertilizers were applied uniformly through Urea, single super phosphate and muriate of potash at the rate of 20,60 and 20 kg N, P, and K/ ha, respectively**.** Theobservations on weed growth, at 30 days after application and yield attributing traits and yield were recorded at harvest. The different agronomic indices weeds have been determined as suggested by Awan et al. (2015).

RESULTS

Weed density and weed biomass was higher under weedy check plots. Among the herbicidal treatments, the reduction in weed density and weed biomass was higher when propaquizafop and imazethapyr mixture was applied at 53+74, 56+78 and 100+140 g/ha and proved significantly superior over weedy check, other mixtures including both the check herbicides propaquizafop 100 g/ha and imazethapyr 100 g/ha applied alone. However, none of the herbicidal treatments surpassed the hand weeding twice which curbed the weed growth to the maximum extent (99.62 %). The unchecked weed growth throughout the season caused 43.58 % reduction in yield of blackgram. But yield reduction was checked appreciably (1.49 to 0.007 %) when propaquizafop was applied along with imazethapyr at 53+74 or at higher dose (56+78 to 100+140g/ha). Seed and haulm yields of blackgram were minimum under weedy check plots but these higher under propaquizafop and imazethapyr mixture applied at the rate of 53+74 g/ha being at par to higher doses of propaquizafop and imazethapyr mixture (56+78 and 100+140 g/ha) including hand weeding twice. All agronomic indices like HEI, CRI, attained lower values. When propaquizafop + imazethapyr mixture (47+66 g/ha) was applied at lower rates but these were increased with corresponding increase in rates of application (47+66 to 100+140 g/ha). However, values of these indices were lower when propaquizfop (100 g/ha) and imazethapyr (100 g/ha) was applied alone.

CONCLUSION

Post-emergence application of propaquizafop along with imazethapyr at 53+74 g/ha was most effective for controlling weeds and enhancing the seed yield of blackgram whithout any phytotoxic effect on crop plants.

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Weed management strategies in chickpea (*Cicer arietinum*) for higher productivity and profitability in North-West India

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Chickpea (*Cicer arietinum* L.) is an important protein rich legume crop grown in India. In Punjab, it was grown on 1.9 thousand ha with a production of 2.4 thousand tones during 2013-14 (Anonymous, 2015). The productivity of chickpea is quite low due to number of reasons but predominantly due to lack of suitable weed control measures. Weeds pose a serious problem in this crop due to its short stature and slow initial growth and also weeds compete severely with the crop for all the growth factors. Weeds reduce grain yield of chickpea by 60% (IIPR, 1997) and even higher upto the extent of 75% as reported by Chaudhary *et al.* (2005). Therefore, there is a need to identify effective herbicides and also to integrate various methods of weed control for effective and economical weed management in this crop. Hence, a research trial was conducted to find out the effective herbicide for integrated method which can provide good control of weeds in chickpea.

METHODOLOGY

A field experiment was conducted to assess the effect of different weed management practices in chickpea at Research Farm, Department of Agronomy, Punjab Agricultural University, Ludhiana during *rabi* seasons of 2009-10 and 2010-11. The experiment was laid out in randomized complete block design with 15 treatments replicated three times. The treatments comprised of pre-emergence (PE) application of oxyflourfen (23.5 EC) 0.15 kg/ha *fb* one hand weeding at 45 DAS, oxyflourfen 0.175, 0.200, 0.225 kg/ha, Alachlor (PE) 2.0 and 2.5 kg/ha each *fb* one hand weeding 45 DAS, pendimethalin (PE) 30 EC 0.75 kg *fb* one hand weeding (HW) at 45 DAS, tank-mix pendimethalin+alachlor (PE) 0.50+1.25, 0.75+1.25 kg/ha, pendimethalin+oxyflourfen (PE) 0.75+0.15 kg/ha, trifluralin+alachlor (PE) 0.50+1.25, 0.75+1.25 kg/ha, trifluralin+oxyflourfen (PE) 0.75+0.15 kg/ha, weed free and unweeded control. All herbicides as per the treatment were applied with knap sack sprayer fitted with flood jet nozzle with discharge rate of 500 litres of water/ha. The data on yield attributes and seed yield and weed parameters were recorded and analyzed statistically using online analysis of data (http://stat.iasri.res.in/sscnarsportal).

RESULTS

The crop was naturally infested with both grass and broad leaf weeds and the major weed flora observed in the experimental field were *Phalaris minor, Chenopodium album, Medicago denticulata, Coronopus didymus, Rumex dentatus, Anagallis arvensis* etc. The results (Table 1) revealed that density of grass weeds was observed minimum in oxyflourfen 0.150 kg/ha *fb* one hand weeding which was statistically at par with pendimethalin 0.75 kg/ha *fb* one hand weeding (45 DAS), alachlor 2.0 and 2.5 kg/ha each *fb* one hand weeding 45 DAS, pendimethalin+alachlor 0.75+1.25kg/ha, trifluralin+alachlor, 0.5+1.25 kg/ha and 0.75+1.25 kg/ha and significantly less than all other treatments. Tank mix application of pendimethalin+oxyflourfen (0.750+0.150 kg/ha) or trifluralin+oxyflourfen (0.750+0.150 kg/ha) proved more effective and also recorded significantly lesser numbers of grass weeds than that of oxyflourfen alone when applied at 0.200 or 0.225 kg/ha alone. Similarly the density of broadleaf weeds was significantly less in oxyflourfen treated plots irrespective of its doses as compared to other herbicides and was statistically at par with trifluralin+oxyflourfen 0.75+0.150 kg/ha. Further, higher doses of oxyflourfen (0.200 and 0.225 kg/ha) proved more effective in controlling grass and broadleaf weeds both in terms of density and dry weight. Pendimethalin controlled the weeds effectively upto 30-35 days and later on weeds started emerging which were effectively controlled by one hand weeding 45 DAS hence showed much better results. Significant reduction in dry weight of grass weeds was recorded in pendimethalin 0.75 kg/ha *fb* one hand weeding at 45 DAS which was equally effective as tank mix application of trifluralin + alachlor (0.50+1.25 kg/ha and 0.75+1.25 kg/ha), pendimethalin + oxyflourfen 0.75+0.150 kg/ha, pendimethalin + alachlor 0.75+1.25 kg/ha but showed superiority over rest of the treatments. Likewise dry matter of broadleaf weeds was significantly less in pendimethalin 0.75 kg/ha *fb* one hand weeding (45 DAS) and at par with pendimethalin+oxyflourfen 0.75+0.150 kg/ha. However, sig-

Table 1. Effect of different weed control treatments on weed dynamics at 60 DAS and yield and profitability of chickpea (pooled data of two years)

Treatment	Dose (kg/ha)	Weed density (No./m²)		Weed dry weight (g/m²)			Seed yield (kg/ha)	B:C ratio	WCE (%)
		Grasses	BLW	Grasses	BLW	Total			
Oxyflourfen *fb* 1 HW (45 DAS)	0.150	3.5 (11.8)	3.9 (14.2)	4.8 (22.4)	7.1 (48.7)	8.5 (71.1)	1468	1.16	67.9
Oxyflourfen	0.175	4.2 (16.9)	3.6 (11.9)	5.8 (32.1)	7.9 (62.0)	9.8 (94.1)	1163	1.01	57.5
Oxyflourfen	0.200	4.1 (15.9)	3.4 (10.9)	5.4 (28.6)	7.7 (58.5)	9.4 (87.0)	1101	0.94	60.7
Oxyflourfen	0.225	3.5 (11.0)	3.5 (11.0)	5.7 (31.4)	7.4 (53.7)	9.3 (85.1)	1062	0.90	61.6
Alachlor *fb* 1 HW (45 DAS)	2.00	3.1 (8.6)	4.6 (20.6)	5.7 (31.5)	7.7 (57.8)	9.5 (89.3)	1270	0.96	59.7
Alachlor *fb* 1 HW (45 DAS)	2.50	3.2 (9.5)	5.0 (23.6)	5.6 (30.3)	7.5 (55.0)	9.3 (85.3)	1121	0.83	61.5
Pendimethalin *fb* 1 HW (45 DAS)	0.75	3.3 (9.7)	4.5 (19.5)	4.8 (22.4)	7.1 (49.1)	8.5 (71.5)	1428	1.11	67.7
Pendimethalin + Alachlor	0.50+1.25	3.5 (11.4)	5.3 (26.8)	5.3 (27.0)	8.2 (65.0)	9.6 (91.9)	1064	0.87	58.5
Pendimethalin + Alachlor	0.75+1.25	3.2 (9.5)	4.8 (22.5)	4.9 (22.7)	8.2 (66.4)	9.5 (89.1)	1156	0.98	59.8
Trifluralin + Alachlor	0.50+1.25	3.2 (9.2)	5.1 (24.5)	4.8 (22.5)	8.3 (67.9)	9.6 (90.4)	1218	1.05	59.2
Trifluralin + Alachlor	0.75+1.25	3.2 (9.0)	5.1 (25.2)	4.9 (23.5)	8.1 (64.9)	9.5 (88.4)	1186	1.02	60.1
Pendimethalin + Oxyflourfen	0.75+0.150	3.4 (10.6)	4.1 (15.9)	5.0 (23.8)	7.7 (58.0)	9.1 (81.8)	1171	1.07	63.1
Trifluralin + Oxyflourfen	0.75+0.150	3.1 (8.8)	3.9 (13.8)	5.1 (25.5)	7.5 (55.4)	9.1 (80.9)	1125	0.96	63.5
Weed free	-	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)	1472	1.02	100
Unweeded control	-	5.0 (23.8)	12.2 (148)	9.8 (95.4)	11.3 (126.2)	14.9 (221.6)	541	0.50	-
SEm±	-	0.09	0.12	0.10	0.08	0.09	-	-	-
CD (P=0.05)	-	0.3	0.3	0.3	0.2	0.3	-	-	-

*Figures in parenthesis are subjected to square root transformation

nificantly higher weed dry matter was obtained in tank mix application of alachlor with pendimethalin and trifluralin at both the respective doses. Similar trends were noticed in total weed dry matter accumulation. Pendimethalin 0.75 kg or oxyflourfen 0.15 kg/ha each integrated with one hand weeding at 45 DAS decreased dry matter accumulation by weeds to the tune of 67.7 and 67.9% as compared to unweeded control. Integration of hand weeding with pre-emergence application of pendimethalin 0.75 kg/ha or oxyflourfen 0.15 kg/ha resulted in significant reduction in dry matter accumulation by weeds as compared to oxyflourfen alone irrespective of its different doses (0.175, 0.200 and 0.225 kg/ha). Highest WCE was recorded in weed free as the plots were free from weeds. It was followed by oxyflourfen 0.15 kg/ha or pendimethalin 0.75 kg each integrated with one hand weeding at 45 DAS due to better control of weeds. The seed yield was significantly high in weed free as compared to all other treatments during both the years and comparable with pre-emergence application of pendimethalin 0.75 kg/ha or oxyflourfen 0.150 kg/ha each *fb* one hand weeding at 45 DAS and were significantly higher than all other herbicide treatments during both the years. Correlation and regression analysis indicated that there was significant negative linear relationship between seed yield and weed dry weight at 60 DAS. Benefit-cost ratio was markedly higher in oxyflourfen 0.15 kg/ha *fb* one hand weeding at 45 DAS (1.16) followed by pendimethalin 0.75kg/ha along with one hand weeding (1.11) over all other weed control treatments.

CONCLUSION

Integrated treatments of pre-emergence application of either pendimethalin 0.75 kg/ha or oxyflourfen 0.15 kg/ha each *fb* one hand weeding at 45 DAS produced the best results in reducing the weed density and dry weight in chickpea. Further, it can be concluded that pre-emergence application of oxyfluorfen 0.15 kg/ha or pendimethalin 0.75 kg/ha each *fb* one hand weeding at 45 DAS was found to be more effective in getting higher yield and economic returns of chickpea in North-West India.

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Evaluation of wheat accessions for drought tolerance under rainout shelter condition

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Wheat is the second most important staple food crop grown in India as well as in the world after rice. In India it is cultivated in about 31.2 m/ha area with a production of 95.9 m. tonnes and productivity of 3075 kg/ha (Agri. Stat., 2014). The productivity under rainfed and late sown wheat are about 50% in irrigated and timely sown crops. Abiotic stresses adversely affect almost all major field-grown plants belonging to varied ecosystems. The severity of abiotic stresses is on the rise due to the practice of intensive cultivation in farming areas as well as due to environmental deterioration caused by the greenhouse effect. In marginal or arid lands, environmental factors such as drought, high salinity, high temperature and flooding are serious problems. Among them drought stress cause a great amount of loss that lead to instability in crop production. Assimilate availability is further reduced by water deficit stress as it induces and enhances the rate of senescence. Stay green colour, erect canopy, waxi-coating and leaf rolling are some important morphological traits that have been used to evaluate drought tolerance in moisture stress environment. Keeping in view the above constraints an effort has been made to evaluate theeffect of moisture stress on various morpho-physiological traits of wheat accessions under normal and moisture stress conditions.

METHODOLOGY

The experiment was conducted at NBPGR, Farm IARI, New Delhi during 2013-2014 with 40 selected wheat accessions in augmented block design under normal and moisture stress conditions in rainout shelter. The crop was sown on 19.11.2013. Standard agronomic practices were followed for raising the crop. The methods were used for estimation of relative water content (Barrs and Weatherley, 1962), membrane stability index (Deshmukh et al., 1991), Growing degree day and heat use efficiency, Heat susceptibility index, Yield stability index. Observations were recorded for different phenophases, chlorophyll concentration index (SPAD), membrane stability index, relative water content, canopy temperature(Infrared thermometer), chlorophyll fluorescence (Fluorescence meter), Peduncle length, seed protein content (NIR 1241 Grain analyzer), yield and yield attributes under normal and moisture stress conditions.

RESULTS

The data recorded on different traits indicated wide range of variability in the accessions. In general, values of all traits were lower under moisture stress conditions due to less moisture.Days to heading in moisture stress ranged from (<69) in IC 36882, IC 128641, IC 145527 to IC 252480 (99); Days to anthesis in moisture stress varied from (<77)in IC 36882, IC 128641, IC 145527 to IC 252480 (108);days to milk stage in moisture stress ranged from (<102) in IC 36882, IC 128641, IC 145527 to IC 252480 (116); days to dough stage in moisture stress varied from (<122) in IC 36882, IC 128641, IC 145527 to IC 252480 (131);days to physiological maturity in moisture stress ranged from (<131) in IC 36882, IC 128641, IC 145527 to IC 252480 (140);chlorophyll concentration index (%) in moisture stress at grain development stage (<20.0) in IC 252710 to (>25.0) in IC 290190, IC 144921, IC 128587; Plant height varied in moisture stress ranged from (<83 cm) in IC 252710, IC 252479 to IC 28923 (126 cm); membrane stability index (%) at grain development stage in moisture stress ranged from (<52.0)in IC 145288, IC 144921, to (>70.0) in IC 145527, IC 28923, IC 252369; Relative water content (%) at grain development stage in moisture stress ranged from (64.8) in IC 145316 to (>79.0)in IC 252369, IC 28923, IC 145527. Tas and Tas (2007) observed significant reduction in RWC, MSI and Chlorophyll content of all the cultivars under water stress.Canopy temperature (^{o}C) at anthesis stage in moisture stress at grain development stage (<22.0) in IC 252890, IC 252918, IC 279868 to (>29.9) in IC 112205, IC 28904; Chlorophyll fluorescence (F_V / F_M) at grain development stage in moisture stress ranged from (<0.61) in IC 111840, IC 145623 to (>0.78) in IC 145345, IC 145685, IC 252724;Peduncle length in moisture stress varied from (21.6) in IC 128457 to (>45.0) in IC 138428, IC 28904, IC 28923;No. of tillers/pl. moisture stress ranged from (4) inIC 145288 to (>8)in IC 145683, IC 28904, IC 128641; No. of spike in moisture stress varied from (4) in IC 145288 to (>8) in IC 145683, IC 28904, IC 128641;Length of Spike (cm) in moisture stress ranged from (>7.0) in IC 252890, IC 28904 to (<11.0) in IC 138428, IC 128284, IC 111840;No. of seed / spike in moisture stress from (<31) in IC 128200, IC 252625, IC 252514 to (>50) in IC 112205, IC 290190, IC 145345; Biomass/pl. (g) in moisture stress varied from (12.3) in IC 252514 to (>32.0) IC 138629, IC 138428;Seed yield/pl. (g) in moisture stress ranged from (3.8) in IC 252514 to (>10.5) in IC 138428, IC 138629;1000 gr. wt. (g) in moisture stress varied from (21.5) in IC 145716 to (>43.0) in IC 252918, IC 138428, IC 128284; Drought stress during anthesis to maturity causesreduction in grain number and grain weight (Rane et al., 2001). Harvest Index (%) in moisture stress ranged from (>20.0) in IC 252742, IC 145623 to (>35.0) in IC 128284, IC 252480, IC 252718;Seed protein content (%) in moisture stress ranged from (11.42) in IC 252710 to (>15.0) in IC138629, IC 252441, IC 138428; GDD (^{o}D) in moisture stress varied from (1989.1) in IC 36882, IC 145527 to (2260.3) in IC 252480;YSI (%) in moisture stress ranged from (>39.0) in IC 128200, IC 252724 to (<93.0) in IC 252441, IC 252890 (93.2); HUE (g/plant/^{o}day) of Biomass/ plant in moisture stress ranged from (0.58) in IC 252514 to (>1.50) in IC 138629 (1.52), IC 138428 (1.51);HUE (g plant^{-1} ^{o}day^{-1}) of seed yield/plant in moisture stress varied from (0.16) in IC 252480 to (0.43) in IC 28904, IC 128645, IC 252718 and HSIof seed yield (g/plant) in moisture stress ranged from (0.19) in IC 252441, IC 252890 to (>1.72) in IC 128200, IC 252724. Besides, Erect canopy (7), Long peduncle (9), Leaf rolling (8), Stay green (16), Waxy coating peduncle (18), Bold ears (11), More tillering germplasm (10), Early maturing(7), High biomass (13), Tall (5) and Tip sterility (9) were recorded in 106 wheat accessions.

CONCLUSION

On the basis of earliness, canopy temperature, biomass per plant, seed yield per plant, relative water content, membrane stability index, seed protein content, GDD, HUE and 1000 grain wt. accessions IC 145527, IC 28923, IC 138629, and IC 138428 were found drought tolerant under moisture stress conditions. Therefore these accessions may be used in breeding programme for enhancing the yield potential of wheat under moisture stress conditions.

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Evaluation of herbicides and their combinations for control of weed in direct dry seeded rice

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Weed control is more difficult in direct dry seeded rice than transplanted rice because of simultaneously emerging rice seedlings with weeds in dry–DSR which are less competitive than 30-35 days old rice seedlings use in transplanted rice and initial flooding in transplanted rice is effective for weed control but it is lacking in dry- DSR (Kumar and Ladha, 2011). Therefore, weeds present are the main biological constraint to the success of DSR and failure to control weeds result in yield losses ranging from 50 to 90% The traditional methods of weed control in rice include hand-weeding by hoe or hand pulling, but this is becoming less common because of labour scarcity at critical time of weeding and increasing labour costs. However, adoption of DSR technology usually leads to shift in weed flora composition towards difficult-to-control weeds (Singh *et al.*, 2013). In this situation, use of herbicides is becoming more popular in DSR because they are more effective, easy to apply, provide selective control, saves on labour and costs less. Farmers generally apply herbicides by mixing them in sand for easy operation and prefer to use either single application of Pre or Post herbicides which fails to control diverse weed flora observed in DSR. However, it is important to use a broad-spectrum herbicide program including PRE and POST herbicides and their combination for season-long effective weed control and to avoid shifts toward problematic weed or evolution of herbicide-resistant weed biotypes.

METHODOLOGY

A field experiment was conducted during *Kharif* season of 2010 and 2011 at N.E. Borlaug Crop Research Centre, G.B. Pant University of Agri. & Tech., Pantnagar, U.S. Nagar, Uttarakhand to evaluate the efficacy of pre and post-emergence herbicides and their combinations for weed control in direct dry seeded rice. The treatment consisted of pyrazosulfuron @ 25 g/ha, pretilachlor @ 750 g/ha, cyhalofop butyl @ 90 g/ha, fenoxaprop @ 60g/ha, cyhalofop + (chlorimuron + metsulfuron) @ 90 +20 g/ha, fenoxaprop + (chlorimuron +metsulfuron) @ 60+20, azimsulfuron @ 35 g/ha , bispyribac sodium @ 25 g/ha, fenoxaprop + ethoxysulfuron @ 60+15 g/ha, oxyflurofen + 2,4-D @ 300+500 g/ha, Two hand weeding at 20 and 40 DAS and weedy check were laid out in randomized block design with three replications. Rice variety "Sarjoo 52" was sown at row spacing of 20 cm on June 09, 2010 and June 14, 2011 following the recommended package of practices of the area. The observation on density and dry matter of weeds were taken at 60 DAS. The data on weed density and weed dry matter were analyzed after subjecting to square root transformation by adding 1.0 to original values prior to statistical analysis. Crop yield was recorded at the time of harvesting.

RESULTS

The major weed flora infested the experimental crop were consisted of *Echinochloa colona, Echinochloa crusgalli* and *Leptochloa chinensis* among grasses, *Caesulia axillaris* and *Trianthema monogyna* among broad leaved weeds and *Cyperus rotundus* as sedges during 2010 and 2011 respectively. Density of grassy weeds was significantly controlled by the combination of cyhalofop + (chlorimuron + metsulfuron) @ 90 +20 g/ha which was at par with fenoxaprop + ethoxysulfuron @ 60 + 15g/ha as compared to rest of the herbicidal treatments. All the herbicidal treatments provided the excellent control of broad leaved weeds over the weedy check. Significant reduction in the density of sedges was recorded with alone application of azimsulfuron @35 g/ha than remaining herbicidal treatments. Total weed density of weeds was effectively reduced by azimsulfuron @ 35 g/ha and cyhalofop butyl +(chlorimuron + metsulfuron) @ 60+20 g/ha which were at par with each other followed by fenoxaprop + ethoxysulfuron @ 60 + 15g/ha and twice hand weeding at 20 and 40 DAS than other herbicidal treatments. The lowest dry weight of weeds was recorded with twice hand weeding which was at par with combined application of fenoxaprop + ethoxysulfuron @ 60 + 15g/ha and fenoxaprop + (chlorimuron +metsulfuron) @ 60+20g/ha followed by bispyribac sodium @ 25 g/ha and fenoxaprop @ 60g/ha as compared to other herbicidal treatments. The highest weed control efficiency was recorded with twice hand weeding at

Table 1. Effect of different treatments on total weed density, weed biomass, weed control efficiency and grain yield in direct dry seeded rice at 60 DAS (Pooled data of 2 years)

Treatment	Dose g ai./ha	Application stage (DAS)	Weed density (No./m^2) Grasses	Broad leaved weeds	Sedges	Total weed density (No./m^2)	Weed Dry weight (g/m^2)	WCE (%)	Grain yield (t/ha)
Pyrazosulfuron(10 % WP)	25		7.4 (54.0)	1.2 (0.7)	5.4 (35.3)	9.5 (90.0)	18.0 (323.5)	34.8	0.6
Pretilachlor (50 % EC)	750	4	5.8 (33.3)	1.2 (0.7)	9.0 (90.7)	11.2 (124.7)	17.4 (303.8)	38.8	0.5
Cyhalofop- butyl (10 % EC)	90	4	5.4 (28.7)	1.2 (0.7)	12.8 (168.7)	14.0 (198.1)	15.2 (241.1)	51.4	1.4
Fenoxaprop (10 % WP)	60	30	5.3 (27.3)	2.1 (4.7)	11.2 (135.3)	13.0 (167.3)	11.3 (126.1)	74.6	2.4
Cyhalofop butyl +(Chlorimuron +Metsulfuron)	90+20	30	2.7 (7.3)	1.4 (1.3)	5.2 (28.0)	6.0 (36.6)	14.1 (203.6)	58.9	1.5
Fenoxaprop +(Chlorimuron +Metsulfuron)	60+20	30	7.0 (49.3)	1.0 (0.0)	6.6 (46.7)	9.8 (96.0)	7.9 (60.9)	87.7	3.0
Azimsulfuron (50 % WP)	35	30	4.8 (22.7)	1.0 (0.0)	1.2 (0.7)	4.9 (23.4)	11.5 (141.0)	71.6	2.1
Bispyribac- sodium (10 %EC)	25	20	4.2 (17.3)	1.0 (0.0)	7.5 (60.7)	8.6 (78.0)	9.4 (89.1)	82.1	3.1
Fenoxaprop+ Ethoxysulfuron	60+15	20	3.1 (9.3)	1.0 (0.0)	7.7 (58.7)	8.3 (68.0)	7.1 (51.3)	89.7	3.5
Oxyflurofen +2,4-D	300+500	30	7.1 (49.3)	1.0 (0.0)	6.9 (52.7)	10.1 (102.0)	15.8 (255.8)	48.5	1.0
Two hand weeding	20 & 40 DAS		4.7 (21.3)	1.2 (0.7)	4.7 (25.3)	6.9 (47.3)	6.9 (50.3)	89.9	3.5
Weedy	-		7.6 (56.7)	3.4 (11.3)	13.3 (176.0)	15.5 (241.3)	22.3 (496.4)	-	0.4
CD (P=0.05)			1.0	0.6	2.7	2.3	1.6	-	0.3

*Values within parentheses are original. Data are subjected to square root transformation(Öx+1)

20 and 40 DAS (89.9%) followed by fenoxaprop + ethoxysulfuron @ 60 + 15g/ha, fenoxaprop + (chlorimuron + metsulfuron) @ 60+20 g/ha, bispyribac sodium @ 25 g/ha and fenoxaprop @ 60g/ha over the weedy check. The higher grain yield (3.5 t/ha) was recorded with fenoxaprop + ethoxysulfuron @ 60 + 15g/ha, which was at par with twice hand weeding at 20 and 40 DAS followed by bispyribac sodium @ 25 g/ha alone and fenoxaprop+(chlorimuron +metsulfuron) @ 60+20 than rest of the herbicidal treatments.

CONCLUSION

It is concluded that combined application of fenoxaprop + ethoxysulfuron @ 60 + 15 g/ha applied at 20 DAS and fenoxaprop + (chlorimuron +metsulfuron) @ 60+20 at 30 DAS was found more effective in controlling weeds and adhering good yield of direct dry seeded rice .

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A novel strategy for management and mitigation of herbicide resistant weeds in wheat

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Rice–wheat cropping system (RWCS) occupies 10.6 m ha of the Indo-Gangetic Plains in India and is crucial for the food security of the country. Sole reliance on POST herbicides has resulted in the evolution of multiple herbicide resistance inlittle seedcanary grass (*Phalaris minor*), the most ubiquitous weed of wheat in India. *P. minor* is neither being effectively controlled at double the application rates nor with sequential/ mixed use of several POST herbicides and thus denting the productivity and profitability of wheat. Two weeds namely, toothed dock(*Rumex dentatus*), a major broad leaf weed of wheat and rabbit foot grass (*Polypogon monspeliensis*) have also evolved resistance to ALS inhibitor herbicides (Chhokar *et al.*, 2015). Recently, a population of wild oat (*Avena ludoviciana*) has been confirmed for clodinafop resistance (Singh, 2016). Thus, explode of herbicide resistance is evident in India and preemptive strategies are required for its management and mitigation. Keeping this in view, the primary objective of this study was to develop exigent tactic for integration of PRE herbicides and rice straw mulch for better weed control in wheat.

METHODOLOGY

Five weed control treatments (three PRE mixtures) including unsprayed and weed free checks were randomised within the sub-sub plots, replicated thrice. One day after wheat sowing, PRE herbicides were sprayed on the soil surface using knapsack sprayer delivering 500 L/ha spray volume; and immediately loose rice straw was applied as per the treatments. In another supplementary study, PRE herbicides were applied at different rates either on top or below the mulch to control the seeded *P minor*. In top of mulch experiment, pendimethalin at 1.0, 1.5 and 2.0 kg/ha; and metribuzin at 0.140 and 0.280 kg/ha were sprayed on top of the mulch (0, 6 and 9 t/ha) whereas, in below the mulch experiment, pendimethalin at 0.75, 1.0 and 1.5 kg/ha; and metribuzin at 0.140 and 0.280 kg/ ha were applied on soil surface below the mulch load of 0, 6 and 12 t/ha. Carrier water volume used was 500 L/ha and there were untreated plots in which herbicides were not sprayed. Weed count and biomass were recorded at 60 days after sowing (DAS).

RESULTS

The dominant weed species present in the experimental plot were *Phalaris minor*, *Rumex dentatus*, *Chenopodium album, Melilotus alba, Medicago denticulata, Coronopus didymus, Anagallis arvensis Lathyrus aphaca* and *Vicia sativa*. In ZT sown wheat with higher seeding rate (125 kg/ha), single application of PRE mixture pendimethalin 1.5 + metribuzin 0.210 kg/ha beneath 8 t/ha mulch provided excellent control of all the weeds (>96 %) and recorded wheat yield (5.65 t/ha) at par with weed free treatment. In auxiliary study, PRE herbicides when sprayed on top of the mulch, increased rates didn't improve weed control. In contrast, if herbicides were applied under mulch, even reduced rates with lower mulch level provided satisfactory control of seeded*P minor*. Application of 12 t/ha of loosestraw mulch recorded 11 % higher growth of *P. minor* but pendimethalin 1.0 kg/ha PRE reduced it by 66 % as compared to no mulch no herbicide treatment. Amazingly, the application of pendimethalin 1.0 kg/ha under 12 t/ha mulch provided 100 % control of *P. minor* which can be attributed to reduced herbicide losses due to photolysis and volatilization with better soil moisture under the mulch.The differential dissipation of PRE herbicides placed on top or below the mulch was also confirmed through herbicide residue analysis.

CONCLUSION

Results revealed that PRE herbicides mixture placed beneath the rice straw mulch provided excellent control of all the weeds in wheat throughout the season and there was no need of POST herbicides. ZPM is a proactive, diversified solution butexigent tactics are obligatoryto position the herbicides under mulch.

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Yield augmentation of wheat (*Triticum aestivum* L.) through broad spectrum weed control by herbicide combinations

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To repress mixed population of weeds as also to avoid herbicides resistance by continuous use of single herbicide, compatible mixtures or sequential application of herbicides can be employed to widen the spectrum of weed control (Das and Yaduraju, 2012). Keeping in view the above facts, a field trial was carried out at Udaipur (Rajasthan) to investigate bio-efficacy of herbicide alone and in combinations for broad spectrum weed control and productivity of wheat (*Triticum aestivum* L.).

METHODOLOGY

The experiment was carried out on clay loam soil alkaline in reaction (pH-8.2)at Agronomy Farm, Maharana Pratap University of Agriculture and Technology, Udaipur during winter season of 2015-2016. The experiment consisting of thirteen treatments (Table 1) was carried out in randomized block design in three replications. Wheat variety 'Raj.-4037' was sown at 22.5 cm row distance using 100 kg /ha seed rate. The category wise weeds were pickedfrom within 0.25 m^2 quadrate placed at two randomly selected spots in each plot and oven dried at 70° C till constant weight was achieved. The final dry weight of broadleaf and grassy weeds was recorded and expressed in kg/ha. The crop was raised with standard package of agronomic practices.

RESULTS

Application of herbicides either as premix, tank mix or sequentially resulted in significantly reduced broadleaf, grassy and total weed dry matter with sulfosulfuron + metsulfuron showing best results followed by mesosulfuron + iodosulfuron. The sulfosulfuron + metsulfuron and mesosulfuron + iodosulfuron mixtures recorded 67.6 and 61.3

Table 1. Effect of treatments on weed dry matter, weed control efficiency and yields of wheat

Treatment	Weed dry matter (g/m^2) at 60 DAS			kg/ha		
	Broad leaf	Grassy	Total	Grain yield	Stover yield	Biological yield
1. Pendimethalin* 750 g /ha PE	36.53	35.08	71.61	4713	6104	10816
2. Sulfosulfuron 25 g /ha POE at 35 DAS	32.64	23.12	55.76	4840	6396	11236
3. Metribuzin 210 g /haPE	37.38	53.63	73.01	4502	6205	10706
4. Clodinafop 60 g /ha POE at 35 DAS	34.07	23.04	57.11	4741	6250	10990
5. Pendimethalin fb sulfosulfuron 1000 g PE + 18 g /ha POE at 35 DAS	22.10	22.31	44.41	5283	6530	11813
6. Pendimethalin+ metribuzin (Tank mix) 1000 g +175 g /haPE	25.97	24.65	50.63	5327	6401	11727
7. Sulfosulfuron+metsulfuron (Premix) 30 g + 2 g /ha POE at 35DAS	13.29	15.45	28.75	6022	6490	12511
8. Pinoxaden+ metsulfuron (Tank mix) 60 g + 4 g /ha POE at 35 DAS	17.23	19.57	36.76	5403	6484	11887
9. Mesosulfuron+iodosulfuron (Premix) 12 g + 2.4 g /ha POE at 35 DAS	15.69	17.44	33.12	5798	6399	12196
10. Clodinafop+ metsulfuron (Premix) 60 g + 4 g /ha POE at 35 DAS	16.35	18.70	35.05	5556	6447	12002
11. One hand weeding at 30 DAS	40.45	40.12	80.56	4070	6153	10222
12.Two hand weeding at 30 and 45 DAS	37.26	34.30	71.56	4295	6367	10662
13. Weedy check	80.11	70.78	150.89	3594	5804	9398
SEm ±	0.71	0.60	1.27	117	137	259
CD(P=0.5)	2.07	1.76	3.70	343	400	756

Pendimethalin* (Stomp Xtra 38.7% CS); DAS: days after sowing; PE: pre-emergence; POE: post-emergence per cent yield enhancement over weedy check and were at par to each other. These were followed by clodinafop + metsulfuron which brought 54.6 per cent increase and was at par with mesosulfuron + iodosulfuron. Except for pre-emergence pendimethalin alone and one hand weeding, all the weed control treatments produced significantly higher straw yield over weedy check. The range of increase over weedy check was from 6.9 (under metribuzin) to 12.5 per cent (under pendimethalin fb sulfosulfuron). The greatest biological yield wasobtained by sulfosulfuron + metsulfuron followed by mesosulfuron + iodosulfuron, clodinafop + metsulfuron, pinoxaden + metsulfuron and pendimethalin fb sulfosulfuron However, all these treatments were at par.

CONCLUSION

Weed control in wheat infested with complex weed flora should be done by post-emergence application at 35 DAS by either sulfosulfuron + metsulfuron (premix) 30 g + 2 g /ha or mesosulfuron + iodosulfuron (premix) 12 g + 2.4 g /ha.

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Weed management in drilled paddy

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Weed infestation is one of the limiting factors in rice cultivation. The loss in grain yield due to unchecked weed growth throughout the crop growth period was estimated to be 30 to 35% in drilled rice (Moorthy and Saha, 2002). Mechanical and cultural methods are not always possible to be adopted on account of scarcity and high cost of labour during peak period of rice cultivation and secondly hand weeding is slow and tedious process. Similarly removal of the weeds at the critical period by mechanical means is not possible due to unfavorable weather conditions. Under such situation, the use of herbicides is the only way to control weeds. In view of above the present study was undertaken to study the effect of herbicide alone & in combination for weed control in drilled paddy.

MATERIALS AND METHODS

The study was conducted at Agronomy Farm, College of Agriculture, Nagpur during *kharif* 2014–15. The experiment was conducted on clayey soil with pH 7.8. The soil was medium in nitrogen and phosphorus and high in potassium. The experiment was laid out in randomized block design with ten treatments replicated thrice. The seed of paddy crop (var. PKV-Khamang) was sown by drilling on 14th July 2016 at 25 cm apart and cultivated with recommended package of practices except weed management. The treatments are Control (T_1), 2 hand weedings at 20 and 40 DAS (T_2), Butachlor @ 1.5 kg a.i./ha at 7 DAS (T_3), Pretilachlor @ 750 g a.i./ha at 7 DAS (T_4), 2, 4 D @ 1 kg a.i./ha at 20–25 DAS (T_5), Pyrazosulfuron ethyl @ 25 g a.i./ha at 20–25 DAS (T_6), Butachlor @ 1.5 kg a.i./ha at 7 DAS + 2, 4-D @ 1 kg a.i./ha at 20–25 DAS (T_7), Butachlor @ 1.5 kg a.i./ha at 7 DAS + Pyrazosulfuron ethyl @ 25 g a.i./ha at 20–25 DAS (T_8), Pretilachlor @ 0.75 kg a.i./ha at 7 DAS + 2, 4-D @ 1 kg a.i./ha at 20–25 DAS (T_9), Pretilachlor @ 0.75 kg a.i./ha at 7 DAS + Pyrazosulfuron ethyl @ 25 g a.i./ha at 20–25 DAS (T_{10}). Herbicides were sprayed with knapsack sprayer having flat fan nozzle using 500 liters of water/ha.

RESULT AND DISCUSSION

Effect on weeds

Data in the table revealed that the weed control treatments showed the significant reduction in the weed dry matter as compared to control treatment. The treatment comprising of two weedings at 20 and 40 DAS showed maximum reduction in weed dry matter and highest weed control efficiency amongst all other treatments except treatments of Butachlor @ 1.5 kg a.i./ha at 7 DAS + 2, 4-D @ 1 kg a.i./ha at 20-25 DAS (T_7), Butachlor @ 1.5 kg a.i./ha at 7 DAS +

Pyrazosulfuron ethyl @ 25 g a.i./ha at 20–25 DAS (T_8), Pretilachlor @ 0.75 kg a.i./ha at 7 DAS + 2, 4-D @ 1 kg a.i./ha at 20–25 DAS (T_9), Pretilachlor @ 0.75 kg a.i./ha at 7

DAS + Pyrazosulfuron ethyl @ 25 g a.i./ha at 20–25 DAS (T_{10}). However, they were found at par with 2 hand weedings at 20 and 40 DAS (T_2) in respect of weed dry matter. This could be due to better control of weeds by hoeing and weeding and application of chemical herbicides. Kachroo and Bazaya (2011) reported that weed dry matter was reduced significantly thereby increasing weed control efficiency due to combined use of herbicides.

Effect on crop yield and economics

The grain and straw yield of paddy was found significantly higher with the treatment of 2 hand weedings at 20 and 40 DAT (T_2) as compared to other treatments. However, the treatments of Butachlor @ 1.5 kg a.i./ha at 7 DAS + 2, 4 D @ 1 kg a.i./ha at 20–25 DAS (T_7), Butachlor @ 1.5 kg a.i./ha at 7 DAS + Pyrazosulfuron ethyl @ 25 g a.i./ha at 20–25 DAS (T_8), Pretilachlor @ 0.75 kg a.i./ha at 7 DAS + 2, 4-D @ 1 kg a.i./ha at 20–25 DAS (T_9), Pretilachlor @ 0.75 kg a.i./ha at 7 DAS + Pyrazosulfuron ethyl @ 25 g a.i./ha at 20–25 DAS (T_{10}) were at par with treatment 2 hand weedings at 20 and 40 DAT (T_8). This might be due to suppression of weeds by cultural and combined use of herbicides (Pre and post emergence) that helped in reducing soil moisture and nutrient losses through weeds which were made available to paddy crop. Similar results were recorded by Upasani et. al. (2014).

As regards economic returns 2 hand weedings at 20 and 40 DAS (T_2) recorded significantly higher gross and net monetory returns as compared to all other treatments except treatments Butachlor @ 1.5 kg a.i./ha at 7 DAS + 2, 4-D @ 1 kg a.i./ha at 20-25 DAS (T_7), Butachlor @ 1.5 kg a.i./ha at 7 DAS + Pyrazosulfuron ethyl @ 25 g a.i./ha at 20-25 DAS (T_8), Pretilachlor @ 0.75 kg a.i./ha at 7 DAS + 2, 4–D @ 1 kg a.i./ha at 20–25 DAS (T_9), Pretilachlor @ 0.75 kg a.i./ha at 7 DAS + Pyrazosulfuron ethyl @ 25 g a.i./ha at 20–25 DAS (T_{10}) which were found at par with treatment 2 hand weedings at 20 and 40 DAS (T_2). This might be attributed due to higher

Table 1. Weed dry matter, Weed control efficiency, Grain and straw yield and economics of drilled paddy as influenced by various treatments

Treatments	Weed dry matter ($g\ m^{-2}$)			Weed control efficiency (%)			Grain yield (kg/ha^{-1})	Straw yield (kg/ha^{-1})	GMR (Rs/ha^{-1})	NMR (Rs/ha^{-1})	B: C ratio
	30 DAT	60 DAT	At harvest	30 DAT	60 DAT	At harvest					
T_1- Control	11.64 (135.28)	13.66 (186.26)	14.09 (198.20)	-	-	-	1123	2024	24484	6019	1.33
T_2- 2 hand weedings at 20 and 40 DAS	4.73 (21.87)	5.57 (30.60)	6.40 (40.46)	83.57	83.57	79.58	2705	3863	57963	36618	2.72
T_3- Butachlor @ 1.5 kg a.i. ha^{-1} at 7 DAS	6.36 (40.04)	8.06 (64.48)	8.80 (76.87)	70.40	65.38	61.22	1650	2550	35550	16035	1.82
T_4- Pretilachlor @ 750 g a.i. ha^{-1} at 7 DAS	6.46 (41.26)	8.58 (73.18)	8.97 (80.06)	69.50	60.71	59.61	1520	2533	32933	13733	1.72
T_5- 2, 4 D @ 1 kg a.i. ha^{-1} at 20-25 DAS	6.53 (42.15)	8.56 (72.83)	8.99 (80.42)	68.84	60.90	59.42	1373	2330	29790	10925	1.58
T_6- Pyrazosulfuron ethyl @ 25 g a.i. ha^{-1} at 20-25 DAS	6.68 (44.20)	8.52 (72.23)	9.06 (81.68)	67.33	61.22	58.79	1437	2470	31210	11745	1.60
T_7- Butachlor @ 1.5 kg a.i. ha^{-1} at 7 DAS + 2, 4 D @ 1 kg a.i. ha^{-1} at 20-25 DAS	5.21 (26.64)	6.10 (36.73)	6.91 (47.39)	80.30.	80.28	76.09	2547	3457	53650	33735	2.69
T_8- Butachlor @ 1.5 kg a.i. ha^{-1} at 7 DAS + Pyrazosulfuron ethyl @ 25 g a.i. ha^{-1} at 20-25 DAS	6.29 (27.46)	6.15 (37.32)	7.00 (48.53)	79.70	79.96	75.51	2437	3333	52073	31558	2.54
T_9- Pretilachlor @ 0.75 kg a.i. ha^{-1} at 7 DAS + 2, 4 D @ 1 kg a.i. ha^{-1} at 20-25 DAS	5.35 (28.17)	6.19 (37.87)	7.04 (49.19)	79.17	79.67	75.18	2383	3267	50927	31327	2.60
T_9- Pretilachlor @ 0.75 kg a.i. ha^{-1} at 7 DAS + Pyrazosulfuron ethyl @ 25 g a.i. ha^{-1} at 20-25 DAS	5.41 (28.86)	6.22 (38.30)	7.09 (49.89)	78.67	79.43	74.82	2250	3203	48203	28003	2.39
SE (m)±	0.23	0.23	0.24	-	-	-	165	224	3289	2921	-
CD at 5%	0.69	0.70	0.72	-	-	-	489	667	9774	8680	-
GM	6.37 (43.59)	7.76 (64.98)	8.43 (74.94)	67.77	65.11	62.02	1953	2903	41678	21970	

Note- Figures in parenthesis are original values whereas above figures are $\sqrt{x+0.5}$ transformed values grain yield of paddy due to effective weed control by these treatments that resulted in higher monetary returns. Similar results were reported by Gopinath et al. (2012). The highest B: C ratio was recorded with 2 hand weedings at 20 and 40 DAS (T_2) followed by Butachlor @ 1.5 kg a.i./ha at 7 DAS + 2, 4 D @ 1 kg a.i./ha at 20-25 DAS (T_7) and Pretilachlor @ 0.75 kg a.i./ha at 7 DAS + 2, 4 D @ 1 kg a.i./ha at 20-25 DAS (T_9). The lowest B:C ratio was recorded with control treatment (T_1) due to higher crop weed competition for various resources that reduced the paddy yield and monetary returns.

CONCLUSION

Thus it can be concluded that 2 hand weedings at 20 and 40 DAS and application of Butachlor @ 1.5 kg a.i./ha at 7 DAS along with 2, 4 D @ 1 kg a.i./ha or Pyrazosulfuron ethyl @ 25 g a.i./ha at 20–25 DAS showed significant reduction in weed dry matter and increased weed control efficiency thereby increasing monetary returns and B: C ratio amongst all the other treatments.

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Evaluation of quizalofop-p-ethyl against weeds in cotton

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Considering the present day labour scarcity and their higher wages for cultural and mechanical weed control, the economics and feasibility of cotton cultivation is quiet disturbed. Hence the emphasis should be given to adapt the chemical methods of weed control to solve the problem of minimum available labours and their high cost. In this view, the present investigation was conducted to find out the best suitable combination of different herbicides to control weeds in cotton with lower cost and higher cotton yield.

METHODOLOGY

The field experiment was conducted at Zonal Agricultural Research Station, Chhindawara-480 001 Madhya Pradesh, (21.28 ^{0} N latitude, 78.4^0 E longitude and altitude of 675 m above MSL) in *kharif* season of the year 2014-15 in randomized block design with eight treatments and replicated thrice. The soil of experimental field was clayey loam in reaction with pH 7.2 and low available N (185 kg/ha), medium P (18.2 kg/ha) and high in K (412 kg/ha). The cotton variety 'Suraj' was sown at 90 cm X 60 cm spacing on 10th July. Treatment consist of weedy check, recommended practice of weed management (weed free check 15 days interval) and post-emergence application of quizalofop -p- ethyl @30 g, 40g, 50g, 60g, 80 a.i./ha, Pendimethalin was applied as pre-emergence at 2 DAS, while quizalofop -p- ethyl all dose were applied as post emergence at 2-4leafstage ofweeds During the kharif season from (June to September, 2014) the rainfall received during the cotton growing period was 588.0 mm. the relative humidity ranged from 31.7 to 99 %. The average maximum and minimum temperature ranged from 26.7 to 43.0 ^{0}C and 22.6 to 32.7 ^{0}C.

RESULTS

The prominent grassy weed species in the weedy plot at 60 DAS are *Brachiaria* spp. (14.65 %), *Digitariaads endense* (17.88 %), *Echinochloacrusgalli* (30.05 %), *Echinochloa colonum* (19.28 %), and *Eleusine indica* (4.83 %), while among the broad leaf *Ageratum conyzoides* (0.61 %), *Alternanther asessilis* (0.55 %), *Euphorbia geniculata* (0.96 %) and *Parthenium hysterophorus* (0.63 %). *Cyperus*

Table 1. Effect of various treatments on yield and yield attributing characters of cotton and dry weight of weeds and weed index

Treatment	Plant height (cm)	No of branch/ plant	No of boll/ plant	Boll weight (g/plant)	Seed yield (kg/ha)	WDW at harvest (kg/ha)	WI(%)	WCE (%)	HEI (%)
Quizalofop-P-Ethyl 5% EC (30)	156	18.6	32.4	2.81	1198	49.45	15.51	83.21	29.09
Quizalofop-P-Ethyl 5% EC (40)	158	19.2	32.9	2.89	1224	43.29	13.68	85.27	31.89
Quizalofop-P-Ethyl 5% EC (50)	155	18.1	32.4	2.92	1265	35.48	10.78	88.01	36.31
Quizalofop-P-Ethyl 5% EC (60)	158	18.8	33.5	3.29	1289	22.65	9.05	92.46	38.90
Quizalofop-P-Ethyl 5% EC (80)	158	17.9	32.8	3.28	1332	19.76	6.08	93.40	43.50
Pendimethalin 30% EC (900)	152	17.1	32.1	2.68	1309	41.23	7.68	85.95	41.05
Weedy check	128	12.1	18.7	2.16	928	292.32	34.55	00.00	00.00
Weed free check	161	20.2	35.1	3.35	1418	2.19	–	99.31	–
SEm±	2.12	1.18	2.87	0.14	89	2.09	–	–	–
CD (P=0.05)	5.87	3.52	7.07	0.39	264	6.58	–	–	–

WDW=Weed Dry Weight, WI=Weed Index, WCE=Weed Control Efficiency, HEI= Herbicidal Efficiency Index
Parenthesis indicated that Dose ml a. i. /ha

rotundus (2.78 %) and *Cynodon dactylon* (2.18 %) were the sedges present in the experimental plot. As the doses of Quizalofop-P-Ethyl 5% EC increases from 30 to 80 g a.i./ha, there was drastic reduction in grassy weeds. Weed count was carried out at 60 DAS and the post emergence application of various doses of herbicides was done at 25 DAS. So that the effectiveness of various doses of Quizalofop-P-Ethyl should be observed at 60 DAS weed count. All the doses of Quizalofop-P-Ethyl 5% EC from 30 to 40 and 50 to 80 g a.i./ha was found effective against Grassy. However, application of Pendimethalin 30% EC 900 g a.i./ha provided good control of grassy, broad leaf and sedge weeds as it was applied as pre-emergence, which provided the early weed free conditions and ultimately better crop growth and survival. Higher dose of Quizalofop-P- Ethyl 5% EC 80 g a.i./ha was better than its lower doses in controlling the infested grassy weed species. All the herbicidal treatments resulted in significant reduction in the density at 60 DAS and dry weight of weeds at harvest. There was considerable increase in efficacy of Quizalofop-P-Ethyl 5% EC over weeds with corresponding increase in their dose of application. All the doses of Quizalofop-P-Ethyl 5% EC of 30, 40 50, 60 and 80 g a.i./ha were ineffective against broad leaf weeds, but provided satisfactory control of grassy weeds. While application of Pendimethalin 30% EC 900 g a.i./ha and weed free treatment have effective control of all the grassy, broad leaf and sedge weed species, which was followed by Quizalofop-P-Ethyl 5% EC applied at 80 g a.i./ha and its corresponding lower doses. All the treatments have considerable reduction in weed biomass as compared to weedy check. Besides weed free treatment, among the tested herbicides, Quizalofop-P-Ethyl 5% EC 80 g a.i./ha recorded the lowest dry weight of weeds, followed by Pendimethalin 30% EC 900 g a.i./ha. This can be attributed to prolonged effectiveness of Quizalofop-P-Ethyl 5% EC. Higher dose of Quizalofop-P-Ethyl 5% EC 80 g a.i./ha was better than lower doses in controlling the density of infested grasses. Besides weed free treatment, Pendimethalin 30% EC 900 g a.i./ha applied as pre-emergence and Quizalofop-P-Ethyl 5% EC 60 and 80 g a.i./ha as post-emergence recorded significantly lower density of *Echinochloa crusgalli, Echinochloa colonum, Digitaria adsendense* and *Eleusine indica* as compared to other treatments. The cotton seed yield and yield attributes were significantly influenced due to different weed control treatments. Among the weed control treatments, the highest weight of cotton boll, No of boll/plant and cotton seed yield were recorded with weed free treatment due to highest WCE and less weed-crop competition during the crop growth period and plant had not to face stress of other nutrients, moisture, light and space as compared to under heavy weed infestation these helped the plant to put optimum growth parameters. Further, it might have enhanced photosynthetic activity and partitioning of assimilates, resulting in improved yield attributes, evidently resulted in higher cotton seed yield. Weed control showed marked improvement in seed yield and next to the weed free treatment, the maximum cotton seed yield was recorded with Quizalofop-P-Ethyl 5% EC 80 g a.i./ha (1332 kg/ha), followed by Pendimethalin 30% EC 900 g a.i./ha (1309 kg/ha) and Quizalofop-P-Ethyl 5% EC 60 g a.i./ha (1289 kg/ha), which also comparable to corresponding doses of Quizalofop-P-Ethyl 5% EC. However, minimum cotton seed yield was recorded under weedy check, which was attributed to more weed growth and ultimately poor yield attributes formation resulted in poor yield.

CONCLUSION

From present investigation it can be concluded that, application of quizalofop ethyl @ 80 g a.i. /ha as post-emergence herbicides in cotton is the best weed management practice to obtain greater yield and economic return with more efficient weed control.

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Micronutrient status under salinity stress in India

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Micro-nutritional disorders are common nutritional imbalance in plants and affect greatly plants performance and their response to surrounding environment. Micronutrients deficiencies exert secondary, often unpredicted influences on the growth of plants by changes in growth pattern, chemical composition, and antioxidant defence capacity of plants and particularly decrease the resistance of plants to biotic and abiotic environmental stresses. Low productivity because of limited mineral nutrient supply is common under various environmental conditions. Plant growth and internal changes responds to salinity by a way of rapid osmotic phase which inhibits growth of leaves by hampering photosynthesis and another slower but disastrous ionic phase that accelerates senescence of leaves. These concentrations of soluble salts through their high osmotic pressures affect plant growth by restricting the uptake of water by the roots. Salinity can also affect plant growth because the high concentration of salts in the soil solution interferes with balanced absorption of essential nutritional ions by plants. Because of the significant effect of beneficial elements on plants growth and productivity under marginal environmental conditions, we present detailed information on how these elements alleviate plants stress injuries.

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Effect of planting and weed control methods on maize

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Maize crop management involves decision making on several cultural/agronomic practices aimed to maximize grain yields like planting methods (Conservation Agriculture based RCTs), improved varieties and proper nutrient and weed management. Interventions in the form of new resource conservation technologies (RCTs) like zero-tillage (ZT) and furrow irrigated raised bed system (FIRBS) coupled with crop diversification by including maize in place of rice may be a viable solution. Management of weeds is considered to be an important factor for achieving higher productivity as weed problem is more severe during continuous rains in early stages of maize growth which can't be controlled by traditional cultural practices alone due to too much wetness. Girma and Chinawong (2005) that where weed population and dry matter production of weeds were effectively suppressed with PRE and POE applications of atrazine or metolaclor 3.0 kg/ha+ 2, 4-D 1.0 kg/ha. Under this situation, managing weeds through PRE and POE herbicides or integrated with normal weeding will be an ideal means for controlling weeds in view of their economics and effectiveness in maize. Keeping this in view, the present investigation was carried out during *kharif* 2013 to 2015.

METHODOLOGY

The field experiment was conducted during *kharif* season of 2013-15 at Research Farm of Department of Agronomy, CCS Haryana Agricultural University, Hisar. The experiment was laid out in split plot design having three planting methods viz. zero tillage (ZT), conventional tillage (CT) and FIRBS in main plots and atrazine (50% WP) 750 g/ha (PRE), tembotrione (42% SC) 120 g/ha + Surfactant (S) 1000 ml/ha (POE: 10-15 DAS/2-4 leaf stage), two HW (20 &40 DAS) and weedy check in sub-plots. The herbicides were applied with flat fan nozzle using spray volume of 500 l/ha. The data on yield and weeds was recorded to assess the effect of planting and weed control methods on maize crop.

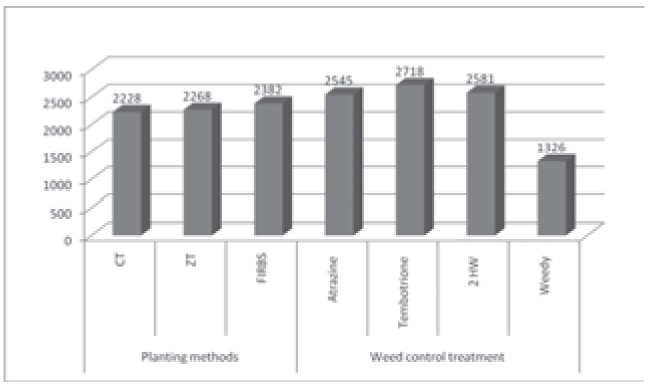

Fig.1. Maize grain yield (kg/ha) (mean of 3 year)

RESULTS

Productivity (mean of three years) of high quality protein maize (HQPM 1) was highest under FIRBS (2382 kg/ha) followed by ZT (2268 kg/ha) and CT (2228 kg/ha). Yield under tembotrione (42% SC) 120 g/ha + S 1000 ml/ha (10-15 DAS/ 2-4 leaf stage) was significantly higher as compared to other treatments (Fig. 1). POE application of tembotrione (42% SC) 120 g/ha + S 1000 ml/ha (10-15 DAS/2-4 leaf stage) also significantly reduced the dry matter of weeds and gave highest maize grain yield over the period.

CONCLUSION

Productivity of maize was higher under FIRBS and ZT as compared to CT whereas for controlling the weeds and taking higher maize yield, use tembotrione (42% SC) 120 g/ha + S 1000 ml/ha (10-15 DAS/2-4 leaf stage).

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Integrated weed management studies in rainfed pigeonpea (*Cajanus cajan* (L.) Millsp)

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In Uttar Pradesh, state pigeon pea grown over an area of 0.32 m ha and produces 0.29 m tonnes with productivity 891 kg ha^{-1}, respectively (Anonymous, 2012-2013). The weeds are serious problem in pigeon pea and drastically reduce the yield.Development and implementation of integrated weed management (IWM) strategies is becoming more important. The IWM aimed to bring down the intensity of weed growth to the economically insignificant level with minimum influence on environmental pollution. The combined application of agronomic, mechanical, biological and chemical methods usually referred to the IWM which is one of potential leavers for providing the optimum condition for better crop growth and adverse environmental effect to weed growth (Ready, 2007).

Table 1. Effect of various weed control treatments on yield of pigeon pea.

Treatment	Seed yield (t/ha)	Stalk yield (t/ha)	Harvest index (%)
Fluchloralin @ 1 kg a.i./ha as PPI	1.54	7.91	16.34
Fluchloralin @ 1 kg a.i./ha as PPI +one hand weeding at 30 DAS	1.75	8.75	16.70
Anilophos @ 1 kg a.i./haas PE	1.40	6.94	16.79
Anilophos @ 1 kg a.i./ha as PE +one hand weeding at 30DAS	1.57	8.30	15.89
Pendimethalin @ 1 kg a.i./ha as PE	1.69	8.83	15.91
Pendimethalin @ 1 kg a.i./ha as PE +one hand weeding at 30 DAS	1.91	9.06	17.41
One hand weeding at 25 DAS	1.39	6.94	16.73
Two hand weeding at 25 and 45 DAS	1.89	9.02	17.32
Weedy check	11.31	55.42	16.95
Weed free check	20.22	93.06	17.83
SEm±	0.51	2.43	0.36
CD (P=0.05)	1.51	7.22	1.07

METHODOLOGY

The experiments were conducted during *Kharif* season 2011- 2012 at Agronomy Research Farm of Narendra Deva University of Agriculture & Technology, Kumarganj, Faizabad (U.P.). Geographically, experimental site is situated at 26^0 47' N latitude, 82^0 12' E longitudes and an altitude of 113 metres above the mean sea level in the North Indo-gangeticplain. The experiment was laid out in randomized block design having ten treatments i.e. (Fluchloralin @ 1kg a.i./ha PPI, Fluchloralin @ 1kg a.i./ha as PPI + one hand weeding at (30DAS), Anilophos @ 1 kg a.i./haas PE, Anilophos @1 kg a.i./ha as PE one hand weeding at (30 DAS) Pendimethalin @ 1 kg a.i./ha as PE, Pendimethalin @ 1 kg a.i./ha as PE + one hand weeding at (30 DAS), one hand weeding at (25 DAS), two hand weeding (25 and 45 DAS), weedy check and weed free check. All the treatments were replicated three times. Rests of the inputs were applied as per package and practices of NDUA & T Kumarganj, Faizabad (U.P.).

RESULTS

The yield of pigeonpea viz., seed and stalk yields and harvest index (%) were significantly influenced due to various weed control method.The crop available weed free condition throughout the season yielded significantly higher seed yield (2.03t/ha) than other weed management practices. As far as application of various herbicides is concerned the pendimethalin @ 1.0 kg a.i./ha+ one hand weeding at 30 DAS gave significantly higher seed yield (1.91 t/ha) as compared to other herbicides. Significantly higher seed yield due to less or no weed competition in there treatments which resulted in higher seed yield of pigeon pea. The present findings are in conformity to result obtained by and Pardeshi *et al.* (2008). The maximum stalk yield was recorded in weed free check (9.31 t/ha), which was comparable with application of pendimethalin @ 1.0 kg a.i./ha + one hand weeding at 30 DAS and it was significantly superior over other treatments. This indicated that uncontrolled weeds were more aggressive to check growth and development of crop plants due to which lowest stalk yield was recorded under weedy check. Significantly higher harvest index was calculated in weed free treatment which was closely followed by pre-emergence application of pendimethalin @ 1.0 kg a.i./ha + one hand weeding at 30 DAS and lowest was recorded under weedy check. Significantly higher seed and stalk yields were recorded under the impact of above treatments, which favourers the way to obtain higher value of harvest index. Similar findings were also reported by Singh (2007).

CONCLUSION

On the basis of economics computation the highest yield and net return was recorded under the effect of weed free check treatment.

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Biotic stresses in crops with special reference to weed management

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Weeds are one of the major biological constraints that limit crop productivity. They compete with crops for various resources available at sites. The huge yield losses due to weeds and increase in rice yield in response to proper weed management indicate the potential of weed management in rice (Jabran and Chauhan 2015). However, the yield losses are largely dependent on cultivation method and management practices followed. In the central India hand weeding is very common, but due to high labour wages, and their timely availability are major concerns. There are several management options available to minimize the menace of weeds in rice. Green manuring is one of the possible options which not only adds organic matter to the soil and improve the crop yield but also suppress the weed growth. Selection of cultivars is another option that could be potentially utilized as per the weed flora available in the vicinity. Nutrient management also influences the growth and emergence of weeds. Nitrogen favours crop and weeds and ultimately increases the total biomass production. There are reports which contradict the response of N on weeds, it favours the N responsive weeds and reduces the crop yield (Andreasen *et al.,* 2006). In contrary to these, N fertilizer application favoured crop more than weeds (Abouziena *et al.,* 2007). Under labour crises, herbicides are gaining importance to manage weeds; however, herbicides alone cannot provide effective and season-long weed control. Weeds are considered to be one of the most important factors affecting crop yield. Even a small change in weed dry weight per unit area could greatly affect the crop productivity. Thus, integration of herbicides with other management practices is very much important. Therefore, field studies were conducted to evaluate the weed suppression by various management options in rice.

METHODOLOGY

The field studies were conducted at ICAR-National Institute of Biotic Stress Management, Raipur during 2013-2015 on with and without *Dhaincha*, rice cultivars on weed suppression ability, omission of primary nutrients and different herbicides on weed suppressing ability separately. *Dhaincha* was incorporated 30-35 days after sowing and rice was transplanted after 6 days of incorporations. Promising rice cultivars were transplanted and tested against weed suppression ability. Omissions of primary nutrient were also tested against the weed flora, and different herbicides available for rice were tested alone, in combinations and with sequential application, and evaluated the weed suppression ability. The studies were conducted in transplanted rice where 21 days old seedlings were transplanted in puddle field and followed the set of recommendation suggested for the region other than the variables. Weed data were recorded from 0.5 x 0.5 m area; these were grouped into grasses, sedges, and broadleaved weeds and interpreted. The aboveground parts were dried in an oven at 70°C for 48 hr and recorded weed dry weight. Total weed dry weight was determined by summing up the dry weight of each plant. Yield was recorded at 14% of grain moisture content.

RESULTS

Incorporation of *Dhaincha* significantly contributed to yield attributes and weed suppression in rice. *Dhaincha* incorporated plots had 13.8% higher panicle/m^2, panicles were 2.7% longer, 7.4% heavier, 14.9% more filled grains and recorded 21.1% lesser chaffy grains over without *Dhaincha*. The *Dhaincha* incorporated plots had 16.4% higher grain and 5% more straw yield than without *Dhaincha* plots. This also suppressed the weed density by 57% resulting 37% reduction of weed dry weight over without *Dhaincha* (Fig. a and b). Rice cultivars have the capability to suppress the emergence of a group of weeds. The tall stature varieties recorded with more of grassy weeds (10-10.8/m^2), and the lowest with Swarna (6.8 grasses/m^2). In contrary to these, short stature varieties have more of broadleaved weeds highest with PKV HMT and Mahamaya (13.8/m^2). Stature of plant also influenced the solar radiation interceptions, which may be essential for germination and emergence of weeds. Tall stature varieties intercepted 55.8-57.8% solar radiation at middle and 83.8-84.5% solar radiation at bottom of the crop canopy, whereas, the short stature varieties had only 35.9-45.5% at middle and 65-75.7% at bottom of the crop canopy. The short stature varieties suppressed 29.2% of grassy weeds against Dubraj, whereas, tall stature varieties had only 4.2% suppression. In contrary to grasses, taller varieties had noticed 16.7%

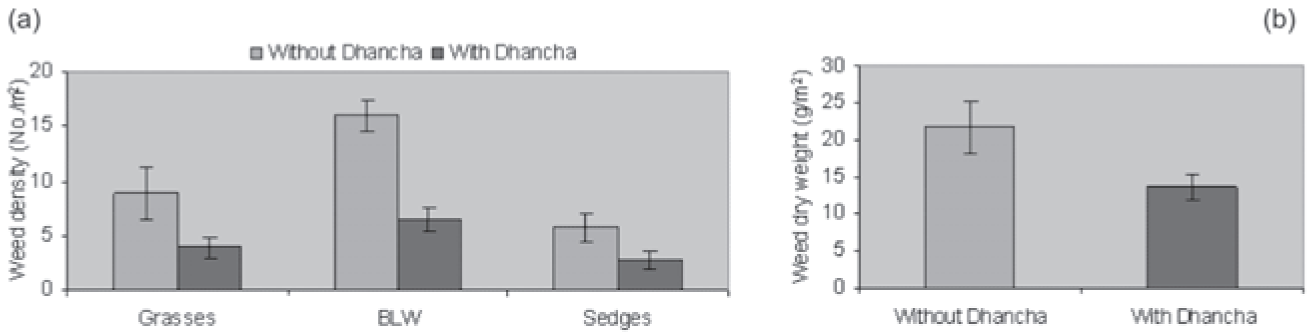

Fig. 1. With and without *Dhaincha* influence the density of weeds (a), and weed dry weight (b)

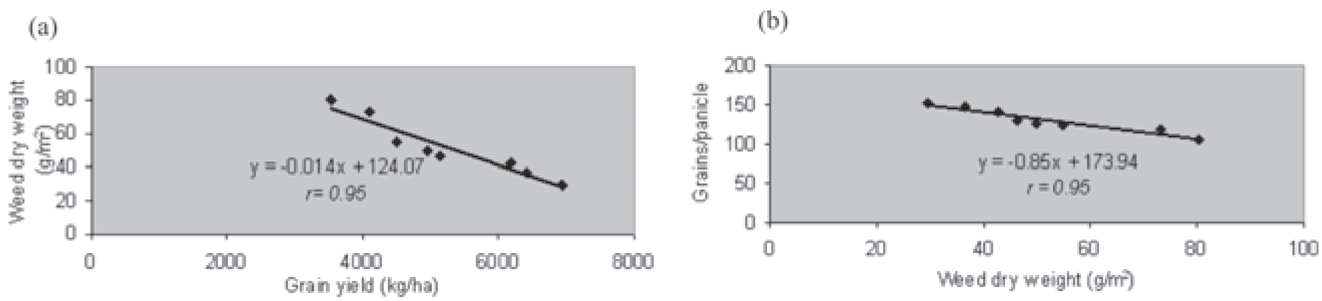

Fig. 2. The relationship between weed dry weight and a) grain yield, and b) grains/panicle in rice

of broad leaved weed suppression over Mahamaya and only 4% suppression with short stature varieties. Applications of RDF N100 $P_2O_5$60 K_2O 40 here after N100P60K40 kg/ha improved the growth and development of rice, which restricted the lesser solar radiation to transmit to the ground resulting lowered weed seed germination. Application of N reduced the broad leaved weeds, further weed density lowered with addition of P and K over the control plots (i.e. N0P0K0). The highest grain yield was harvested with N100P60K40 (6.93 t/ha) followed by N100P60K0 (6.42 t/ha), whereas, the lowest yield noticed with N0P0K0 (3.53 t/ha). There was negative linear correlation between weed dry weight and grain yield (r=0.95) (Fig. 2a), and grains/panicle (r=0.95) (Fig. 2b).At 45 DAT, the relative densities of grasses, broad leaved weeds and sedges were 46, 44.1 and 9.9%, respectively, which changed to 31.9, 65.7 and 2.3%, respectively at 75 DAT irrespective of treatments. At 45 DAT, the highest weed control efficiency (WCE) recorded with two hand weeding at 20 and 40 DAT (93.9%), followed by pyrazosulfuron-ethyl 10 WP *fb* bispyribac sodium 10 SC (80.3%) and pendimethalin 30 EC *fb* bispyribac sodium 10 SC (78.7%), ready mix of pretilachlor 6% + pyrazosulfuron 0.15% GR (75.5%) and bispyribac sodium 10 SC (72.4%) over the control. However, the efficacy of the molecules was further improved at 75 DAT and followed the similar trend (Table 1). Fenoxaprop-p-ethyl 9.3 EC alone or in combination with any other molecules were equally effective against grasses. Similarly, pendimethalin 30 EC followed by (*fb*) bispyribac sodium 10 EC, and pyrazosulfuron-ethyl 10 WP *fb* bispyribac sodium10 SC along with ready mix application of pretilachlor 6% + pyrazosulfuron 0.15% GR had also suppressed the grasses except few. Pyrazosulfuron-ethyl 10 WP was weak against most of the grasses. However, it was noticed that tank mix application of pretilachlor 50 EC and pyrazosulfuron-ethyl 10 WP was little less effective than the ready mix of pretilachlor 6% + pyrazosulfuron-ethyl 0.15% GR, this has phytotonic effect on plant. The highest grain yield was recorded with two hand weeding at 20 and 40 DAT (7.45 t/ha) followed by pyrazosulfuron-ethyl 10 WP *fb* bispyribac sodium 10 SC, pendimethalin 30 EC *fb* bispyribac sodium 10 SC and ready mix application of pretilachlor 6% + pyrazosulfuron-ethyl 0.15% GR over the control (3.62 t/ha).

CONCLUSION

Incorporation of *Dhaincha* at 30-35 DAS followed by 75% of recommended dose of fertilizer with weed competitive cultivars would suppress the weeds. If still weeds are there that could be managed by applying pyrazosulfuron-ethyl 10 WP @ 20 g/ha *fb* bispyribac sodium 10 SC @ 25 g/ha would be sufficient to bring down the weed density within the thresh-hold level and to obtain higher rice grain yield.

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Influence of crop establishment methods and different weed management practices on growth, yield and quality of direct seeded rice (*Oryza sativa*)

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A field experiment was designed in strip plot, having three rice establishment methods (broadcasting sprouted seed on puddled bed, dry seeding in rows 20 cm apart and drum seeding of sprouted seeds on puddled bed) in main plots and eight herbicidal treatments (pre-emergencebutachlor @ 1.5 kg/ha, pre-emergencebutachlor @ 1.5 kg/ha + post-emergence bispyribac @ 25 g/ha, pre-emergence pretilachlor @ 0.75 kg/ha, pre-emergence pretilachlor @ 0.75 kg/ha + post-emergence bispyribac @ 25g/ha, pre-emergence pendimethalin @ 1.0 kg/ha, pre-emergence pendimethalin @ 1.0 kg/ha + post-emergence bispyribac @ 25 g/ha , two hand weedings at 20 and 40 DAS and weedy check) in sub plots. The weed population, dry weight and nutrient uptake clear cut shows the growth and yield pattern. The pre and post-emergence applications of pendimethalin + bispyribac and drum seeding of sprouted seed is best among all the treatments. Weed control efficiency of pendimethalin + bispyribac (71.67%) was best. Pretilachlor + bispyribac (Rs. 29,181/ha) has highest net return. The highest B:C ratio of 1.29 was observed for pretilachlor.

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Interaction of mulch and Preherbicides on emergence and growth of *Phalaris minor*

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The major sustainability issue of rice-wheat cropping system is the production of huge amount ofrice residue (7-10 t/ha) which are mostly burnt *in situ* by the farmers within 3-4 weeks during October-November. This leads to soil health and environmental concerns. However, utilization of rice residue as mulch in wheat offers a variety of benefits such as improved soil health, reduction in greenhouse gas emissions, regulation of canopy temperature, improved water use efficiency in addition to weed growth suppression. At present, *Phalaris minor*, the most ubiquitous weed of wheat, has evolved multiple herbicide resistance andit is neither being controlled at double the application rates nor with sequential/ mixed use of several post-emergence herbicides. Utilization of surplus rice straw as mulch can be an important component of integrated management of resistant *P. minor* in combination with PRE herbicides. Higher levels of surface mulch reduce and delay weed seedling emergence, most likely by preventing light penetration and decreasing thermal amplitude and a longer time needed for seedlings to emerge through the residue cover. Although, rice mulch does not suppress weeds completely and cannot substitute herbicide application but the suppression of weeds by mulch can reduce herbicide requirements.However, prior studies have shown that crop residues can intercept 15 to 80% of PRE herbicides, which may result in reduced weed control but herbicide performance can be improved by rainfall or irrigation and through the use of high carrier volumes. Pre-emergence herbicides with low water solubility bind to the stubbles and prevented from reaching the weed seeds on the soil surface.Even herbicides with high water solubility are physically impeded by dense stubbles and are reliant on rainfall or irrigation to wash them onto the soil (Borger *et al.*, 2013). In conservation agriculture systems, increased microbial activities can potentially facilitate herbicide degradation (Locke *et al.*, 2002) and high organic matter can bind soil applied herbicides (Chauhan and Abugho, 2012); therefore, higher rates of PRE herbicides might be needed for adequate weed control.In conventional wheat crop, management of multiple herbicide resistant *P. minor* is not possible without the sequential and tank-mix application of PRE and POST herbicides. But exigent tactics are obligatory for the design of PRE herbicides-mulch combinations for better herbicide performance and to evade the POST herbicides. Therefore, a field study was conducted to determine the effects of rice straw mulch amount and PRE herbicides on emergence and growth of *P. minor*.

METHODOLOGY

A field study was conducted at CCS, Haryana Agricultural University, Regional Research Station, Karnal, Haryana, India during winter seasons of 2014-15 and 2015-16 using different mulch levels, PRE herbicides and their mixtures. The experiment was laid out in randomized complete block design with six mulch and five herbicide treatments. The seeds of *P minor* at seeding rate of 7.5 kg/ha were sown in lines at 30 cm row spacing in plot size of 2 m by 4 m and irrigated immediately. Chopped and sun dried rice straw mulch was spread on the soil surface after 5 days of sowing at 0, 4, 6, 8, 10 and 12 t/ha. Immediately after application of mulch, PRE herbicides (pendimethalin 1.5 kg/ha, pyroxasulfone 0.1275 kg/ha, pendimethalin 1.0 + pyroxasulfone 0.1275 kg/ha, pendimethalin 1.5 + metribuzin 0.140 kg/ha) were sprayed over straw mulch using carrier water volume of 1000 L/ha or left unsprayed (control treatment). The field was surface irrigated once after 30 days of spray. Seedling emergence, plant height and shoot biomass of *P. minor*and soil moisture content were recorded at 30 and 60 days after sowing (DAS). Data were pooled and ANOVA was performed on non-transformed and square root-transformed values.

RESULTS

The interaction effects of mulch and herbicides were significant for seedling emergence and shoot biomass of *P. minor*at 30 and 60 DAS and for plant height at 60 DAS. In untreated treatment, emergence of *P. minor* significantly reduced with the application of mulch. At 30 DAS, residue mulch of 4, 6 and 12 t/ha suppressed the seedling emergence by 49, 66 and 78%, respectively as compared to no residue. Under no residue treatment, all the PRE herbicides significantly suppressed seedling emergence as compared to control. Pendimethalin + pyroxasulfone and pendimethalin + metribuzin reduced the emergence by 98 and 99%, respectively as compared to the untreated at 60 DAS. Emergence of *P. minor* successively reduced whereas the fresh biomass per plant increased with the increase in mulchload. Residue mulch of 12 t/ha suppressed the seedling emergence by 73%; however, the fresh biomass per unit area was significantly at par with untreated control (no mulch, no herbicide). Tank mixture of pendimethalin + pyroxasulfone/ metribuzin as PRE provided significantly better control of *P. minor*either without mulch orin combination with high mulch level (12 t/ha) as compared to low mulch level (6 t/ha).

CONCLUSION

The results of this study revealed that emergence of *P. minor*reduced successively with the increase in mulchload, however fresh biomass per plant increased in succession probably due to lack of crop competition and better moisture availability. *P. minor* escaped the application of herbicides as rice straw mulch intercepted the PRE herbicides and resulted in lower efficacy. Tank mixture of pendimethalin + pyroxasulfone/metribuzin as PRE either without mulch or with mulch provided better control of *P. minor* than their alone application.

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Effect of weed management practices on weed dynamics and seed yield of berseem

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Weeds are the main constraint in berseem seed production. Weeds impact berseem seed yields by competing with crop for light, moisture and nutrients.The green fodder and seed yield reduction due to the weed infestation in berseem may be up to 5- 20% and 13 – 37% (Wasnik *et al.,* 2015). Most of the yield reduction due to weed competition occurs during the first five weeks after sowing the crop. Therefore, major emphasis on weed control should be given during this period. Manual weeding is expensive; energy and time consuming as well as difficult, herbicides not only control the weeds timely and effectively but also offer a greater scope for minimizing the cost of weed control. In this view, the present investigation was conducted to find out the best suitable combination of different herbicides to control the weeds in berseem seed production.

METHODOLOGY

A field experiment was carried out during *rabi* season of 2015-16 at central research farm of Indian Grassland and Fodder Research Institute, Jhansi. The experiment was laid out in randomized block design with three replications having nine treatments,viz.weedy check,weed free,oxyfluorfen @ 0.02 kg a.i./ha PE,oxyfluorfen @ 0.03 kg a.i./ha PE, oxyfluorfen @ 0.04 kg a.i./ha PE, imazethapyr @ 0.05 kg a.i./ha POE, imazethapyr @ 0.075 kg a.i./ha POE, imazethapyr @ 0.100 kg a.i./ha POE and oxyfluorfen (0.03) PE – imazethapyr @ 0.100 kg a.i./ha after first cut. The doses of herbicides as per the treatments were mixed in 500 litres of water and sprayed by knapsack sprayer with flat fan nozzle. The berseem variety 'Wardan' was sown at 40 cm row to row spacing with a seed rate 20 kg/ha. Fertilizers were applied uniformly through urea, single super phosphate and muriate of potash @ 20 kg N, 80 kg P_2O_5 and 40 kg K_2O/ha respectively. The first cutting was done at 55 days after sowing and subsequent two cuttings were done at 30 days interval.After three cuttings, the crop was left for seed production. The weed density and dry weight were recorded from each plot in a quadrate of one square meterat the time of first cut. Weed data were subjected to square root transformation ($\sqrt{x+0.5}$) before statistical analysis to normalize data distribution

Table 1. Weed density, weed dry weight, weed index, green fodder and seed yield of berseem as influenced by different weed control treatments

Treatments	Weed density at 55 DAS (No./m^2)	Weed dry weight at 55 DAS (g/m^2)	WCE (%)	Weed index for seed yield (%)	Plant height at harvest (cm)	Yield (t/ha)		
						Green fodder	Seed	Straw
Weedy check	*16.55 (273)	*5.81 (33.33)	-	40.45	68.67	31.4	0.293	1.82
Weed free	0.71 (0.00)	0.71 (0.00)	100	-	80.07	43.4	0.492	2.91
Oxyfluorfen @ 0.02 kg a.i./ha PE	15.23 (231)	4.87 (23.17)	30	37.13	70.55	33.6	0.309	1.90
Oxyfluorfen @ 0.03 kg a.i./ha PE	14.97 (224)	4.61 (20.83)	38	32.25	71.11	34.9	0.333	2.26
Oxyfluorfen @ 0.04 kg a.i./ha PE	14.57 (212)	4.32 (18.17)	45	23.78	73.56	35.9	0.375	2.44
Imazethapyr @ 0.05 kg a.i./ha POE	4.63 (21)	2.67 (6.61)	81	15.85	72.89	37.3	0.414	2.41
Imazethapyr @ 0.075 kg a.i./ha POE	4.30 (18)	2.44 (5.50)	83	11.18	75.78	38.6	0.437	2.65
Imazethapyr @ 0.100 kg a.i./ha POE	3.94 (15)	2.04 (3.67)	89	8.74	78.30	40.2	0.449	2.80
Oxy. (0.03) PE – Ima. @ 0.100 kg a.i./ha after first cut	15.09 (227)	4.73 (21.80)	35	14.43	76.57	38.2	0.421	2.51
CD(P=0.05)	0.33	0.20	-	-	3.61	1.19	0.011	0.11

*Data transformed using square root $\sqrt{(x+0.5)}$ and values in parenthesis are original, PE- Pre- emergence, POE-Post-emergence, WCE-Weed-control efficiency, DAS- Days after sowing

RESULTS

Weed management practices had marked effect on weed density, weed dry weight and weed control efficiency. Imazethapyr @ 0.100 kg a.i./ha application at 20 days after sowing recorded significantly lower weed densityand dry weight(Table 1). The highest weed control efficiency (89%) was also recorded in imazethapyr @ 0.100 kg a.i./ha applied treatment. Plant height recorded at harvest was maximum under weed free treatment and it was at par with imazethapyr application @ 0.100 kg a.i./ha treatment. Weed index which indicates fall in yield over a weed free practice for seed yield was lowest in imazethapyr @ 0.100 kg a.i./ha application. The highest green fodder and seed yield was recorded in weed free plot. Among herbicidal treatments, imazethapyr application @ 0.100 kg a.i./ha recorded maximum green fodder and seed yield which were significantly superior compared to other treatments.

CONCLUSION

From the present investigation it can be concluded that application of imazethapyr @ 0.100 kg a.i./ha at 20-25 days after sowing was the most effective herbicide for controlling the weeds in berseem crop seed production.

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Extended Summaries Vol. 1 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Optimizing rate of a new herbicide (flurochloridone 20% CS) in sunflower

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Sunflower (*Helianthus annuus*) is an important oil seed crop of India. The productivity of sunflower in India is quite low compared to that in other sunflower growing countries. One of the causes for low yield is the weed growth which competing with the crop for nutrients, water, sunlight and space. One of the causes for low yield is the weed growth which competing with the crop for nutrients, water, sunlight and space. Wide row spacing and slow initial growth of sunflower provide enough room for weeds to establish and to take advantage of slower initial growth of the crop (Baskaran and Kavimani, 2014). Further, non-availability of labour and high rate of wages during peak periods of agricultural operations increased hiring charges of bullock-drawn intercultural implements (Sankar and Subramanyam, 2011). Hence, there is a need to find out alternate method of weed control. Herbicide based weed management is becoming popular among farmers on account of its lower cost and less labour requirement. Keeping these facts in view herbicide Flurochloridon 25% CS was used to evaluate bio-efficacy against major weeds.

METHODOLOGY

The field experiment was conducted under the supervision of Department of agronomy, Banaras Hindu University, Varanasi during *Zaid/Spring* season of year 2014 and 2015 to evaluate the effect of different dose of flurochloridon 25% CS in sunflower. The experiment comprised of six treatments as given in the table no.1 replicated four times in Randomized Block Design. A water volume of 500 lit/ha was used for the application of the herbicide. The crop was grown with recommended package of practices for sunflower in the area. Data was recorded from an area enclosed in the quadrate of 1x1 m^2 randomly selected at three places in each plot. Weed species were separately counted from each sample and their density was recorded as average number/ m^2. Hand weeding was taken up at 20 and 40 DAS. Weeds data were subjected to square root transformation ("x+0.5) before statistical analysis. Collected data was statistically analyzed as per standard procedure to draw a valid conclusion.

RESULTS

The relevant data on weed density reveals that application

Table 1. Effect of different treatments on weed density, weed dry weight (30 days after application) and seed yield in sunflower (Data pooled over two years)

Treatments	Rate (ml/ha)	Weed density (no./m^2)		Weed dry weight (g/m^2)		Seed yield (t/ha)
		Monocot	Broad leaf weeds	Monocot	Broad leaf weeds	
Flurochloridon 20% CS	2500	5.12 (25.67)	4.20 (17.16)	4.25 (17.6)	4.34 (18.30)	0.775
Flurochloridon 20% CS	3125	3.50 (11.75)	2.72 (6.88)	2.85 (7.61)	2.47 (5.59)	1.22
Flurochloridon 20% CS	3750	3.27 (10.17)	2.57 (6.08)	2.75 (7.04)	2.39 (5.22)	1.26
Pendimethalin 30% EC	3300	4.11 (16.37)	3.32 (10.55)	3.45 (11.41)	3.23 (9.93)	0.99
Weed free (Hand weeding)	-	2.54 (5.96)	1.99 (3.465)	2.02 (3.59)	1.77 (2.65)	1.29
Weedy check (Control)	-	7.71 (58.97)	7.07 (49.51)	6.77 (45.3)	7.00 (48.54)	0.70
CD (P=0.05)	-	0.70	0.45	0.61	0.55	0.10

Figures in the parentheses are original values.

of flurochloridon 20% CS at 3750ml/ha as pre emergence recorded significantly lower population of all the weed species and was on par with flurochloridon 20% CS at 3125ml/ha. Both these treatments were superior to standard check treatments i.e. pendimethalin 30% EC. The weed dry weight was also less in treatments having lower density of weeds. However, all the herbicide treatments were superior to untreated control in reducing weed growth at all the stages of observation. Maximum yield of sunflower was recorded in hand weeding treatment followed by flurochloridon 20% CS at 3750 ml/ha but did not differ significantly from flurochloridon 20% CS at 3125ml/ha. Both these treatments had significantly higher yield than standard check treatment.

CONCLUSION

Based on present study, it can be concluded that flurochloridon 20% CS at 3125-3750 ml/ha as pre-emergence is safe for sunflower crop. This rate of herbicide is effective against most of the present monocot and dicot (BLW) weeds observed in sunflower crop.

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Spent wash and cropping sequence: A method to convert rocky barren landinto crop cultivation

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Large areas of barren and uncultivable terrain as developed from superficially subdued basalt igneous rocks exist in peninsular India. These lands are porous, shallow in depth, gravelly, low in organic matter, high bulk density and poor water retention capacity. There is general lack of techniques for the quicker disintegration of the *murrum* so that the land can be put into cultivations. Distilleries, one of the most important agri-based industries in India, produce ethyl alcohol from molasses, generate large volumes of spentwash(SW). Approximately 40 billion litres of SW are generated per annum from 285 distilleries in the country (Chhonker*et al*., 2000). SW contains considerable amounts of organic matter and plant nutrients; these may act as a source of plant nutrients and have been reported to increase the yield of the crops (Pathak *et al*., 1999). However, as the SW contains a considerable quantity of salt, its indiscriminate use for a long time has the risk of deteriorating the properties of the soil. Within a cropping system, degree and stability of aggregation depend on management e.g. nature of crops (cereals or pulses) or fodder; annual or perineal, seasonal or annual cultivation, nutrient requirement, irrigation, etc. The other alternative can be to get benefits from differential rhizo-depositions and crop residues under various cropping systems in the region.Availability of information on effect of cropping system and continuous application of SW or PME on physical and chemical properties of *murrum*is meagre.Therefore, a long term experiment has been initiated at ICAR-NIASM farm to study the impact of these factors on *murrum* disintegration.

METHODOLOGY

Experimental land was a barren basaltic rocky terrain with soil depth that seldom exceeded 0.3 m and. Therefore to hasten the pace of disintegration and soil development, the principle of physical (mechanical) along with chemical weathering processes were adopted. In mechanical process, parental rocks were targeted to be disintegrated into smaller sized either by blasting or ripping.The hard rocky portions left in patches after chaining and ripping by the heavy dozers were shattered by micro-blasting.Long term field experiment has been initiated in 2012 to study the impact of spent wash and cropping systems in inducing *murrum*disintegration. A total of 13 treatments; 10 under irrigated viz. sugarcane cropping with and without SW, soybean-wheat, lucerne, maize-sorghum fodder, subabul and napier grass and three under rainfed conditions viz., subabul, anjan grass and sorghum, being replicated four times in randomized block design. The SWhas been initially applied @ 0.4 million l/ha. Thereafter, dhaincha was cultivated and incorporated at 40 DAS. Initially the soil fraction was only about 23 per cent while rest is different sized gravels. Crops were planted during *rabi* and recommended package of agronomic practices was followed.

RESULTS

After completion of three year experimentation,amongst different cropping sequences Napier crop has recorded maximum *murrum* disintegration (37.89%), which may be due to its large quantity of fibrous roots. It has been observed that treatment comprising SW generated in 3.08 to 3.74% higher *murrum* disintegration due to its acidic nature. Overall, sugarcane crop along with annual application of SWhad registered maximum *murrum* disintegration (41.28%).So, due to interactive effect of crops, SWand irrigation the rate disintegration of *murrum* has followed the trend: Sugarcane + SW> Soybean-Wheat + SW> Napier > Sugarcane >Subabul >Soybean-Wheat > Lucerne > Subabul (R-Rainfed) > Maize-Fodder Sorghum> Control + SW> Anjan (R) > Fodder Sorghum (R)> Control. Application of SW also improved growth and yield of crops due to its high organic carbon content (4.2%).Sugarcane equivalent yield was recorded maximum in Sugarcane + SW(9.74 t/ha/yr) which was significantly superior to all other treatments and has followed the decreasing trend in the order of Sugarcane + SW> Napier > Sugarcane > Soybean- Wheat *fb* wheat residue incorporation + SW> Lucerne > Soybean- Wheat > Maize- Fodder sorghum in irrigated condition and Anjan > Fodder Sorghum in rainfed condition.

CONCLUSION

On the basis of three year experimentation it can be inferred that the sugarcane cultivation along with annual appli-

Table 1. Sugarcane equivalent yields and disintegration of *murrum* under various treatments

Treatment	Sugarcane equivalent yield (t/ha)	Fraction of < 2 mm soil particles (%)	Fraction of 2-4 mm particles (%)	Fraction of 4-6.3 mm particles (%)
Control (Left as such)	-	25.26	16.20	5.72
Control + Spent wash	-	28.47	13.64	5.56
Irrigated				
Sugarcane	6.58	35.78	10.63	4.96
Sugarcane+ Spent wash	9.74	41.28	8.64	4.15
Soybean-Wheat	4.85	34.44	11.27	4.85
Soybean– Wheat- Spent wash	5.94	39.80	8.96	4.26
Lucerne	5.20	32.35	11.87	5.28
Maize- Fodder sorghum	3.68	31.15	12.06	5.89
Subabul	-	34.76	11.02	4.62
Napier grass	6.65	37.89	9.51	4.50
Rainfed				
Subabul	-	31.25	12.43	5.30
Anjan	7.50	27.98	13.90	5.55
Sorghum	3.83	27.25	14.13	5.42
CD (P=0.05)	3.43	3.48	1.94	1.07

cation of spentwash @ 0.4 million/ha can be utilized as a viable technology to generate considerable income from barren and rocky land.

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Symposium 6

Efficient Soil, Water and Energy Management

Extended Summaries Vol. 1 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Homogeneous land unit based decision support system for enhancing water productivity of irrigated rice-wheat cropping system

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Development of Decision Support System (DSS) and its applicability to regional scales pertaining to irrigated rice-wheat cropping system is of paramount importance for judicious agricultural water management (Kumbhar and Singh, 2013; Bandyopadhyay *et al.*, 2012; Patel *et al.*, 2012). Moreover, delineation of homogeneous land units at regional scales using soil, water and vegetation parameter assist in deciding the best agricultural water management practices for enhancing agricultural productivity. Further, the crop production functions developed for each homogeneous units can be programmed in the DSS to generate alternative scenarios of irrigation water use and subsequent crop yield and water productivity information under different rice cultivation methods. Such information systems would assist the user in deciding the suitable cultivar and rice cultivation method based on soil texture and water availability to get optimum yield and maximum water productivity at regional scales.

METHODOLOGY

An attempt was made in this study to delineate homogenous land units (HLUs) in the rice-wheat cropping regions of Agro-climatic Region (ACR)-VI encompassing Punjab and Haryana states of India based on the soil texture, rainfall and ground water depths. A DSS was developed using the experiment generated data, secondary data base besides validated crop model based crop-water production functions pertaining to three rice cultivation methods [*viz.* direct seeded rice (DSR), SRI and puddled/conventional cultivation] under two different irrigation regimes for the delineated HLPUs of ACR-VI. Generated data base of different rice cultivars (*viz.* PUSA-1509, PRH-10, PUSA-1460, Pusa Sugandh-5, PUSA-1121, PUSA-44, PR-122) and wheat cultivars (*viz.* HD-2967, DBW-17, PBW-621, HD-3086, WH-1105) in sandy loam and clay loam soil textures under full and deficit irrigation regimes with three rice cultivation methods were used for development of production functions using the validated DSSAT and AquaCrop models. Using this procedure, production functions were developed for seventeen different HLUs' in the study region and were coded in JAVA programming language using JDK 1.7 and NetBeans 7.2 software. Grain yield, irrigation schedule, effective rainfall, total water used and estimated water productivity of different rice and wheat cultivars and their all possible combinations of rice-wheat cropping system was incorporated in the data base of DSS. The programming construct *if…then...else* was used in the DSS to assist the user in obtaining a desired output based on a given query pertaining to each HLU to obtain the water productivity of crops or cropping systems under DSR, SRI and conventional puddle transplanted method of rice cultivation. DSS also provides different scenarios of grain yield, irrigation water use, total water use, water productivity and water savings for different cultivars of rice and wheat for each delineated HLU. Besides this, a module was coded in the DSS to estimate the possible rise of ground water table due to saving of irrigation water by cultivating rice using DSR and SRI methods of cultivation as compared to the puddled method of rice cultivation in a particular HLU.

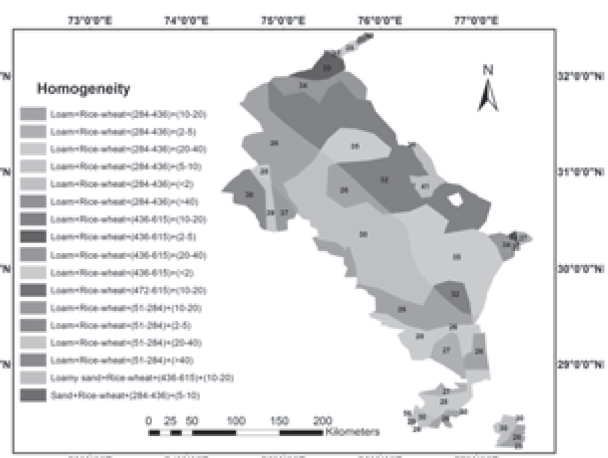

Fig. 1. Delineated Homogeneous Land Units in the rice-wheat cropped regions of ACR-VI

RESULTS

Delineated HLUs of ACR-VI is presented in Fig. 1. It can be observed from the figure that there are 17 distinct units having uniform soil texture, crop type, rainfall and water table depths. Production function developed for PUSA-1460 cultivar under DSR method of cultivation using validated DSSAT crop model for varying irrigation water depth and corresponding crop yield is presented in Fig. 2. Similar production functions are developed for all experimented cultivars for both rice and wheat crops are were coded in the DSS. Captured screen of the DSS for a HLU with PUSA-1460 rice cultivar under puddled method of cultivation is presented in Fig. 3. It can be observed from Fig. 3 that the user can input the rainfall depth and amount of irrigation to obtain expected yield of crop. It was also observed that the crop yield increased up to a given depth of water application and after that there was no significant increase in grain yield. This information will assist the user to apply water upto the optimum yield level to save water and enhance productivity in the region. The drop down menus with information of different rice and wheat cultivars can be used for acquiring information of irrigation water used and subsequent crop yield of different cultivars. Besides this, the DSS is also having a module to compare the grin yield and subsequent saving of water under DSR, SRI and puddled methods of rice cultivation followed by wheat in rice-wheat cropping system. The water saved due to adoption of DSR and SRI methods as compared to puddled method or area share basis is also estimated by the DSS. Subsequently, the information on possible ground water rise due to such water saving is also estimated by the DSS. The homogeneous land parcel unit based DSS developed in this study would assist the stake holders and policy makers in selection of different cultivar and the possible grain yield under different rice planting

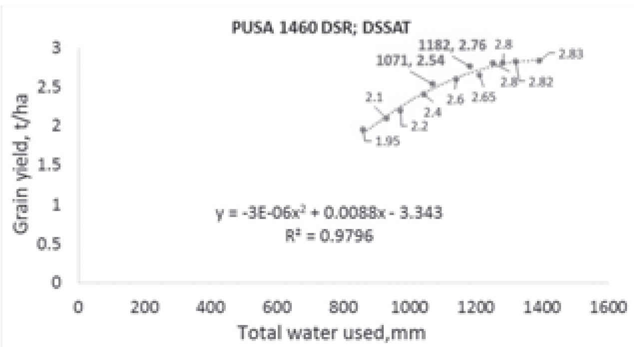

Fig. 2. Crop yield and water use production function of PUSA-1460 rice cultivar under DSR cultivation method developed using validated DSSAT model

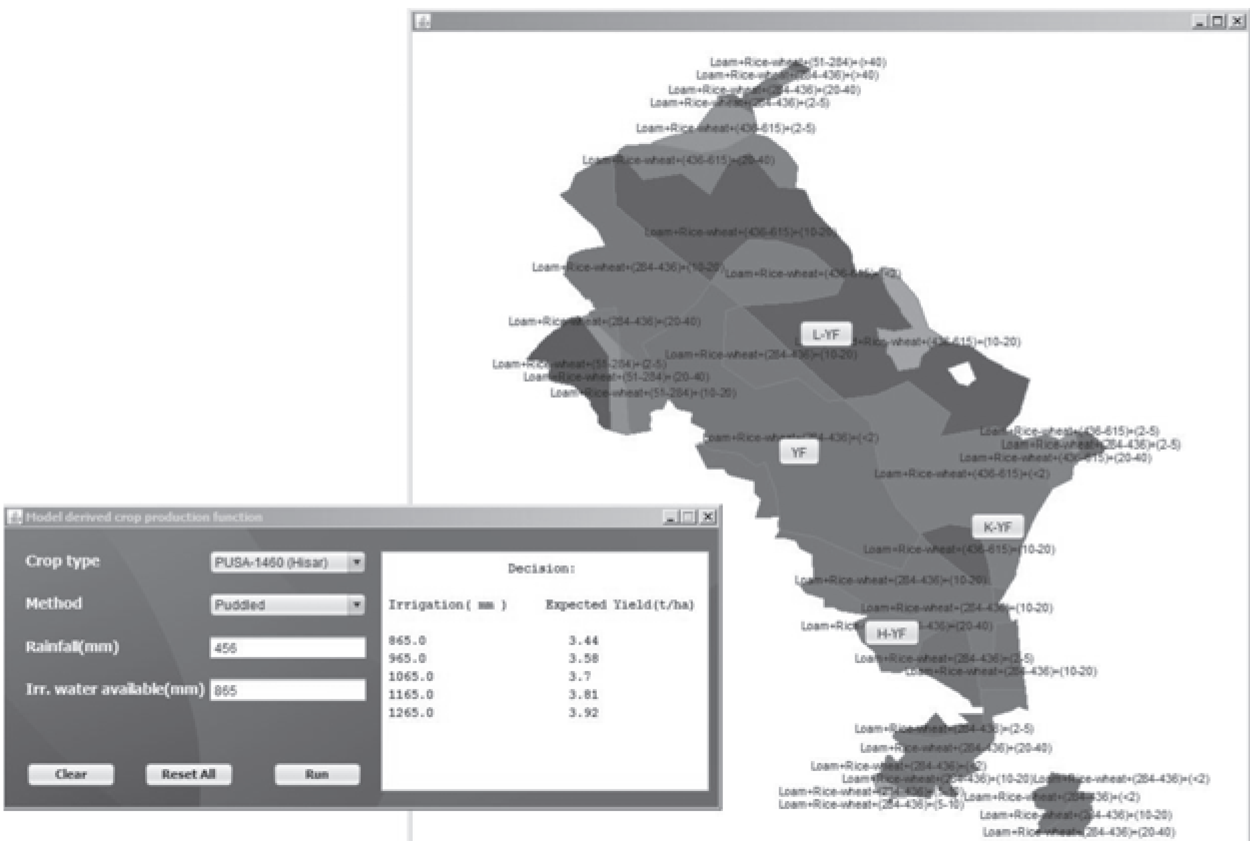

Fig. 3. Captured Screen of DSS with the expected grain yield and irrigation water use information for PUSA-1460 cultivar for a given HLU

method based on water availability situations to enhance water productivity of the ACR VI region. Developed DSS is also flexible enough to include the data generated from similar experiments or secondary data sources for its wider applicability to other such regions.

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Water productivity and yield of summer rice under different moisture regimes in eastern regions of Indian subcontinent

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Rice has largest contribution to sustained self-sufficiency in food grain production. Development of input-responsive varietal introduction capable of achieving high yield potential particularly under irrigated ecology is responsible to this attainment. The area under total rice growing eco-system of the country is 44.0 mha, amongst which upland rice shares only 7.0 mha and lowland covers 17.0 mha. The productivity of upland and lowland rice are 0.65 and 1.9 t/ha, respectively. In West Bengal total rice growing area is 5.6 mha, amongst which up and lowland rice are having 1.01 and 1.85 mha, with the productivity levels of 0.95 and 2.01 t/ha, respectively. Rice both under low/up land ecosystem is primarily grown under rainfed conditions having production constraints of entirely opposite in nature. Very low productivity under rainfed eco-system is mainly due to yield depressing factors caused by biotic stresses across the rice ecology, either resulted from excess or deficit water due to uneven and erratic distribution of annual rainfall. The coverage of rice under irrigated eco-system is 21.0 mha that is 47 % of the total rice crop grown with higher production potential. In West Bengal, rice under irrigated eco-system is 2.52 mha that is 45% of the total rice grown area in the state. Not more than 50% of yield potential could be made possible to realize till now from irrigated rice ecology mainly due to managerial gap of integrated input management and availability of quality seeds. Rice grown under risk prone zone is traditionally *boro*-growing tract that would be categorized either flooded or deep water rice in ‘high potential low productive zone’ where there is still possibility of enhancing rice production as well as productivity up to a furthest extent. High cost of production with less remunerative support prices of rice has made the rice cultivation as losing profession.

The average consumptive use of rice varied 150 to 250 cm. Total water requirement of rice is around 180 cm during rainy season and 120 cm during summer season. 80% of this total requirement during rainy season comes from rainfall whereas only 10-15% of total water requirement for summer rice comes from surface sources and remaining from groundwater source. Rice both under low/up land ecosystem is primarily grown under rainfed conditions having production constraints of entirely opposite in nature. Very low productivity under rainfed eco-system is mainly due to yield depressing factors caused by biotic stresses across the rice ecology, either resulted from excess or deficit water due to uneven and erratic distribution of annual rainfall. The coverage of rice under irrigated eco-system is 21.0 mha that is 47 % of the total rice crop grown with higher production potential. Not more than 50% of yield potential could be made possible to realize till now from irrigated rice ecology mainly due to managerial gap of integrated input management and availability of quality seeds. Rice grown under risk prone zone is traditionally *boro*-growing tract that would be categorized either flooded or deep water rice in 'high potential low productive zone' where there is still possibility of enhancing rice production as well as productivity up to a furthest extent. Growing rice with minimal water implies rice cultivation through water saving technologies where enhancement of water productivity has got paramount importance to bring back rice growing as profitable proposition. On the contrary, growing rice, now a day can only ensure livelihood security where the resource poor farmers are operating, if the attitudes of the rice grower remain unaltered. The alternative use of rice co-products that includes high quality rice powder, value added puffed, popped and flake rice could be the agenda of the hour along with nutritionally enriched genotypes those could be evaluated and selected for conserved biodiversity and for preparation of rice cake and pudding while rice productivity level was almost static since last few years. The water-nutrient productivity of the rice-based system is to be optimized by improving soil environment. Organic fertilizers could play an important role in this direction to develop and providing balance nutrition for rice and its subsequent crops and quality produce in Indo-Gangetic basin. Thus, growing rice with adoption of water saving technologies are only option to maintain sustainability in agricultural production and keep food basket full of the Asian rice bowls. Drum seeding, system of rice intensification and aerobic rice cultivation has come forward as water saving rice growing which could drastically reduced the water requirement without much adverse effect on grain yield of rice.

Water management of wet seeded rice during kharif *season using drum seeder*

Drum seeding of wet rice was done during *kharif* season. Land situation was medium upland having good drainage after seeding. Shallow puddling was done for drum seeding in clay soil. One pass of Power tiller followed by a bullock drawn country plough was used for puddling. Seeds were soaked for 24 hours and incubated for sprouting (0.5 cm). Philippines 12-row plastic drum seeder was used. Calibration of seed dropping was done through closing the excess whole by polythene tape. Two farmers under the Case Study 1 and 2 participated in the adaptive trial (Table 1). Crop sequence was Rice-rice. Performances of wet direct seeding was compared against transplanted rice. Performance of wet seeded rice in medium land situation of the command was good as compared to transplanted one. Yield increased to the tune of 22.8 and 14.7% in case of variety Ratna and IET 4094. Plant growth and yield parameters also supported the fact. Wet seeded rice matures one week earlier than transplanted one. Farmers are not motivated with the drum seeding due to high rainfall during July and August and there is a problem of plant emergence due to stagnation of water in the field after wet seeding of sprouted seeds. Drum seeding may be advocated at les rainfall area and in upland area (Zaman, 2012).

Water management under system of rice intensification

SRI is a methodology for increasing the productivity of irrigated rice by changing the management of plants, soil, water and nutrients. These practices contribute to both healthier soil and plants supported by greater root growth and the nurturing of soil microbial abundance and diversity. It is based on a number of agro-ecological principles with good scientific foundations. SRI concepts and practices have also been successfully adapted to upland rice. System of Rice Intensification (SRI) involves the use of certain management practices, which together provides better growing conditions for rice plants, particularly in the root zone, than those plants grown under traditional practices. Four components of SRI

Table 1. Crop performances of drum seeding during *kharif* season

Study items	Farmer 1		Farmers 2	
	DSR	TR	DSR	TR
Area (m^2)	22 X 19	22 X 19	39 X 41	39 X 41
Date of sowing	27.7.06	27.7.06	27.706	27.7.06
Variety	Ratna	Ratna	IET 4094	IET 4094
Line spacing (cm)	20 X conti	20 X 15	20 X conti	20 X 15
Seed rate (kg/ha)	40	40	40	40
NPK (kg/ha)	60:30:30	60:30:30	60:30:30	60:30:30
Date of harvesting	2.11.06	8.11.06	2.11.06	8.11.06
Crop performance				
Plant height (cm)	85	81	92	86
Effective tillers/m^2	381	303	346	325
Panicle length (cm)	21.9	23.1	20.5	21.3
Panicle weight (g)	1.65	1.79	1.46	1.56
Grain yield (t/ha)	4.30	3.53	3.90	3.40
Straw yield (t/ha)	6.05	4.70	5.40	4.85
Harvest Index (%)	41.7	42.8	41.9	42.8

include early planting (12 days' old single seedlings, wider spacing), limited irrigation (2-3 cm depth after the appearance of hairline cracks), weeding and application of more compost and building soil organic matter content. Increased weeding is required, because rice fields are not kept continuously flooded. But farmers report that with SRI methods, their rice plants are better able to resist damage from pests and diseases, making agrochemicals usually unnecessary. Compost gives even better results than does fertilizer with SRI methods. With SRI there can be water savingsof around 50%.

Water management of rice under aerobic conditions

Traditional lowland rice with continuous flooding in Asia has relatively high water inputs. Because of increasing water scarcity, there is a need to develop alternative systems that require less water. "Aerobic rice" is a new concept of growing rice: it is high-yielding rice grown in non-puddled, aerobic soils under irrigation and high external inputs. To make aerobic rice successful, new varieties and management practices must be developed. Because of its low water use, aerobic rice can be produced in areas where lowland rice cannot (anymore) be grown. Since aerobic rice is targeted at water-short areas, socio-economic comparisons must include water-short lowland rice and other upland crops. The development of high-yielding aerobic rice is still in its infancy and germplasm still needs to be improved and appropriate management technologies be developed. Bouman, Peng, Castaneda, Visperas, (2005). Reported the highest yields under aerobic conditions were realized in the dry season with the improved upland variety Apo (5.7 t ha^{-1}) and the lowland hybrid rice Magat (6 t ha^{-1}). On average, the mean yield of all varieties was 32% lower under aerobic conditions than under flooded conditions in the dry season and 22% lower in the wet season. Total water input was 1240-1880 mm in flooded fields and 790-1430 mm in aerobic fields. On average, aerobic fields used 190 mm less water in land preparation, and had 250-300 mm less seepage and percolation, 80 mm less evaporation, and 25 mm less transpiration than flooded fields. Without plastic sheets to prevent seepage in flooded fields, the water productivity of rice (with respect to rainfall and irrigation water input) under aerobic conditions was 32-88% higher than under flooded conditions.Choudhury, Singh, (2007) reported that yield of aerobic rice cultivated on raised-beds under different soil-moisture regimes was considerably less, varying from 12-24% at field capacity to 40-46% in beds irrigated as compared with the direct-seeded flat land at 20 cm row spacing. Thus the aerobic rice left an enormous scope of future study to grow rice with less water enhancing water productivity.

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Impact of planting layouts on yield attributes and yields of summer sesamum

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Sesamum is an East Indian important oilseed crop belongs to family pedaliaceae and the genus Sesamum. Even though, it is grown all over the world for its importance in food, medicine and industries. The crop is highly drought tolerant, grows well in most kind of soils, regions and is well suited to different crop rotations. In reality, sesame is mostly grown under moisture stress with low management input by small holders. Among the oilseed crops, sesame ranks first for having the highest oil content generally varies from 48 to 52 per cent and contains 6355 kcal/kg energy in seeds. The seed is also rich source of proteins (20-28%), sugars (14-16%) and minerals (5-7%) particularly nutrients like calcium (1.31%) and phosphorus. Hence, sesamum is known as "queen of oilseed crops" by virtue of the excellent quality of oil as used for domestic purpose. It is one of the most important ancient edible crops grown in India next to groundnut and rapeseed-mustard. India is now considered as the basic centre of origin. The highest production is in China with higher productivity. India ranks first in area (45%), production (32%) and export (40%) of sesamum in the world. The area under sesamum in India was 18.1 lakh ha with the production of 7.32 lakh tonnes having productivity of 354 kg/ha during 2012-13. Optimizing of plant spacing and management of pest is very important for improving seed yield in a particular environment. Keeping this in view and the contradictory findings about of different crops, this study was designed to see the effect of planting layouts on growth, yield and quality of summer sesamum (*Sesamum indicum* L.) in relation to weather parameters.

METHODOLOGY

The field experiment was conducted during summer season of 2014 on sesamum (cv.) 'JLT-408' at Experimental Farm of Agril. Meteorology Department, College of Agriculture, Pune, Maharashtra State. The experiment was laid out in split plot design with three replications. Twelve treatment combinations were formed considering main plot treatments comprise four planting layouts and three sub-plot treatments of mulches.

RESULTS

Significantly higher seed weight/plant (3.84 g) was obtained with ridges and furrows spacing at 45 cm x 10 cm as compared with the other planting layouts. The weight of straw/plant was significantly influenced by different planting layouts. The highest weight of straw/plant (12.15 g/plant) was obtained with the ridges and furrows spacing at 45 cm x 10 cm as compared with the rest of the planting layouts. Treatments of planting layouts showed statistically non significant effect on test weight. Treatments of planting layouts showed significant effect on the grain yield. The significantly more grain yield (850.3 kg/ha) was obtained in the planting layout as ridges and furrows spacing at 45 cm x 10 cm than rest of the planting layouts. Different planting layouts showed significant effect on the straw yield. Among the planting layouts significantly maximum straw yield (1535.3 kg/ha) was obtained in ridges and furrows at 45 x 10 cm^2 than rest of the treatments but it was found at par with ridges and furrows at 30 x 15 cm^2. The harvest index of summer sesamum was found differed due to planting layouts. The maximum harvest index (35.64 %) was noticed in ridges and furrows at 45 x 10 cm^2 than other planting layouts. Amongst the treatments, sowing of sesamum on ridges and furrows at 45 x 10 cm^2 spacing was found significantly superior in seed weight/plant (3.84 g) and grain yield (850.33 kg/ha).

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Optimizing water application field parameters for higher use efficiency in sugarcane under sub- tropical Indian conditions

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Under subtropical conditions the sugarcane crop passes with three situations *viz*., moisture deficit during summer (formative phase), optimum moisture during early rainy season followed by water logging (grand growth phase). There is need for judicious management of water in all the three situations. Due to longer crop duration water requirement of sugarcane is high and varies from 140 to 180 ha cm in north Indian conditions. The life cycle of the crop passes through all the three seasons *viz*., summer, winter and rainy. During raining season if amount and distribution of rainfall is normal, the water requirement of the crop is fulfilled. During summer and post rainy season crop depends fully on irrigation. Flat bed planting followed by flood method of irrigation is most common practice in sugarcane under subtropics. Under Flat-Flood (F-F) system of sugarcane cultivation the water use efficiency is very low (30-35%) and loss of water is more, through evaporation, surface runoff, deep percolation and seepage. The loss of nutrient is also high in such systems. The water requirement of sugarcane in India varies widely from 1143 to 3048 mm (Hapase *et al*., 1990). As the water is becoming scarce, it is becoming important to conserve and save the available water. New and perplexing water issues are creating nationwide demand for alternative and innovative water management solutions. Furrow method of irrigation is more efficient as the surface area for evaporation is reduced. Furrow method or skip furrow method of irrigation was developed as water saving/increasing WUE mechanism (Singh *et al*., 2014). Field application parameters like discharge and cut of length plays a vital role in improving the irrigation efficacy but these parameters have not been optimized yet for sugarcane crop. Hence, the present study was undertaken with optimizing field application parameters to improve the irrigation use efficiency.

METHODOLOGY

Field experiments were conducted during 2013-14 and 2014-15 at the Research Farm of Indian Institute of Sugarcane Research, Lucknow (26^0 56' N, 80^0 62' E and 111 m above sea level), Uttar Pradesh, India falling in subtropical belt of sugarcane cultivation. The soil of the experimental field was sandy loam (*Inceptisol*), neutral in reaction (pH 7.6), low in organic carbon (0.33%) and available N (187.5 kg/ha), medium in available P (19.7 kg/ha) and K (239.4 kg/ha). The field experiment was conducted to optimize the irrigation application parameters viz. furrow length, discharge rate and cut off length respectively (in furrow irrigation system). The treatment consisted of two length of furrows (F1-50 m and F 2- 75 m) and six discharge and cut off length (D1: Furrow- 8 lps +75% cut off length, D2: Furrow- 10 lps + 75% cut off length, D3:Furrow-8 lps +85% cut of length, D4: Furrow-10 lps +85% cut of length, D5: Border -75% cut off length and D6: Border- 85% cut off length). Experiment was laid out in split plot design replicated thrice. The findings of the experiment resulted in bringing out the best irrigation application parameters with significant reduction in total water use. Soil moisture spread along the furrow viz. head, middle and tail region were also characterized. Impact of different treatments on growth, yield and juice quality parameters were also observed and assessed.

RESULTS

Significantly highest shoot count (168.6 thousand/ha at 180 DAP), Number of millable canes (106.6 thousand/ha), cane yield (54.5 t/ha) and sugar yield (6.88 t/ha) were recorded with the discharge of 10 lps + 85% cut off length (Table 1). The combination of 10 lps+85% cut off has also resulted in highest IWUE of 2239.7. This combination has also saved 41% of total irrigation water as compared to border irrigation method (general farmers practice). A strong correlation was observed between the total water used and yield. However, yield per se was not significantly different between the check (border irrigation- 85% cut off length) and highly water efficient system (10 lps+85% cut off). Juice quality parameters *viz*. brix pol and purity were not found to be significant among any treatments. The effect of different amount of discharge and cut off length was also measured on moisture flow pattern. It showed a clear downward flow of water in all the furrow irrigation combination methods with required water availability at tail end region. Treatment of furrow-10 lps+85% cut off length and furrow-10 lps+75% cut off length showed the optimum discharge rate to move water towards tail end.

CONCLUSION

Therefore it may be apprehend that to conserve and save irrigation water a cut at 85% or 75% furrow length and discharge of 10 lps is found to be efficient to soak the water at tail end of the field. This system improved the irrigation water use efficiency. Border irrigation method has shown a total irregular pattern of flow with ups and downs in head, middle and tail region along different depths resulting in inefficiency

Table 1. Effect of different treatments on yield, quality and water use efficiency in sub-tropical sugarcane

Treatment	Germination at 45 DAP (%)	Tiller count at 180 DAP (000/ha)	NMC (000/ha)	Cane Yield (t/ha)	Sugar Yield (t/ha)	IWUE (kg/ha-cm)
Furrow length						
50 m	34.69	144.4	80.2	45.2	6.55	1659.0
75 m	34.84	153.2	109.3	50.9	6.32	1942.5
SEm ±	0.94	3.27	4.69	2.23	1.21	-
CD (P= 0.05)	NS	9.61	13.69	NS	NS	-
Discharge and cut of length						
8 lps + 75% cut of length	34.56	130.2	83.4	43.4	6.37	1956.9
8 lps+ 85% cut of length	35.32	140.1	89.8	45.2	6.10	2220.3
10lps+ 75% cut of length	34.40	138.5	89.8	45.1	5.92	1729.8
10lps+ 85% cut of length	34.68	168.6	106.6	54.5	6.88	2239.7
Border-75% cut of length	34.73	147.1	94.1	47.5	6.23	1356.5
Border-85% cut of length	34.89	168.3	104.7	53.3	7.11	1301.3
SEm ±	0.83	3.48	5.29	2.76	0.12	-
CD (P=0.05)	NS	10.23	15.49	8.11	0.25	-

of water use and should be avoided in scheduling irrigation in sugarcane.

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Studies on irrigation scheduling and weed management in chickpea (*Cicer arietinum* L.) under different land configurations

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Chickpea is the most important *Rabi* pulse crop of India. Ridge/Broad Bed Furrow sowing are gaining popularity in case of heavy soils. Flood irrigation in flat bed sowing in heavy soils badly damages the chickpea crop due to water stagnation. If the chickpea is sown on ridge- furrow or broad bed furrow method, less irrigation water is required to crop under water stress conditions and improves seed size and grain yield. Weeds are a serious constraint in increasing production and easy harvesting in chickpea. Chickpea is a poor competitor to weeds because of slow growth rate and limited leaf area development at early stage of crop growth and establishment. Keeping in view these factors, this experiment was planned to study the impact of land configurations, irrigation scheduling and weed management on yield and to work out net monetary return and benefit: cost ratio of the treatments

METHODOLOGY

A field investigation was conducted at Agronomy Research Farm, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (M.P.) during *Rabi season*of 2013-14. The soil of the experimental field was Sandy clay loam. The treatments comprised three land configurations (*viz.*, Flat bed, Broad bed furrow and Ridge-furrow) and three irrigation schedules (*viz.,* Irrigation at branching, Irrigation at pod development, Irrigation at branching and pod development) as main plot treatments and three weed management (*viz.,* Weedy Check, Hand weeding twice at 25 and 50 DAS, Pendimethalin @1.0 kg/ha PE)as sub-plot treatments were laid out in split plot design with three replications. Chickpea variety JG 322 at the seed rate of 80 kg/ha was sown with different land configuration methods on flat bed, broad bed and ridge-furrow. The recommended doses of fertilizer 20: 60: 20 N: P_2O_5: K_2O kg/ha was applied uniformly. Entire quantities of NPK were applied as basal at the time of sowing.

RESULTS

Perusal of the data Table indicates that among the different land configuration methods, ridge-furrow method resulted in significantly higher seed yield (1512.33 kg/ha) which was 10.82 and 19.78 % more in comparison to broad bed furrow and flat-bed methods, respectively. Different land configurations exhibited almost similar trend in haulm yield and harvest index as observed in case of seed yield. These results in agreement with the findings of Patel *et al.* (2009). Irrigations at branching and pod development gave appreciably higher seed yield of 1483.33 kg/ha which was 11.12 and 14.22 % higher than that irrigation at pod development and at branching alone, respectively. Haulm yield and harvest index indicated similar influence due to irrigation levels as noted in case of seed yield. Similar results are also advocated by Munirathnam and Sangita (2009). Among the different weed control treatments, application of Pendimethalin @ 1.0 kg/ha PE as pre emergence resulted in 52.17 % more seed yield (1592.74 kg/ha) over weedy check. However, hand weeding twice registered markedly higher seed yield of 1719.56 kg/ha being 7.37 % more in comparison to application of Pendimethalin @ 1.0 kg/ha PE (1592.74 kg/ha). The weed management treatments exerted almost similar influence onhaulm yield and harvest

Table 1. Seed yield, haulm yield, harvest index and economics of chickpea as influenced by different treatments

Treatment	Seed yield (t/ha)	Haulm yield (t/ha)	Harvest Index (%)	Net Monetary Returns (Rs/ha)	Benefit: Cost Ratio
Land Configuration					
Flat Bed	1.21	2.99	28.78	29921	1.95
Broad Bed Furrow	1.35	3.25	29.19	36273	2.14
Ridge-Furrow	1.51	3.56	29.61	43991	2.40
SEm±	0.029	0.072	0.07	1476	0.05
CD (P=0.05)	.089	0.217	0.20	4426	0.14
Irrigation Schedules					
Irrigation at branching	1.27	3.14	28.71	33080	2.05
Irrigation at pod development	1.31	3.17	29.29	35017	2.12
Irrigation at branching and pod development	1.48	3.51	29.57	42089	2.31
SEm±	0.029	0.072	0.07	1476	0.05
CD (P=0.05)	0.089	0.217	0.20	4426	0.14
Weed management					
Weedy Check	0.76	1.88	28.75	10340	1.37
Hand weeding twice (25 and 50 DAS)	1.72	4.05	29.74	50343	2.45
Pendimethalin @1.0 kg/ha PE	1.59	3.89	29.07	49504	2.66
SEm±	0.020	0.048	0.06	1028	0.03
CD (P=0.05)	0.060	0.138	0.18	2951	0.10

index as observed in case of seed yield. These results are also supported with the finding of Singh *et al.* (2008)

Among the land configurations, Ridge-furrow method registered statistically higher net monetary returns (₹43991/ha) and benefit: cost ratio (2.40). Irrigations at branching and pod development resulted in appreciably higher net monetary returns (₹42089/ha) and benefit: cost ratio (2.31) over rest of irrigation schedules. In all the different weed control treatments, hand weeding twice gave significantly lowerbenefit: cost ratio (2.45) due to enhanced higher labour cost for weed control. Pendimethalin @ 1.0 kg/ha PE registered higher net monetary returns (₹49504/ha) and benefit: cost ratio (2.66), respectively over weedy check. It was noticed that hand weeding twice had on increment of ₹839/ha only in comparison to Pendimethalin @ 1.0 kg/ha PE.

CONCLUSION

Based on the above findings it could be concluded that ridge-furrow method with two irrigations at branching and pod development as well as application of Pendimethalin @1.0 kg/ha as pre emergence or hand weeding twice (25 and 50 DAS) resulted in higher yield, net monetary returns and benefit: cost ratio of chickpea under sandy clay loam soil of Jabalpur (M.P.)

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Maximization of wheat productivity by hydrogel application with irrigation and nutrient management

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Water scarcity is the major constraint in Indian agriculture to increase productivity of food grain crops particularly in case of rice and wheat for achieving the food security of 127 crore population. Efficient utilization of available water by synchronizing the demand by crop with its application at proper growth stage along with some other ways to increase the water holding capacity of soil for longer period *viz*. hydrogel polymers may become as the hopeful options to deal with the issue of yields maximization under water stress condition.

METHODOLOGY

To improve the wheat productivity under limited water availability, an experiment was conducted at Norman E. Borlaug Crop Research Centre, GB pant University of Agriculture and Technology, Pantnagar for two consecutive years 2011-12 and 2012-13 with different irrigation regimes, NPK levels and hydrogel doses. The experiment was conducted in split-plot design and three replications with three irrigation regimes in main plot and six combinations of hydrogel and nutrient doses in sub plots (Table 1). All the other agronomic practices of sowing, weed control, plant protection were followed in similar way for all the treatments.

RESULTS

The number of irrigation with their application at different stages significantly affected the yield characters of wheat *viz.* yield, earheads/m^2 and 1000 grain weight. The equivalent yield of wheat produced with irrigating the crop for two (at crown root initiation and boot leaf) and four (at crown root initiation, tillering, boot leaf and milky stages) times. Application of hydrogel with 2.5 and 5.0 kg/ha produced higher amount of all the yield attributing characters as compared to the other treatments. Wheat grain was found to be higher by 105 and 108% in application of 100% of recommended NPK along with hydrogel @ 2.5 kg/ha and 5.0 kg/ha, respectively over no hydrogel application. The yield response of wheat crop with hydrogel application might be due to the improved physico- biological propertied of soil (*viz.* porosity, bulk density, water holding capacity, microbial growth, etc.). Meena *et al.* (2015) has been also reported the similar results of hydro-

Table 1. Effect of application of hydrogel and irrigations on wheat (pooled data of year 2010-11 and 2011-12)

Treatment	Grain yield (t/ha)	Ear head/ m^2	Grains/ ear head	1000 grain weight (g)
Irrigation stages				
No irrigation	3.28	338.5	26.9	36.4
CRI+ BL	3.82	370.5	28.4	36.6
CRI+ T+BL+M	3.81	376.0	28.0	37.7
CD (P= 0.05)	0.33	23.6	NS	1.2
Hydrogel				
100% NPK without hydrogel	3.65	356.5	28.8	36.2
100% NPK with 2.5 kg/ha hydrogel	3.83	377.5	27.7	37.4
100% NPK with 5.0 kg/ha hydrogel	3.96	391.5	27.0	38.1
70% NPK without hydrogel	3.25	326.5	28.9	35.0
70% NPK with 2.5 kg/ha hydrogel	3.51	350.5	27.7	37.1
70% NPK with 5.0 kg/ha hydrogel	3.64	366.5	26.4	38.2
CD (P= 0.05)	0.16	10.1	2.5	2.8

(CRI: Crown root initiation, BL: Boot leaf, T: Tillering, M: Milking) gel application and nutrient management in wheat crop.

CONCLUSION

Wheat productivity may be increased by application of recommended NPK and 5 kg/ha hydrogel along with two irrigations at CRI and BL under water stressed condition.

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Effect of irrigation scheduling and nitrogen application on yield, water and nitrogen use efficiency of direct–seeded rice

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Rice (*Oryza sativa* L.) is the staple food of more than 50% of the world population and supplies 20% of total calories required by world and 31% required by the Indian population. Therefore provides food security to billions of people in India. Here, generally irrigated transplanted puddle rice (TPR) is grown which consume a lot of water. Further, with looming water threat under changing climatic conditions an additional 500 litres of water will be required to have 1 kg of rice in 2025 (Kukal *et al*., 2010). Direct–seeded rice (DSR) is one of alternative of TPR which requires less water, labour and tends to mature faster (Chauhan *et al*., 2012). The sowing of DSR is done under aerobic environment which avoids the puddling and maintains continuous moist soil conditions and thus reduces the overall water demand for rice culture. The infestation of weeds, nitrogen and iron deficiency are the major limiting factor in enhancing the DSR yield. There is hardly 30% recovery of applied nitrogen as most of the applied nitrogen through fertilizer is lost from the soil in various ways like through leaching, volatilization, denitrification and runoff kind of processes. One of the major factors contributing to low N use efficiency is the uniform application rates of N fertilizer to spatially variable landscapes. The adoption of alternative method of rice establishment with better nitrogen management practices to enhance the water and nitrogen use efficiency under increasing water shortage and changing climate is the need of hour. Therefore, an experiment was carried out to study the effect of irrigation and nitrogen on yield and yield attributes, and to optimise the nitrogen and water use efficiency in DSR.

METHODOLOGY

The field experiment was carried out to study the effect of irrigation scheduling and split application of nitrogen in direct–seeded rice (DSR) during the *kharif* season of 2015 at the research farm of ICAR-Indian Agricultural Research Institute, New Delhi, India. The farm was situated at latitude of 28°40' N and longitude of 77°12' E, altitude of 228.6 m above the mean sea level. The soil of the experimental field was sandy clay loam in texture having good water holding capacity. The soil was low in organic C and available N, medium in available P and high in available K at the experimental site. Soil was slightly alkaline in reaction with pH 7.9. The experiment was laid out in split plot design with 12 treatments combination of irrigation scheduling (0 kPa; 10 kPa, 20 kPa and 40 kPa irrigation scheduling threshold was maintained between tillering to flowering stages) in main plot and N application of 150 kg /ha as (control (N_0), ½ RDN basal+ ¼ at 2 week+ ¼ at 5 week and ¼ RDN basal+ ¼ at 2 week+ ¼ at 5 week+ ¼ at 9 week after sowing) in sub plot with three replication. Growth parameters, yield attributes and other biometrics observations were undertaken as per requirements for validation of findings. Soil and plant analysis were made following standard procedures in laboratory.

RESULTS

The findings indicated that all yield attributes and yield was observed with irrigation scheduling at 0 kPa i.e. in saturated condition which was found at par with maintaining water

Table 1. Effect of irrigation scheduling and N application on yield attributes and yield, agronomic and water use efficiency of direct–seeded rice.

Treatment	Effective Tillers/m^2	1000-grain weight (g)	Grain yield (t/ha)	Net returns (X 10^3/ ha) (kg grain increased/kg N applied)	Agronomic efficiency	Water use efficiency (kg/ ha-mm)
Irrigation scheduling						
0 kPa	370	23.0	4.83	45.0	2.94	4.26
10 kPa	364	22.8	4.68	45.1	3.55	4.63
20 kPa	353	22.3	4.24	39.2	8.59	4.56
40 kPa*	341	21.6	3.96	37.4	7.10	4.75
SEm±	5.5	0.19	0.13	1.59	0.93	0.140
LSD (*P*=0.05)	18.9	0.68	0.46	5.51	3.23	NS
Nitrogen application						
Control (N_0)	205	20.5	3.60	28.1	-	3.66
N_1**	279	22.9	4.62	44.8	6.92	4.76
N_2***	286	23.7	5.06	52.1	9.71	5.24
SEm±	2.65	0.09	0.06	0.83	0.47	0.064
LSD (*P*=0.05)	7.93	0.28	0.18	2.49	1.41	0.19

*10 kPa throughout the growing season except 40 kPa during tillering to flowering
**½ basal + ¼ at 2 week+ ¼ at 5 week
***¼ basal + ¼ at 2 week+ ¼ at 5 week + ¼ at 9 week

threshold in soil through irrigation at 10 kPa. Thereafter irrigation scheduling at higher threshold i.e. 20 kPa and 10 kPa throughout the growing season except 40 kPa during tillering to flowering recorded a decline in grain yield of DSR during the growing season. Likewise, the highest values of all these parameters were recorded with ¼ RDN basal+ ¼ at 2 week+ ¼ at 5 week+ ¼ at 9 week followed by ½ RDN basal+ ¼ at 2 week+ ¼ at 5 week. The maximum gross return (‘84.7 × 10³ /ha) and net return (‘45.1 × 10³ /ha) were recorded with irrigation scheduling at 0 kPa and 10 kPa, respectively. The split application of N as ¼ basal+ ¼ at 2 week+ ¼ at 5 week+ ¼ at 9 week recorded maximum gross return (‘88.7 × 10³ /ha) and net return (‘52.2 × 10³ /ha) followed by ½ basal+ ¼ at 2 week+ ¼ at 5 week N application. The different threshold of irrigation influenced the concentration and uptake of N in grain and straw of DSR. Likewise, the split application of N as ¼ basal+ ¼ at 2 week+ ¼ at 5 week+ ¼ at 9 week gave the highest values of N uptake and N use efficiency compared to no application of N.

CONCLUSION

On the basis of the findings, it can be concluded that alternative irrigation threshold of 0 kPa (complete saturation) could be 10 kPa without any reduction in grain yield of DSR. Likewise, split application of recommended dose of 150 kg N /ha as ¼ basal + ¼ at 2 week + ¼ at 5 week + ¼ at 9 week gave the highest grain yield and economics in DSR. Application of irrigation water at tillering to flowering is very crucial to obtain higher yields in direct seeded rice.

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Tillage management in sorghum + cowpea - wheat cropping system under limited irrigation conditions for sustainable crop production

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Conventionally, sorghum and wheat cultivation requires fine seed bed but now a day's mind set of farmers and scientists has changed to reduce the number of tillage operations to minimize the cost of production and sustain the productivity of system. Delayed sowing of wheat beyond November reduces grain yield by 30-50 kg/ha/day (Chauhan *et al.,* 2001). Moreover, to overcome the energy crisis conservation tillage viz., zero/minimum tillage practice of can be a tool for reducing fuel consumption during land preparation and minimization of land degradation. Therefore a field study was initiated to assess the influence of various tillage combinations on the productivity of fodder-food system under limited irrigation conditions in semi-arid region of Bundelkhand.

METHODOLGOY

Four years (*kharif* 2009 to *rabi* 2013) field study was conducted at Central Research Farm in sorghum + cowpea- wheat cropping system.The experiment was laid out in strip plot design with three replications. Nine tillage rotations viz., CT-CT: conventional tillage in *kharif* (CT) - conventional tillage in *rabi* (CT), CT-MT: conventional tillage in *kharif* (CT) - Minimum tillage in *rabi* (MT), CT-ZT: conventional tillage in *kharif* (CT) - zero tillage in *rabi* (ZT), MT-CT: Minimum tillage in *kharif* (MT) - conventional tillage in *rabi* (CT), MT-MT: Minimum tillage in *kharif* (MT) - Minimum tillage in *rabi* (MT), MT-ZT: Minimum tillage in *kharif* (MT) - zero tillage in *rabi* (ZT), ZT-CT: zero tillage in *kharif* (ZT) - conventional tillage in *rabi* (CT), ZT-MT: zero tillage in *kharif* (ZT) - Minimum tillage in *rabi* (MT) and ZT-ZT: zero tillage in *kharif* (ZT) - zero tillage in *rabi* (ZT) kept in horizontal strips and two summer ploughings viz., WSP: without summer ploughing and ASP: alternate year summer ploughing in vertical strips. During *kharif* season sorghum + cowpea was grown for fodder purpose under seasonal rainfed condition and during rabi*duram* wheat was grown for food purpose under limited irrigation conditions. Fodder sorghum and cowpea in 2:2 row ratio with row to row spacing of 30 cm and *duram* wheat with row to row spacing of 20 cm were sown with tractor driven ferti-cum-seed drill. To control the weeds of previous crop (season) in zero tilled plots, non-selective herbicide glyphosate was applied 10$\pm$2 days before the sowing of succeeding crop.

RESULTS

Conventional tillage during *kharif* and minimum tillage during *rabi* recorded significantly higher green and dry biomass yield than all the other treatments however it was statistically at par with the treatments conventional tillage during *kharif* and conventional tillage during *rabi* and conventional tillage during *kharif* and zero tillage during *rabi*. Data on wheat grain yield was recorded and it was found that during all the years of experimentation, all the tillage management practices (*kharif* and *rabi* tillage & summer ploughing) gave statistically similar yield. Mean data of four years study revealed that minimum tillage during *kharif* and minimum tillage during *rabi* gave highest yield (4.86 t/ha) but it was at par with rest of the treatments. Similar to *kharif – rabi* tillage, summer ploughing treatments also recorded statistically similar grain yield. Four years mean data showed that no summer ploughing gave 4.72 t/ha and alternate year summer ploughing gave 4.7 t/ha wheat grain yield. System productivity in terms of wheat equivalent yield (WEY) of fodder sorghum + cowpea – wheat cropping system was studied and it was found that WEY did not affected significantly due to tillage management practices during all the years of experimentation except during 2010-11 when conventional tillage based treatments gave significantly higher WEY (9.48 to 9.49 t/ha). Summer ploughing treatments also remain unaffected and but WEY under alternate year summer ploughing treatment gave higher WEY (9.14 t/ha) than without summer ploughing treatment. Maximum net return (Rs. 67226/ha) was obtained under minimum tillage during *kharif* season and minimum tillage during *rabi* season, MT-MT. The B:C ratio was higher (2.0) under the treatment minimum tillage during *kharif* season + minimum tillage during *rabi* season, MT-MT and minimum tillage during *kharif* season + zero tillage during *rabi* season, MT-ZT. Zero tillage during *kharif* + zero tillage during *rabi* recorded significantly higher OC (0.83 %) than continuous conventional tillage practice (0.71 %), however was at par with rest of the treatments. Similarly OC content in 15-30 cm soil depth also showed similar trend however soil organic matter content in 30-45 cm soil depth remain unaffected due to tillage management practices in *kharif* and *rabi* seasons. In case of summer ploughing treatments, alternate year summer ploughing treatment recorded significantly lower organic carbon content (0.76 %) than no summer ploughing (0.82 %) in the soil layer 0-15 cm.

CONCLUSION

On the basis results of four years field experimentation it is concluded that for higher net return and B:C ratio and improved soil health under *fodder* sorghum + cowpea – *duram* wheat cropping system, minimum tillage during *kharif* season and minimum or zero tillage during *rabi* season may be recommended.

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Managing root zone salinity through deficit saline water irrigation and mulching in salt affected soils under limited fresh water irrigation

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Soil salinity has emerged as the most significant problem constraining agriculture in 6.74 mha in different parts of country (CSSRI, 2015). Saline soil and saline groundwater coexist in nature, leaving very limited option for reclamation using fresh water either from rain water harvesting and/or canal water. In many farming situations, the scarcity of fresh water has forced farmers to use saline groundwater, which helps to overcome drought and increase crop yields (Sharma and Minhas, 2005). However, in the absence of proper soil-water-crop management practices use of saline waters also increases the risk of soil salinization and deterioration of soil and environment health. This experiment was conducted to evolve ideal soil and water management strategies for manipulating the root zone salinity and sustaining crop production seems promising in productive utilization of salt-affected lands and use of poor quality water.

METHODOLOGY

Experiment was laid out in *kharif*-2014 at Nain Experimental Farm, CSSRI, Panipat with three tillage treatments *viz.* zero, conventional and reduced tillage in main plot and six treatments comprising irrigation (100, 80 and 60 % of water requirement) and mulch (0 and 5 t/ha rice straw) combination in subplots. Initial electrical conductivity of the saturation extract (EC_e) of the surface soil of the experimental site varies in the range of 4-36 dS/m. Fodder sorghum (*cv*. HSSG-5000)-wheat (cv. KRL-210) cropping system was adopted. *Kharif* season was rainfed and *Rabi* season was irrigated with saline water (8 dS/m) as per the treatment.

RESULTS

Tillage had no significant effect on wheat grain and fodder sorghum yield (Table 1). Saline soil of experimental plots irrigated with saline water of 8.0 dS/m produced 4.7 Mg/ha wheat. Irrigation with 80% of water requirement (WR) had no significant reduction in the wheat yield. Application of 5 Mg/ha rice straw mulch with 60% WR showed 7.5% increase in wheat yield compared to without mulching (4.0 Mg/ha). *Kharif* rainfed sorghum produced significantly higher green forage yield in the plots irrigated with 60% WR (6.42Mg/ha) in *Rabi* season compared to treatments irrigated with 100% WR. Tillage, irrigation and mulching had no effect on dry matter content of the fodder sorghum. Soil moisture content of the mulched plots in 0-10 cm and 40-50 cm soil layer were 6-

Table 1. Effect of tillage, mulching and deficit irrigation on the sorghum and wheat yield (Mg ha^{-1})

Treatment	Wheat (2014)	Sorghum GFY (2015)	Sorghum DFY	Dry matter (%)
*Tillage**				
RT-ZT	4.41a	550.0a	137.0a	25.2a
CT-CT	4.52a	562.5 a	132.4a	23.6 a
ZT-ZT	4.51a	558.3a	135.0a	24.3 a
Irrigation and mulching				
100 WR#-no mulch	4.69a	505.6b	125.7b	25.2a
80 WR- no mulch	4.6ab	541.8b	130.7b	24.1a
60 WR - no mulch	4.0b	547.2 b	137.3ab	23.9a
100 WR – mulch**	4.67ab	563.2b	136.7ab	24.2a
80 WR - mulch	4.62ab	541.7b	125.7b	23.5a
60 WR - mulch	4.31ab	641.7a	152.7a	25.2a
100WR-G	4.90a	658.0a	158.4a	24.1a
100WRC	4.70ab	508.3b	126.1b	24.0a

Tillage × irrigation and mulch: NS
*RT-reduced tillage, ZT-zero tillage, CT-conventional tillage; # WR-water requirement; ** Mulch- rice straw mulch (5 Mg/ha) and different letters within columns are significantly different at P = 0.05 according to Tukeys Test for separation of means.

23% higher than non-mulched plots in entire *Rabi* season. Similar trend was observed for soil salinity. Throughout the year EC_2 of the surface soil was lowest in the 60%WR + Mulch (60WRM) treatment (Fig. 1). Soil pH_2 was inversely related with change in soil EC_2. Maximum increase in soil pH was observed in soil irrigated with good quality water (EC_{iw}<1dS/m). Soil pH_2 was positively correlated (r>0.3-0.6) with soil solution indices like sodium adsorption ratio (SAR), Na^+/K^+ (SPR), $Na^+/(Cl^- + SO_4^{2-})$ (NCSR), Cl^-/SO_4^{2-} (CSR)

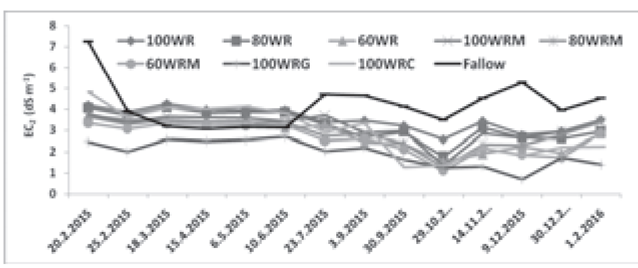

Fig. 1. Effect of deficit irrigation and mulching on soil salinity of the surface soil (0-10 cm)

and dissolved organic carbon (DOC). Ca^{2+}/Mg^{2+} (CMR) was negatively correlated with pH_2.About 85.6% variability in DOC content of soil solution was explained by Ca^{2+}, Mg^{2+}, total nitrogen and $Na^+/(Cl^- + SO_4^{2-})$ ratio.

CONCLUSION

These findings suggest that mulching was effective in increasing root zone soil moisture and reducing the soil salinity. Soil salinity dynamics showed inverse relation with soil pH in root zone. About 85.6% variability in DOC content of soil solution was explained by change in Ca^{2+}, Mg^{2+}, total nitrogen and $Na^+/(Cl^- + SO_4^{2-})$ ratio of the soil.

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Impact of hydrogel in wheat (*Triticum aestivium* L.) under limited irrigation in sandy soil condition

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Wheat (*Triticum aestivium* L.) is considered the main cereal crop in the world as well as in India. Therefore, increasing grain yield production is considered one of the most important national aims to face the great demand of the highly increasing human population. The uses of alternative water holding amendments and irrigation methods will become more important over time, especially in regions of reduced water availability. Hydrogels are super absorbents that absorb and store water hundreds of times their own weight, i.e. 400-1500 g water/dry gram of hydrogel. Water held in the expanded hydrogel is intended as a soil reservoir for maximizing the efficiency of plant water uptake. Application of hydrogels can result in significant reduction in the required irrigation frequency particularly for coarse-textured soils. A two years study during 2013-14 at two sites & 2014-15 at 15 sites on hydrogel was conducted at the farmers' fields of sandy soils of district Bhiwani (Haryana) where pearl millet-wheat cropping system occurs with less water availability. The trials were conducted in Gignau, Surpura Kalan, Haripur & Kari Modh villages. There were three treatments, normal irrigation (Six irrigations), limited irrigation (Four) and Hydrogel application @ 2.5 kg/ha with limited irrigation (Four). Hydrogel was applied by mixing with basal dose of Di Ammonium Phosphate (DAP) fertilizer. Hydrogel application @ 2.5 kg/ha with limited irrigations (Four) gave yield of 4980 kg/ha and net return of Rs. 39995 than normal irrigations (4730 kg/ha and Rs. 36680) and was followed by limited irrigations (Four) (4530 kg/ha and Rs. 32600) respectively.

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Evaluation of chemical extraction methods for predicting agronomic potential of low-grade Indian rock phosphate as phosphorus source

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The biological techniques are the most reliable for assessing the agronomic effectiveness ofphosphate rock (PR), the resources and facilities required, and the time delay in obtaining results,preclude their use for rapid assessments. Of the indirect methods, a chemical extraction procedure offers a simple and rapid alternative. This would be necessary if P sources of varying solubilities were to be compared. In addition to enabling a comparison of PR containing varying amounts of $CaCO_3$), a sequential extraction procedure may improve the predictive ability of conventional chemical extractants in other than the short-term by removing a greater proportion of total P. With the increased interest in India in the possibility of using PR as direct-application phosphate fertilizers (Basak and Biswas, 2016), a reevaluation of chemical extraction procedures for assessing the likely agronomic effectiveness of PR is timely. The ability of chemical extraction procedures to predict the agronomic effectiveness of low-grade Indian is of particular interest.

METHODOLOGY

Three Indian RPs namely, Udaipur (Udaipur RP) from Rajasthan; Jhabua (Jhabua RP) from Madhya Pradesh and Purulia (Purulia RP) from West Bengal were collected for this study. The air dried samples were finely ground to pass through a 100-mesh sieve (150 μm). P released from the four sized fraction of mineral powder was determined by using different extraction methods like water, 2% citric acid, neutral normal ammonium citrate, alkaline normal ammonium citrate and digestion with nitric acid as per the standard procedure (Table 1). Sand culture experiment was conducted in pot by growing Isabgol (*Plantago ovata* Forsk) to see the P uptake from different size fraction of RPs. Plants were harvested at optimum vegetative state (45 days) and biomass yield was recorded after drying the sample. Total P uptake was computed from dry matter yield and P concentration in the plant material.

RESULTS

The amount of P released by the different extractants from four different size fractions of mineral powder showed an interesting trend. The data revealed that P release increased with the increase in fineness of the material while the magnitude of increase differed among the extractants. The lowest P released recorded by distilled water while highest P released was recorded by digestion with concentrate HNO_3 irrespective size fractions. The amount of K released by different extractants followed the order, water <salt solution < organic acid < mineral acid. The response RP application on biomass yield was higher with the finer fraction than coarser one. The improvement in biomass yield, P content and uptake indicates that the low-grade RPs acts a source of P. P utilization from different size fraction of the mineral might be due to prevalence of acidic environment in rhizosphere created by release of organic acid during plant growth. Significant correlation was found between K released from different extractants and biomass yield and K uptake in sand culture experiment (Table 2). P released by normal ammonium citrate showed higher r value as compared to other extractant. Highly significant r values were obtained between P uptake in plant and different extractable P.

Table 1. Amount of P present in RPs estimated by different extraction procedure

Extraction methods	RPs-extractant ration	Shaking time (min)	Reference
Distilled water	1:2.5	30	Jackson, 1979
2% Citric acid	1:100	60	AOAC, 1960
Normal ammonium citrate	1:100	60	AOAC, 1970
Alkaline ammonium citrate	1:200	90	Boxma, 1977
Digestion with nitric acid	1:20	-	Jackson, 1979

Table 2. Correlation coefficient between different forms of P and biomass yield and P uptake (n = 12)

K extractant	Biomass yield	K uptake
Water soluble	0.83	0.88
2% Citric acid	0.86	0.89
Normal ammonium citrate	0.91	0.93
Alkaline ammonium citrate	0.73	0.76
Digestion with nitric acid	0.66	0.72

CONCLUSION

The study indicates that only a portion of the total P in the mineral powder was released by chemical extraction processes commonly used for soil P extraction. But the amount of P release was significantly higher with organic and mineral acid extraction suggesting that the low-grade RP can act as slow release P source. P uptake values in sand culture experiment also indicate that the biologically mobilized P is only a fraction of total P present in RP. Therefore, greenhouse trail with P exhaustive crop as well as long-term cropping studies under field are important to assess the agronomic effectiveness of the low-grade RP.

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Effect of tillage practices on moisture conservation and productivity of groundnut under dry farming conditions

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Groundnut is one of the most important oilseed crops in India. Groundnut contributes nearly 65% to the vegetable oil produced in India and holds the key to the fluctuating fortunes of vegetable oil industry. Groundnut is the most important oilseed crop being grown in Saurashtra region under rainfed conditions. Low and unstable crop yields are common phenomena in dry farming area due to low, erratic and uneven distribution of rainfall. Soil-related constraints that exacerbate drought stress include crusting and compaction, low water infiltration rate, low water retention capacity, high surface runoff, and high losses due to soil evaporation (Lal, 2008). Tillage practices influence soil physical, chemical and biological characteristics, which in turn may alter plant growth and yield (Ozpinar and Cay, 2006). In dry farming area where the rate of infiltration is moderately low (7-8 mm/hr) and the intensity of rainfall is very high, more runoff is observed. It is advisable to open the soils to greater depth to absorb more moisture. Since last several years, the problem of moisture conservation is severe and crop suffers due to moisture stress and ultimately crop yield was reducing drastically in rainfed area of Saurashtra. Keeping in view, the present experiment was conducted tofind out suitable moisture conservation tillage practices for groundnut under dry farmingconditions.

METHODOLODY

A field experiment was conducted on medium black soil during the *kharif* season of 1996 to 2006 at Main Dry Farming Research Station, Junagadh Agricultural University, Targhadia. The soil of experimental field was clayey in texture having pH 7.60 and EC 0.29dS/m and organic carbon 0.54 %. The soil was low in available nitrogen (240 kg/ha) and phosphorus (26.40 kg/ha) and high in available potash (400 kg/ha). The field experiment comprised of four treatments *viz.,* shallow ploughing, deep ploughing every year, deep ploughing alternate year, deep ploughing every third year were tried in CRD design with large plot size. Five samples were taken from each treatment and sample size was 2.0 m X 1.8 m. Deep ploughing was carried out by MB plough up to 25 cm depth. Shallow ploughing was carried out by sweep cultivator up to 10 cm depth. Bunch groundnut was sown at onset of monsoon every year with 45 cm distances between row and applied 12.5 kg N + 25.0 kg P_2O_5/ha. Agronomic practices and plant protection measures were followed as and when required. The total rainfall received during the crop season (June to November) was 457.2, 592.5, 582.4, 319.2, 372.5, 411.6, 311.0, 803.2, 878.9, 1136.2 and 808.2 and mm in 17, 32, 35, 21, 18, 33, 11, 41, 35, 38 and 43 rainy days in the year of 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005 and 2006, respectively. Productivity and soil moisture content at 0-15 and 15-30 cm soil depth and infiltration rate were pooled over eleven years.

RESULTS

Pod and haulm yield of groundnut was significantly af-

Table 1. Productivity, soil moisture content, infiltration rateand economics of groundnut as influenced by tillage practices (pooled data over eleven years)

Treatments	Pod yield (t/ha)	Haulm yield (t/ha)	Soil moisture content (%) at soil depth		infiltration rate (mm/hr)	Net returns (₹/ha)	B:C ratio
			0-15 cm	15-30 cm			
Shallow ploughing	0.664	1.839	22.31	22.57	8.70	5888	1.43
Deep ploughing every year	0.769	2.133	23.96	23.98	12.60	7785	1.52
Deep ploughing alternate year	0.728	2.027	23.13	22.97	11.05	7198	1.51
Deep ploughing every third year	0.716	1.971	22.80	23.30	10.30	6988	1.50
SEm±	0.026	0.054	1.14	1.05			
CD (P=0.05)	0.071	0.149	NS	NS			

fected due to different treatments of tillage practices in pooled results (Table 1). Significantly higher pod and haulm yield of groundnut was recorded under deep ploughing carried out every year as compared to shallow ploughing, but it was remained at par with deep ploughing carried out alternate year and deep ploughing carried out every third yearin respect of pod yield and deep ploughing carried out alternate year in respect of haulm yield of groundnut. Whereas soil moisture content at 0-15 and 15-30 cm soil depth was not affected significantly due to different treatments of tillage practices. However deep ploughing carried out every year recorded comparatively higher soil moisture content at 0-15 and 15-30 cm soil depthwith higher infiltration rate as compared to shallow ploughing and rest of deep ploughing treatments. The results are in confirmative with the earlier findings of Akhtar *et al.* (2005). Economics of different treatments of tillage practices was worked out on the basis of pooled results of productivity of groundnut indicated that deep ploughing carried out every year gave the highest net returns of ₹7785/ha with benefit cost ratio of 1.52.

CONCLUSION

On the basis of the above results, it can be concluded that deep ploughing with M.B. plough up to 25 cm should be performed every year for reducing runoff and getting higher yield of groundnut and net returns as well as maximum moisture conservation under dry farming conditions.

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Water scheduling and nutrient management in aerobic rice (*Oryza sativa* L.)

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Rice (*Oryza sativa* L.) consumes about 90% of the fresh water resources in Asia used for agriculture. The estimated world demand for rice in 2025 will be 140 million tonnes (Singh, 2004), which can only be met by maintaining steady increase in production over years, but the per capita availability of fresh water is declining continuously and could reach alarming levels in most Asian countries by the year 2025. To match with ever increasing food grain demand with less water, the term Aerobic rice was coined by International Rice Research Institute. Aerobic way of growing rice saves water by eliminating continuous seepage and percolation, reducing evaporation and eliminating wet land preparation. Aerobic rice has its own advantages and disadvantages, as water use seems to be around 60% less than that of flooded rice, requires less labour (55%) and can be highly mechanized than low land rice (Wang *et al.* 2002). But yields of aerobic rice said to be 20-30% lower than that flooded rice (Belder *et al.* 2005). Hence there is a need to develop and popularize innovative water saving technologies to "produce more rice crop from every drop", and is essential to develop optimum nutrient levels under different water schedules. The trial was initiated during *kharif* 2010 and continued in 2011, to evaluate different nutrient levels and methods of water management practices for enhancing production and productivity of aerobic rice in split plot design with three replications. The treatments comprised three irrigation schedules (I_1 = Irrigation @ 150% cumulative Pan Evaporation value (CPE); I_2 = Irrigation @ 100% CPE; I_3 = Irrigation @ 75% CPE) as main treatments and eight nutrient management levels ($N_0P_{60}K_{100}$; $N_{120}P_0K_{100}$; $N_{120}P_{60}K_0$; $N_{60}P_{60}K_{100}$; $N_{120}P_{30}K_{100;}$ $N_{120}P_{60}K_{50;}$

$N_{120}P_{60}K_{100}$ and $N_{180}P_{60}K_{100}$) as sub treatments. Based on two years experimentation it was found that aerobic rice requires frequent irrigations compensating more than the evaporation losses. Maintenance of saturated condition at critical stages of active tillering, panicle initiation, flowering to grain filling stage is essential. This is evident that irrigation at 150% CPE ratio gave the higher grain yield (10-23%) than irrigation at 100% CPE and fertilizer schedule of NPK ($N_{120}P_{60}K_{50}$).

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Agro-ecological evaluation of different horti-pastoral systems for peninsular India

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Mango (*Mangifera indica*) and sapota (*Manilkara zapota*) are two major horticultural crops cultivated in the semi-arid transitional tract of Karnataka under rainfed conditions. Owing to uncertain rainfall and undulated terrain, farmers seldom cultivate any crop in the wide intervening space between the trees of mango and sapota. It results in infestation of weeds leading to added cost of cultivation to keep the fields free of weeds. The vacant soil is also subjected to runoff losses of soil and water during rainy season. Horti-pasture system is the most ideal strategy to provide food, nutrition and income security to the people living in rainfed areas (Kumar *et al.*, 2015). There is a great scope for growing of fodder crops as intercrops in mango and sapota, as fodder crops are highly tolerant to shade and perform well under resource poor conditions.Field experiments were carried out to study the feasibility of growing fodder crops as intercrops, to identify the suitable fodder crop/s and to study the effect of fodder crops on the soil health.

METHODOLOGY

Field experiments were carried out at the Tegur farm of the Southern Regional Research Station, Indian Grassland and Research Institute, Dharwad consecutively for 3 years from 2013-15. The soil of the experimental site was sandy loam to gravelly and shallow to medium in depth. The soils were rich in organic carbon (1.2), low to medium in available N, P and K, and slightly acidic in reaction (pH 5.2). The 11 treatments consisted of sole and combinations (1:1 ratio) of fodder crops viz. grazing guinea (*Panicum maximum*), ruzi grass (*Brachiaria ruziziensis*), tall guinea (*Panicum maximum)* (var. BG 2), *Stylosanthes hamata* and *Stylosanthes seabrana* were planted as intercrops in 7 years old mango (var. Alphonso) and sapota (var. Cricket ball) orchards. All standard agronomic practices were followed for growing of both fodder and horticultural crops. The soil samples were taken from 0-30 cm depth before the start of the experiment and after the harvest of fodder crops in the third year to see the difference in the soil physico-chemical properties. The growth and yield of fodder crops were recorded at the time of harvest. The dry yield of fodder crops was estimated by drying the green fodder sample to constant weight and recorded as tonnes per hectare. In addition, obseravations on radiation interception and weed intensity were recorded to study the effect of intercropping of fodder crops. Further observations on mango and sapota yied were recorded to work out the system productivity.

RESULTS

The growth parameters of fodder crops varied among themselves. There was no significant difference in the radiation interception on the top canopy of different fodder crops intercropped in the horticultural crops, however the rows adjacent to fruit crops recorded lower light interception as compared to middle rows. Weed intensity was much lesser in fodder intercrops as compared to sole crops of sapota and mango. In mango orchard, sole guinea grass (Var. BG2) followed by soleruzi grass were found more productive (Table 1). Among

Table 1. Yield (t/ha) of fodder crops intercropped in mango and sapota (Mean of 3 years)

Treatment	In mango		In sapota	
	Green fodder	Dry fodder	Green fodder	Dry fodder
Mango/Sapota + Grazing guinea sole	23.10	5.81	19.17	4.57
Mango/Sapota + Grazing guinea + *S. hamata*	16.47 (0.91)	4.44 (0.23)	14.37 (1.30)	4.12 (0.38)
Mango/Sapota + Grazing guinea + *S. seabrana*	15.53 (0.78)	4.27 (0.19)	15.17 (1.15)	4.26 (0.35)
Mango/Sapota + *Brachiaria ruziziensis* sole	26.60	6.91	25.23	5.67
Mango/Sapota + *B. ruziziensis+ S. hamata*	19.27 (1.26)	5.04 (0.37)	20.43 (1.47)	5.36 (0.49)
Mango/ Sapota + *B. ruziziensis+ S. seabrana*	19.73 (1.25)	4.83 (0.31)	18.24 (1.42)	5.08 (0.45)
Mango/Sapota + *Panicum maximum* (var. BG2) sole	29.77	6.97	26.63	6.52
Mango/Sapota + *P. Maximum* (var.BG2) + *S. hamata*	21.00 (1.38)	5.90 (0.35)	22.17 (1.34)	5.90 (0.37)
Mango/Sapota + *P. Maximum* (var.BG2) + *S. seabrana*	21.63 (1.23)	5.67 (0.33)	20.37 (1.30)	5.21 (0.39)
Mango / Sapota + *S. hamata* sole	3.07	1.07	4.20	1.30
Mango/Sapota + *S. Seabrana* sole	2.77	0.97	4.63	1.49
SEm±	0.77	0.84	0.96	0.74
CD (P=0.05)	2.34	2.55	2.81	2.22

Values in parenthesis refer to intercropped leguminous fodder crop

the mixed fodder cropping systems, guinea grass with either *Stylosanthes hamata* or *Stylosanthes seabrana* recorded higher green and dry biomass of the fodder crops. In sapota based horti-pastoral systems too, intercropping of sole guinea grass followed by ruzi grass found to perform well among the different cropping systems. Further mixed cropping of guinea grass either with *Stylosanthes hamata* or *Stylosanthes seabrana* followed ruzi grass with *Stylosanthes hamata* recorded higher production of fodder. The system productivity was highest in the treatments involving these fodder crops. Further the productivity of mango and sapota were not adversely influenced by the intercropping of fodder crops. The pH, organic carbon and available N, P and K of the soil improved as compared to initial status with the intercropping of fodder crops in both mango and sapota. Likewise, the beneficial microflora of the soil viz. *Rhizobium, Azospirillum, Azotobacter,* free living N fixers and phosphate solubilising bacteria (PSB) too were significantly increased due to intercropping of fodder crops. Sharma (2004) too reported improvement in soil due to horti-pastoral systems in degraded soil under rainfed conditions.

CONCLUSION

On the basis of this 3year study it may be concluded that intercropping of sole guinea grass (Var. BG2) followed by sole ruzi grass and mixed cropping of guinea grass with either *Stylosanthe hamata* or *Stylosanthes seabrana* in both mango and sapotarecorded higher green and dry yield of fodder crops. They also reduced the weed intensity and improved the soil physico-chemical properties, organic carbon content, available N, P and K, beneficial micro flora and system productivity.

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Evaluation of water productivity under system of rice intensification (SRI) in different locations of Tamil Nadu

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The water productivity experiment on SRI was conducted in four locations viz., L1– Karumaniar sub basin (Tirunelveli Dist.), L2– Sevalaperiar sub basin (Virudhunagar Dist.), L3– Ongur sub basin (Chengalpattu Dist.) and L4– Nallavur sub basin (Villuppuram Dist.) in comparison with the conventional method under TN-IAMWARM project to evaluate water productivity and grain yield of rice under SRI and conventional cultivation method. The experiment was laid out in randomized block design (RBD) with four replications. The treatments consist of System of Rice Intensification (SRI) and Conventional cultivation practice (CCP). The data clearly indicated that the water requirement was less under SRI (885 mm) as compared to conventional (1180 mm). SRI registered higher grain yield and WUE 6406 kg/ha and 7.31 kg/ha/mm, respectively as compared to conventional (5284 kg/ha and 4.51 kg/ha/mm). The water productivity indicated that to produce one kilo gram of paddy grain, SRI required 1398 liters whereas conventional required 2274 liters of water. Improvement in yield was to the tune of 21%. Alternate wetting and drying (AWD) under SRI had significant influence on water saving over flooding CCP method respectively.

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Strategies to augment oilseed brassica production in India through systematic evaluation of land resources

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India is world's fourth largest edible oil economy with total consumption of 18.94 mT against domestic availability of 8.96 mT during 2011-12 (DAC, 2013). The gap between demand and domestic supply is expected to widen with annual compounded growth rate of 2.7% in demand in comparison to 2.2% in domestic availability. The gap between production and consumption could be reduced through augmenting productivity, building favourable infrastructure and policy support. And assessment of natural resources and prevailing land use conditions is a pre-requisite for building sustainable production system.Oilseed *Brassica* (OSB) has enormous production potential to meet edible oil demand of the country

(Kandpal *et al*., 2001). But, matching requirement of OSB varieties to existing landuse conditions is essential. This calls for systematic evaluation of all land resources to identify existing and potential high OSB production zones in the country. With this hypothesis an attempts has been made to identify dominant land utilization types (LUTs) under OSB production system and suggested suitable strategies. To develop efficient resource and input based dynamic strategies for enhancing mustard production in the country.

METHODOLOGY

Twelve attributes (Kandpal *et al.*, 2001) from climate normals of 103 observatories and 13 landuse attributes of 242 districts under OSB cultivation were calibrated and statistically analyzed. Various thematic maps were generated and subsequently superimposed to generate LUT map. The final map was used to generate separate strategies using socio-economic conditions, infrastructure and institutional support in respective LUTs.

RESULTS

The important OSB producing districts has been grouped into five LUTs. Subsistence farming is prevalent in 78 districts covering 0.28 mha area. Low adoption of technologies and varieties resulting poor seed yield (<0.78 t/ha). The productivity in this LUT could be improved to 1.35 t/ha through adoption of latest varieties, balance use of NPK fertilizers, soil-water conservation techniques and extensive extension activities. Almost 0.97 mha area of 93 districts with average seed yield of 0.98 t/ha is under transitional phase from subsistence to commercial farming. The productivity potential of 1.8 t/ha have been assessed through adoption of latest varieties, biofertilizer application, ensure use of NPKS fertilizers, protective irrigation, extensive extension activities, promotion of small-scale industries and market support. OSB is one of the important commercial crop in 43 districts occupying 1.26 mha area with average yield of 1.02 t/ha. The LUT has potential to produce seed >2.5 t/ha through assured supply of quality seed, biofertilizer application, soil-test-based application of micro-nutrients, management of biotic stress and market support.OSB is produced as high acreage-high yielding cash crop in 12 districts occupying almost 12% GCA (1.14 mha) with average yield of 1.32 t/ha. While it is most dominant crop in 16 districts covering 1.52 mha area with average seed yield of 1.42 t/ha. These two LUTs has potential to achieve 3.0+ t/ha yield targets through addressing various soil-health issues and adoption of LUT based efficient production technologies.

CONCLUSION

There is significant variability among the OSB cultivation conditions and hence in strategies to enhance production. The technologies for different LUTs are already available but needs refinement for easy adoption. A strong support from extension agencies, policy planner and other stakeholders is also required to achieve the targets.

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Physiological traits and yield of summer groundnut as influenced by land configuration, irrigation regimes and potassium levels

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Groundnut is most important among all oilseed crops of India. More than 80 per cent of its produce is used for extraction of edible oil. As regards the water requirements of crop, out of the total amount of water re-ceived by the soil, tremendous losses are occurred through evaporation and transpiration. The water losses from the soil due to evaporation can be reduced to a great extent by using mulches. Mulching is useful for moderating soil temperature, conserving soil moisture and for controlling weed growth. Application of mulch not only helps in realizing higher yields but also contributes in reducing water requirement by 40 per cent eliminating crop weed competition, minimum incidence of sucking pests and reducing crop duration by 7-10 days (Basu, 2008).

METHODOLOGY

The field experiment was conducted during the summer 2011 and 2012 at, Mahatma Phule Krishi Vidyapeeth, Rahuri. The experiment was laid out in split - split plot design with three replications. There were 27 treatment combinations comprising of three main plot treatments of land configurations *viz.,* Flat Bed, Broad Bed Furrow (BBF) and Broad Bed Furrow (BBF) + Polythene mulch (black), three sub plot treatment of irrigation regimes *viz.,* 0.6 , 0.8 and 1.0 IW/CPE ratios and three sub-sub plot treatment of potassium levels *viz.,* 20, 40 and 60 kg/ha K_2O. The variety used for experimentation was 'RHRG 6083'. The polythene mulch used was of 7 micron. The observations of physiological traits were recorded with the help of Portable Photosynthetic machine (LICOR 6400).

RESULTS

The physiological traits *viz.,* photosynthetic rate, transpiration rate and stomatal conductance were observed significantly higher in BBF + polythene mulch throughout growth period. It was increased upto 84 DAS there after decreased at harvest. The photosynthetic rate (25.74 µ mol/m^2/s), transpiration rate (12.54 mol/m^2/s) and stomatal conductance (0.40 mol/m^2/s) were significantly superior in BBF + polythene mulch at 84 DAS. While reverse trend was observed in stomatal resistance. It was significantly lower in the BBF + polythene mulch (2.54 mol/ m^2/s) at 84 DAS. The results are in accordance with the findings of Garkal *et al.* (2005) and Nautiyal *et al.* (2012). All the higher physiological traits in the BBF + polythene mulch, resulted into significantly higher dry pod yield (4915 kg/ ha) and haulm yield (9189 kg/ ha) in BBF + polythene mulch. The gross monetary returns (Rs. 192302/ ha), net monetary returns (Rs. 117851/ha) and B:C ratio (2.58) was recorded significantly higher in BBF+ polythene mulch. The physiological traits *viz.,* photosynthetic rate, transpiration rate and stomatal conductance were recorded significantly higher throughout growth period with the application of irrigation at 1.0 IW/CPE ratio. All these parameters increased up to the 84 DAS and decreased at harvest. While stomatal resistance was observed significantly lowest with highest irrigation ratio. The photosynthetic rate (23.47 m mol/ m^2/ s), transpiration rate (12.20 mol/m^2/s) and stomatal conductance (0.37 mol/m^2/s) was recorded significantly higher at 84 DAS with the application of irrigation at 1.0 IW/CPE ratio. The significantly higher dry pod yield (4278 kg/ha) and haulm yield (8676 kg/ha) were recorded with application of irrigation at 1.0 IW/CPE ratio. However, it was at par with 0.8 IW/ CPE ratios. The gross monetary returns (Rs. 168004/ha) was higher at 1.0 IW/CPE ratio. However, net monetary returns (Rs. 95888/ha) and B:C ratio (2.35) was recorded significantly higher under 0.8 IW/CPE ratio. The significantly higher photosynthetic rate (22.33 m mol/m^2/s), transpiration rate (11.90 mol/m^2/s) and stomatal conductance (0.37 mol/m^2/ s) were recorded with application of 60 kg/ha K_2O. However, it was at par with 40 kg/ha K_2O. While stomatal resistance was observed significantly the lowest in this treatment. The higher dry pod yield, (4123 kg/ ha) and haulm yield and (8441 kg/ha) was obtained with potassium application @ 60 kg/ha K_2O. However, it was at par with application of 40 kg/ha K_2O. The gross monetary returns (Rs. 161930/ha) was recorded higher at application of 60 kg/ha K_2O. However, net monetary returns (Rs. 90950/ha) and B:C ratio (2.27) was recorded significantly higher with application of 40 kg/ha K_2O.

CONCLUSION

It is concluded that summer groundnut should be cultivated on broad bed and furrow (BBF) with polythene mulch, irrigation on the basis of 0.6 IW/CPE ratio and application of 25:50:40 kg $N:P_2O_5:K_2O$/ha for water saving, achieving higher yield and net realization.

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Deficit irrigation and hydrogel improves the water use efficiency of zero-tilled green gram– jute relay system

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Jute can be sown as relay crop in between the lines of 15-20 days old green gram for additional pulse yield without reducing yield of jute. This relay system adds not only organic matter as green gram green manure but also reduce the cost of land preparation and second weeding of jute due to smothering action of green gram.Main problem of this system is the availability of water, especially, at early stage due to delayed onset and / or erratic distribution pattern of monsoon.Biswas (2016) reported increase in water productivity, yield and reduction in production cost and carbon foot print in zero-tilled wheat. Hydrogel, a synthetic polymercan hold water up to 400 times of its weight and can release 95% of the retained water to crop resulting longer intervals between two irrigations (Narjary *et al*., 2012). The present field experiment was undertaken to find possibility of increasing water use efficiency of zero tilled green gram - jute relay cropping with different irrigation regimes and hydrogel levels.

METHODOLOGY

The field study was carried out during 2014-15 at the Central Research Farm of the Bidhan Chandra Krishi Viswavidyalaya (tropical sub-humid, 1560 mm annual rainfall, Latitude $22^0 58^/$ N, Longitude $88^0 51/$ E altitude 9.75 m amsl, sandy loam soil, aeric Haplaquept, pH 6.75, organic carbon 5.4 g/kg, available N 85 kg/ha, P_2O_5 15.3 kg/ha and K_2O 40 kg/ha) in a split-plot design with four levels of irrigation regimes:no irrigation i.e. rainfed - RF, cumulative pan evaporation 250mm (CPE_{250}), CPE_{125} and CPE_{83} and three levels of hydrogel: no hydrogel (H_0), hydrogel @ 2.5 kg/ha ($H_{2.5}$) and hydrogel @ 5 kg/ha (H_5). Measurements and calculation has been done as described by Bandyopadhyay *et al.* (2005) and Biswas *et al.* (2006).

RESULTS

Throughout the crop growing period a linear positive relationship remained between Leaf Area Index (LAI) and evapotranspiration rate (ETa) (Table 1). At the initial growth stage of the relay system, ETa was mainly regulated by soil evaporation but early vigorous growth habit of green gram quickly increased the share of transpiration in ETa. The strength of relationship between ETa and LAI started increasing and reached at its peak at 7 WAS (R2=0.78) when green gram was at its maturity and both the crops covered the nearly entire base area. This relation starts weakening from 13 WAS due to jute leaf shading.A linear relationship between system yield and ET was also obtained in the present study. Data from figure 1 revealed that at the lower end (ET ranged between 600 to 650 mm) wide variation of system yield was recorded against nominal change in the status of ET. However, when ET value was higher (750mm to 850 mm) a steady increasing trend in yield was recorded with the increment of ET. From this pattern it can be noted stated that under relatively dry water regimes, hydrogel played significant role towards system yield. In contrast, at relatively wet condition frequency of irrigation dominates over the hydrogel treatment. The data also tells that under dry situation partitioning of evaporation and transpirationwas wider than the wet situation. The variation in system yield might be predicted 75% with ET alone. Effective rainfall (Table 2) was reduced with increasing irrigation frequency due to enhanced water supply in contrast to hydrogel application due to difference in water storage capacity. Negative soil moisture storage was observed irrespective of treatments due to onset of monsoon during jute harvest. Irrigation contributed major source of variability of ET.

Table 1. Relationship between leaf area index (LAI) and evapotranspiration rate (ETa) under different irrigation regimes and hydrogel doses in green gram-jute relay system

WAS	E Pan(mm)	ETa equation
3	3.72	ETa = 0.0124 LAI +0.924
5	3.46	ETa = 1.701 LAI + 1.564
7	3.69	ETa = 1.952 LAI + 3.558
9	3.24	ETa = 1.391LAI + 2.861
11	3.71	ETa = 2.469 LAI + 1.926
13	5.35	ETa = 0.213 LAI+ 1.608
15	4.46	ETa = 0.391 LAI + 1.054

WAS: Weeks after sowing

Table 2. Role of irrigation regimes and hydrogel doses on components of water balance (mm) and water use efficiency (WUE kg/mm^3) of green gram-jute relay system

Treatment Combinations	Irrigation (mm)	Effective Rain (mm)	Δ SWS (mm)	ET (mm)	WUE (kg/m^3)
RFH_0	0	560	-6.9	553.1	0.40
$RFH_{2.5}$	0	578	-5.7	572.3	0.42
RFH_5	0	602	-5.4	596.6	0.45
$CPE_{250}H_0$	50	532	-4.2	577.8	0.47
$CPE_{250}H_{2.5}$	50	549	-3.9	595.1	0.51
$CPE_{250}H_5$	50	570	-3.3	616.7	0.53
$CPE_{125}H_0$	150	519	-2.9	666.1	0.44
$CPE_{125}H_{2.5}$	150	523	-2.6	670.4	0.50
$CPE_{125}H_5$	150	551	-2.4	698.6	0.55
$CPE_{83}H_0$	250	512	-3.8	758.2	0.49
$CPE_{83}H_{2.5}$	250	514	-2.5	761.5	0.60
$CPE_{83}H_5$	250	525	-2.0	773.0	0.63

Higher irrigation frequency resulted higher ET loss ranging from 574 mm in RF to 764 mm in CPE_{83}. Hydrogel application also increased water storage on sustained basis and supplied to crops resulting higher ET from 639 mm in H_0 to 671mm in H_5. The water use efficiency (WUE) is an index to quantify the use efficiency of water resources towards crop production under limited water supply condition. This index plays crucial role to select suitable irrigation management. In the present study WUE ranged between 0.4 kg/m^3 (RF) to 0.63 kg/m^3 (CPE_{83} H_5). WUE increased with increased application of irrigation water from 0.42 kg/m^3 in RF to 0.57 kg/m^3 in CPE $_{83}$. This indicates the higher requirement of water of the relay system. Hydrogel application significantly improves the WUE from 0.45 kg/m^3 in H_0 to 0.50 in $H_{2.5}$ and 0.54 in H_5 indicating the efficiency of gel on sustained supply of water during dry spell. Under relatively dry root zone (RF), both evaporation and transpiration remains at suboptimal level resulting in lower ET as well as lower system yield. When the crop was irrigated frequently under CPE $_{83}$ enough moisture remains in the soil surface as well as in sub soil, such environment promotes ET and also yield.

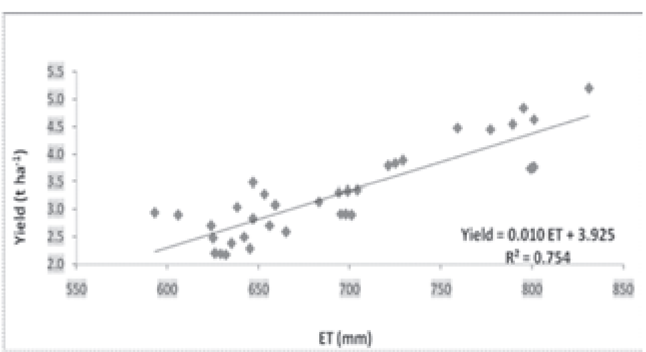

Fig. 1. Relationship between yield and evapotranspiration rate (ETa) under different irrigation regimes and hydrogel doses in green gram-jute relay system

CONCLUSION

The present study shows that green gram – jute relay system, an eco-friendly remunerative approach, can bewater use efficient with 38% higher yield with application of hydrogel @ 2.5 kg/ha under deficit irrigation regime of CPE $_{125}$ over rainfed system without application of gel. Strong positive correlation between leaf area index and evapotranspiration rate and similar relationship of ET with yield contributed this water use efficiency. Application of gel conditioner improved water storage, checked excess water loss from the system, and mitigated ET demand of the relay system for longer time. Hence irrigation frequency was reduced from five times at CPE $_{83}$ to only three times in CPE $_{125}$.This system have potential of bridging gap of pulse deficit in this region and supplying green matter in the form of green gram manure with this water efficient findings but it needs long term experimentation for final recommendation.

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Soil matricpotential based water management in DSR to reduce groundwater withdrawal

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Excessive withdrawal of groundwater to meet water requirement of transplanted rice cultivation in fresh groundwater regions of IGP resulted in declining ofwater table at an alarming rate of 30-90 cm per year (Narjary *et al.*, 2014). This overexploitation of groundwater threatens the sustainability of rice production, and is driving researchers and farmers to find new ways to reduce water input for rice production. Direct seeded rice (DSR) consideredto be relatively less water requiring than transplanted rice could be one of the feasible option for reducing groundwaterwithdrawal in rice production, but its optimal water management is still a researchable issue (Yadav *et al*., 2011).

METHODOLOGY

A field studywas conducted on DSR to develop soil matic potential based irrigation schedule for maximizing on farm rain water utilization and reducing groundwater withdrawal. The DSR was grownin two agro-techniques i.e. tilled and zero till conditionsin combination with and without mulch. No till treatment was continued for last 5years. The irrigations scheduledat-15 kPa soil moisture suction in till and no till combinations with mulch or no mulch were compared with standard water management schedule practiced in puddled transplanted rice (PTR). Tensiometers were installed in DSRfields to continuouslymonitor soil matric potential. In each irrigation, about 5.0- 6.0 cm depth of water was applied. Soil moisture suction was monitoreddaily and irrigation was applied when soil matric potential reached to pre-defined level for applying irrigation.Leaf area index, irrigation water requirement, yield and energy requirement for ground water withdrawal in DSR grown under different tillage, mulch and irrigationschedules were compared withPTR. Components of water balance and system water loss in DSR and PTR were computed to visualize overall groundwater losses scenario.

RESULTS

Initially, leaf area index (LAI) of TPR was lower than that of DSR (Fig.1). It was mainly due to lower stand density and transplanting shock during early establishment phase under TPR as compared to DSR sown 15 days earlier. But, once established, plants in TPR grew at faster rate and attained LAI as high as 4.72 at the peak. The highest LAI was recorded intilledDSR withirrigations scheduled at-15 kPa throughout the crop growing season. It was due to higher plantdensity in tilled DSR treatment which resulted in relatively more number of tillers/unit area and subsequently higher LAI as compared to transplanted rice.

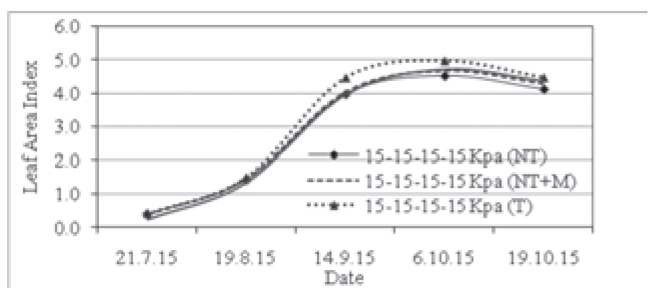

Fig 1. Leaf area index of rice recorded under different treatments

Table 1. Irrigation water applied, water saving, yield and irrigation water productivity of PTR and DSR under different tillage and mulch conditions.

Treatment	Irrigation Water applied (cm)	% irrigation water saving	Yield (q/ha)	Irrigation water productivity (kg/m^3)
PTR	198.1	-	34.35^{A}	0.17
15-15-15-15 kPa (NT-DSR)	166.8	15.8	29.75^{B}	0.18
15-15-15-15 kPa (NT+M)	147.3	25.6	30.40^{B}	0.21
15-15-15-15 kPa (T)	174.5	11.9	31.90^{AB}	0.18

Table 2. Comparative components of water balance in DSR and PTR

Water balance component	PTR	DSR (15-15-15-15 Kpa)
Depth of irrigation and precipitation (cm)	256.8	205.6
Soil evaporation (cm)	29.08	27.27
Root water uptake	30.92	36.29
Change in soil moisture profile (cm)	11.23	6.67
Downward flux/recharge (cm)	185.23	136
System loss (cm)	29.77	27.8

Irrigation water applied, yield and irrigation water productivity of rice under different agro-techniques are given in Table 1.It is clear from the resultsthat PTR required the highest irrigation water (198.1 cm) amongst all treatments and also produced the maximum rice yield. However, the yield oftilled DSRwith irrigations scheduled at-15 kPa was also recordedto be statistically at par with that of PTR.Lesser water application andcomparable yield in DSR in relation to PTR, though resulted in the highestirrigation water productivity (0.21 kg/m^3) in mulched DSR irrigated at -15 kPa soil moisture suction, but the overall system water loss i.e. amount of water pumped for irrigation minus groundwater recharge was only2 cm higher in PTR (Table 2).

CONCLUSION

Irrigation scheduling at -15 kPain DSR has the potential to maintain yield comparableto PTR, however, replacing PTR with DSR had very little advantage in reducingoverall system water loss and thus groundwater depletion.

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Extended Summaries Vol. 1 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Effect of hydrogel on productivity, profitability and water use efficiency of Indian mustard (*Brassica juncea*) in aridisols

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Among rapeseed and mustard, Indian mustard (*Brassica juncea*) is an important *rabi* oilseed crop of arid and semi-arid regions of India as well as Haryana. In South–Western zone of Haryana, only 5-15% of total annual mean rainfall (300-550 mm) is received in *rabi* season which is also unpredictable, inadequate and erratic in nature. Moreover, soils are light textured with poor water retention capacity, mostly affected by sodicity and salinity; and waters are also brackish in nature. Therefore, Indian mustard grown under limited irrigation/conserved soil moisture/rainfed conditions suffers from moisture stress either at vegetative or reproductive stage of crop growth, which is considered as one of the most important constraints for improving the productivity of Indian mustard. Pusa Hydrogel which is semi-synthetic super-absorbent and absorb water up to 350-500 times of its dry weight in pure water and gradually release it for plant growth with passage of time. Beneficial effects of hydrogel in mustard have reported by Rathore *et al.* (2016). Therefore, present investigation was carried out to evaluate the efficacy of hydrogel under different irrigation levels in Indian mustard (*Brassica juncea* L.).

METHODOLOGY

A field experiment was conducted during *rabi* seasons of 2014-15 and 2015-16 at Research Farm of Chaudhary Charan Singh Haryana Agricultural University, Regional Research Station, Bawal-123501, India. The soil of the experimental

Table 1. Seed yield (t/ha), water use efficiency, net returns (x 10^3 /ha) and benefit: cost ratio (kg/ha-mm) of Indian mustard as influenced by different irrigation and hydrogel levels (pooled data of 2014-15 and 2015-16)

Hydrogel level (kg/ha)	Seed yield and water use efficiency				Mean
	Irrigation levels				
	No irrigation (rainfed)	ID/CPE ratio 0.4	ID/CPE ratio 0.6	ID/CPE ratio 0.8	
0.0	1.89 (10.93)*	2.21 (10.15)	2.26 (8.76)	2.22 (7.75)	2.14 (9.40)
2.5	2.18 (11.24)	2.24 (9.58)	2.25 (8.55)	2.22 (7.65)	2.22 (9.25)
5.0	2.23 (11.03)	2.24 (9.27)	2.28 (8.49)	2.23 (7.60)	2.25 (9.10)
Mean	2.10 (11.06)	2.23 (9.66)	2.26 (8.60)	2.22 (7.67)	—

SEm± and CD (P=0.05) for comparing seed yield under irrigation levels (I):0.03 and 0.11; hydrogel levels (H): 0.02 and 0.06; Interactions: I x H: 0.07 and 0.25; and H x I: 0.03 and 0.13, respectively.

	Net returns and benefit: cost ratio				
0.0	29.0 (1.93)**	37.3 (2.12)	37.1 (2.05)	33.8 (1.91)	34.3 (2.02)
2.5	34.4 (1.97)	34.3 (1.92)	32.9 (1.84)	29.9 (1.72)	32.9 (1.86)
5.0	33.1 (1.87)	31.5 (1.78)	30.6 (1.72)	27.2 (1.62)	30.6 (1.75)
Mean	32.2 (1.92)	34.3 (1.94)	33.5 (1.87)	30.3 (1.75)	—

*Figures in parenthesis indicate water use efficiency; and ** benefit: cost ratio

Note: Price of produce (seed): 30500 and 33500/t; price of hydrogel: 1200 and 1200 /kg; cost of soil application of hydrogel : 1000 and 1000 /ha; cost of one irrigation application : 1700 and 2200 /ha; Common cost of cultivation: 30298 and 32143 /ha during 2014-15 and 2015-16, respectively.

field was Typic Ustochrept (Loamy sand) of aridisol order. The experiment was laid out in split plot design with four irrigation levels [irrigation depth (ID)/cumulative pan evaporation (CPE) ratio 0.4 {only one irrigation was given at 48 and 56 days after sowing (DAS)}, 0.6 (two irrigations were given at 29 and 97; and 30 and 89 DAS) and 0.8 (three irrigations were given at 22, 48 and 109; and 22, 56 and 105 DAS) during 2014-15 and 2015-16, respectively.)] in main plot and three hydrogel levels in sub-plots replicated thrice (as given in Table 1). Depth of irrigation was 60 mm. The average available soil moisture was 189 mm/m soil profile at sowing. Hydrogel was drilled below the seed before sowing as per treatments. Indian mustard variety RH 8812 was sown on October 25 and 23; and harvested on March 21 and 10 during 2014-15 and 2015-16, respectively. Recommended package of practices were followed to raise the crop. Periodical soil moisture studies were carried out in two replications from 0-30, 30-60, 60-90 and 90-120 cm soil depth to work out water use efficiency (WUE).

RESULTS

Pooled data (Table 1) on the interaction effect of irrigation and hydrogel levels on seed yield revealed that soil application of 2.5 kg hydrogel/ha in Indian mustard recorded seed yield of 2.18 t/ha; and fetched higher net returns (34416/ha), benefit: cost (B:C) ratio (1.97) and highest WUE (11.24 kg/ha – mm) under no irrigation treatment (rainfed conditions), whereas, application of irrigation at ID/CPE ratio of 0.4 produced seed yield of 2.21 t/ha and gained highest net returns (37292/ha) and B: C ratio of 2.12 under no hydrogel application. Water use efficiency declined with the application of irrigation. Soil application of hydrogel @ 2.5 and 5.0 kg/ha was not found economical under irrigated conditions, whereas, it proved most economical @ 2.5 kg/ha under rainfed conditions.

CONCLUSION

It is concluded that soil application of 'Pusa Hydrogel' @ 2.5 kg/ha in Indian mustard was found adequate to achieve higher seed yield, net returns, benefit: cost ratio and WUE only under no irrigation treatment (rainfed conditions).

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Assessing the soil fertility status and productivity of intensive rice based cropping systems

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Rice- rice cropping system is the most predominant cropping systems in irrigated lands of Eastern India. Productivity of the rice-based cropping system is low, and it continues to decline in India because of worsening soil-related constraints (Chaudhury *et al.*, 2005). Diversification of rice - rice cropping systemwith other crops in dry seasonreduces water use and can accommodate a third crop in the system; leading to the intensification of cropping system in irrigated medium lands.However, intensification of cropping system leads to soil nutrient mining unless the requirement is met out through proper external nutrient supply to the system (Timsina *et al.*, 2010). The present system of fertilizer application is mostly based on the nutrient requirement of individual crops ignoring the carry-over effect of the organic or inorganic fertilizer applied to the preceding crop but organicsources have considerable residual effect on the succeeding crops which may extend up to two/three crops. Keeping this in view an investigation was made forassessing nutrient supply status of the soiland productivity of intensive rice based cropping systems for developing a sustainable production practice.

METHODOLOGY

A field experiment was carried out to study the effect of different nutrient management options on the rice-maize-cowpea and rice-groundnut-cowpea cropping system. The experiment was laid out in a Split plot design with two cropping system i.e. rice-maize-cowpea and rice-groundnut-cowpea in main plots and 5 system based nutrient management option i.e. control-control-control, RDF-RDF-RDF, RDF_{75}(75% of the RDF) + Crop residue Incorporation of previous crop (CRI)- RDF-RDF, RDF_{75}+CRI- RDF+ Straw mulch (SM) - RDF and RDF_{75}+CRI-RDF+SM-RDF_{50}(50% of the RDF) in subplots replicated thrice. The soil of the experimental sites was sandy loam with slightly acidic in nature, low organic carbon, low available nitrogen, low available potassium and medium in available phosphorus. The varieties of different crops used were: rice 'Naveen' (120-125 days), groundnut 'Smruti' (115-120 days), maize 'Hyb super 36' (90-95 days)and Vegetable cowpea 'Banamali' (60-70 days).

RESULTS

Rice yield did not differ significantly with respect to different systems in wetseason after two years of the system. However significantly higher grain yield and yield attributes were recorded with all the fertilized treatments over control and highest grain yield of 4.67 t/ha was observed with RDF_{75}+CRI - RDF + SM - RDF. In second crop of the sequence, significantly higher grain yield was recorded with RDF+SM plots compared to RDF applied plots in maize. The Rice equivalent yield (REY) of groundnut was significantly higher (58.0%) compared to maize in dry season. In groundnut, straw mulched plots also recorded higher pod yield compared to RDF applied plots. In summer season, significantly higher yield of cowpea was recorded in rice - maize -cowpea system compared to rice - groundnut - cowpea system. The REY of cowpea in rice - maize - cowpea system was 61.3% higher over the yield obtained in rice - groundnut - cowpea system which is mainly attributed to the comparatively early sowing of cowpea in rice – maize cropping system. The total productivity of the rice - groundnut - cowpea system was significantly higher compared to that of rice - maize - cowpea system. Among the nutrient management options, the highest REY of 15.19 t/ha was achieved with RDF_{75}+CRI- RDF+SM - RDF treatment, which was at par with that of RDF_{75}+CRI-RDF+SM - RDF_{50} treatments but significantly higher than all other nutrient management treatments. Integrated nutrient management involving incorporation of cowpea residue with 75% of RDF to rice + straw mulching with RDF to Maize/ groundnut + 50 % RDF to cowpea produced significantly highest REY and recorded 30.5% yield advantage over RDF to each crop of the system. After two cycles of the system the organic carbon, available N and P content of the soil did not change with the cropping systems but higher available K was observed with rice - maize - cowpea cropping system. The organic carbon, available N, P and K of residue applied plots was though significantly higher than control but was at par with RDF applied plots.

CONCLUSION

Integrated nutrient management involving incorporation of cowpea residue with 75% of RDF to rice + straw mulching with RDF to Maize/groundnut + 50 % RDF to cowpea produced higher yield and maintained the soil fertility status; therefore,may be practiced for sustainable production in irrigated medium land ecology.

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Extended Summaries Vol. 1 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Effect of nutrient management and micro-irrigation techniques on pigeon pea under transplanted conditions on growth, yield and economics

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Pigeon pea is an important drought tolerant legume. India is the largest producer and consumer of Pigeon pea in the world. It is mainly grown in states of Maharashtra, Uttar Pradesh, Madhya Pradesh, Gujarat, Andhra Pradesh, Telangana, Karnataka and Tamil Nadu and these states constitute 90 per cent of the area. Transplanting technique is a novel and revolutionary agronomic approach to boost Redgram yields. Transplanting technique in Pigeon pea provides ample scope in enhancing the yields and net returns of Pigeon pea farmers under limited water availability conditions in Telangana state especially in ground water dependent areas. As transplanting technique provides more opportunity time for vegetative growth than in the conventional planting system, it may respond positively to the application of external inputs i.e. plant nutrients and irrigation. Hence, it is worthwhile to standardize the Agro-techniques to enhance the productivity of pigeon pea crop. At this juncture, standardization of nutrient and water management techniques would be of great help.

Table 1. Effect of drip-fertigation on yield and economics of transplanted pigeon pea

Treatment	Seed yield (kg/ha)	Number of pods	Harvest index (%)	Stem girth (cm)	LAI	RUE (g/MJ)	Net returns (Rs/ha)	B :C ratio	WUE (kg/ha mm)
Main plot									
I_1 - 60 % of daily pan evaporation	1727	733	22.4	12.0	2.20	0.23	69191	2.54	3.09
I_2-80 % of daily pan evaporation	2072	840	23.3	13.3	3.81	0.25	87729	3.09	4.12
I_3- 100 % of daily pan evaporation	2585	974	23.8	14.0	4.19	0.26	115969	3.93	4.23
I_4- 120 % of daily pan evaporation	3014	1020	24.4	15.9	4.37	0.26	139297	4.56	4.33
SEm±	53.66	35.2	0.3	0.18			3117	0.11	-
CD (P=0.05)	355	NS	1.97	1.16			20658	0.69	-
Sub-plots									
F_1- 75 % of RDF	2186	791	22.4	13.4	2.97	0.23	95223	3.39	7.2
F_2- 100 % of RDF	2401	878	23.5	13.7	3.64	0.25	105916	3.64	7.5
F_3- 125 % of RDF	2461	1006	24.5	14.3	4.32	0.27	108001	3.67	7.8
SEm±	63.34	50.35	0.29	0.34			3551	0.12	-
CD (P=0.05)	261	151.0	0.87	NS			10646	NS	-

*RDF (recommended dose of fertilizer): 20:50:10 N, P_2O_5 and K_2O

METHODOLOGY

The field experiment was conducted at Agricultural Research Station, Tandur, Ranga Reddy (Dist.), Telangana state during *kharif* season from 2013-16. The trial was laid out in split –plot design with three replications comprised of Irrigation levels (four) as main plots based on Pan Evaporation and fertility levels (three) as sub-plots. The irrigation and fertilizers were applied with drip-fertigation system. The gross plot size was 13m x 12m and the seedlings were transplanted at 35 days old. Crop was managed as per the treatment. Leaf area and intercepted radiation was measured with LP-80 canopy analyzer from time to time.

RESULTS

Results indicated that of all the irrigation levels under drip cum fertigation of transplanted Pigeon pea (variety ICPL 87119) irrigation with 120% of daily pan evaporation recorded significantly highest seed yield (3014 kg/ha) which was supported by the harvest index (24.4%), number of pods per plant (1020), leaf area index LAI (4.37), radiation use efficiency (0.26 g/MJ) and water use efficiency (4.33). The same treatment recorded highest net returns (Rs.139297/ha) and Benefit cost ratio (4.33) as indicated in Table 1. Of the three fertility levels 125% recommended dose of fertilizer registered highest seed yield (2461 kg/ha), but was on par with 100% recommended dose of fertilizer (2401 kg/ha. Highest seed yields recorded under Transplanted situation with drip cum fertigation was mainly due to its profuse growth (harvest index 24.5%), LAI (4.32), stem girth (14.3 cm) number of pods/plant (1006), radiation use efficiency (0.27 g/MJ) and water use efficiency (7.80) which might have final positive effect on net returns (Rs. 1, 08,001/ha) and Benefit cost ratio (3.67).

CONCLUSION

Pooled results of the trial indicated that it is better to go for irrigation by drip irrigation system with 120% of daily pan evaporation to Pigeon pea under transplanted conditions. Of the fertility levels 100% RDF recorded highest Pigeon pea yield with drip cum Fertigation.

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Effect of tillage on weed control and energy requirement in summer green gram in Vertisols of central India

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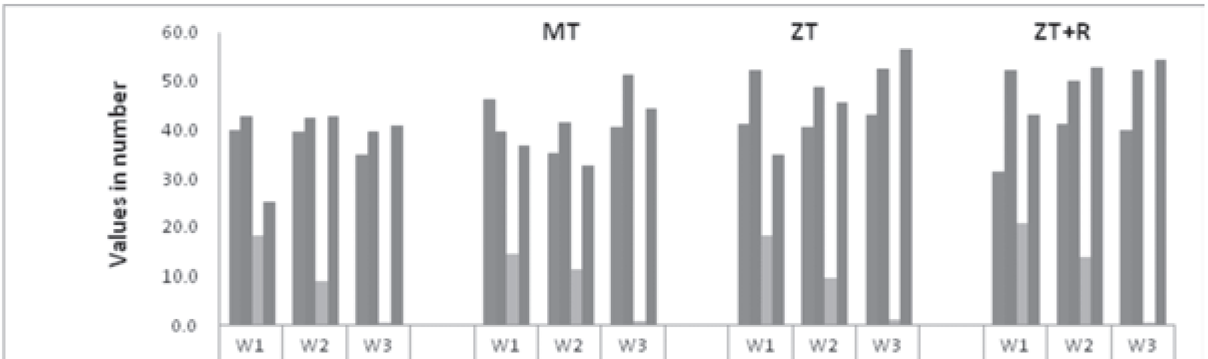
Energy is one of the most important inputs in agricultural production required from land preparation tovalue addition. Seedbed preparation for sowing of crops consumes considerable amount of time and energy. Conventional tillage operations are energy intensive and create the problem in timely seeding of crop, besides increasing the cost of production. The green revolution made the agriculture into an energy intensive production system and present changing scenario of escalating fuel, fertilizers, and other input costs, necessitates the effective use of energy and other vital resources in crop production. Furthermore, energy input–output analysis is useful to assess the efficiency and environmental impact of production systems. Conservation agriculture is referred to be beneficial in improving crop productivity, reducing moisture deficits, breakingup pest and disease cycles, minimizing weeds, enhancing nutrient cycling and soil fertility, improving the biodiversity of soil biota, reducing soil erosion, reduction in emission and increasing carbon sequestration (Freidrich*et al.,* 2016). However, changes in tillage practices influence the vertical distribution of weed seeds in the soil, which may affect their relative abundance in the field (Chauhan and Johnson, 2009; Chauhan and Opena, 2012). Hence, a field experimentwas carried out in summer greengram to study the weed growth, yield performance and energy input-output analysis under different tillage systems.



	W1	W2	W3		W1	W2	W3		W1	W2	W3		W1	W2	W3
No of plants	40.0	39.7	35.0		46.3	35.3	40.7		41.0	40.7	43.0		31.3	41.0	40.0
Plant height (cm)	42.7	42.3	39.7		39.7	41.3	51.3		52.0	48.7	52.3		52.0	50.0	52.0
No of weeds/m2	18.3	9.0	0.7		14.3	11.3	1.0		18.3	9.7	1.3		20.7	13.7	0.7
Pods/plant	25.2	42.8	40.8		36.6	32.8	44.4		35.0	45.4	56.6		43.0	52.8	54.2

Fig.1. Crop establishment, growth and weed control under different tillage systems

METHODOLOGY

The field experiment was conducted at ICAR-DWR, Jabalpur research farm during summer 2016 after the harvesting of *rabi* season mustard crop. Treatment were laid out ina split plot design with the tillage, *viz.* conventional tillage (CT), minimum tillage (MT), zero tillage (ZT) and zero tillage with residue (ZT+R) as main treatments and weed control methods *viz.* weedy check (W1), application of quizalofop @ 50 *a.i.* g/ha as post emergence (W2) and quizalofop @ 50 *a.i.*g/ha at 25 DAS + one hand weeding at 45 DAS (W3) as sub treatments. Each main treatment was maintained a plot size of 16 x 40 mand sub-treatments with a plot size of 16 x 13 m,replicated thrice. In ZT+R treatment, threshed crop residue of mustard was applied uniformly @ 2 t/ha. CT involved 2 times ploughing with cultivator followed by Rotavator, after which sowing was done. MT involved sowing with roto-till seed drill in a single operation. No tillage was done in ZT and ZT+R. The "Samrat" variety of green gram was used in the treatments @ 25 kg/ha with DAP @ 100 kg/ha. Three irrigation was applied at 1, 20 and 42 DAS.Data were recorded on weed growth, crop emergence, energy requirement and yield performance of greengram. Energy balance was computed using the different equivalents of agronomic practices and outputs. Energy equivalents of the machineries used for different tillage operations were calculated based on the conversion factors suggested by Kitani (1990).

RESULTS

A very good crop establishment and initial growth was observedin ZT followed by ZT+R, MT and CT at initial stages. The mustard residue used in the ZT+R was chopped into smaller pieces, which tilledthe space opened by furrow opener. Allopathic effect of this residue appeared to have affected the germination in this treatment. However, better crop germination was observed in MT followed by ZT and CT.Higher number of pods/plant (56.6) and plant height (52.8 cm) were observed under ZT followed by ZT+R, MT and CT. However the seed yield of greengram was the highest in ZT+R (1.08 q/ha) followed closely by ZT (1.06 t/ha), MT (0.98 t/ha) and CT (0.98 t/ha). Higher number of weeds wasalso observed in ZT+R weedy check plot, but they were effectively controlled with herbicide application with and without manual weeding. The highest energy output and energy use efficiency were observed in ZT+R (138951 MJ and 199.8%) followed by MT (125583 MJ and 184.8%), ZT (122987 MJ and181%) and CT (112055 MJ and 163.8 %).

CONCLUSION

It is concluded that summer green gram cultivation under zero tillage with residue was very effective in terms of input saving, energy output and energy use efficiency with effective weed control. Crop cultivation under ZT+R also gave the benefits in terms of environmental impact.

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Effect of moisture regimes and spacing in baby corn in new alluvial zone of West Bengal

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Baby corn, young de-husked cob used as vegetables, is an important nutritional and cash crop in south-east Asia (Thavaprakaash *et al.* 2005). Entirely edible cobs of immature corn are harvested within 2-3 days after silk emergence, just before fertilization, with moisture content of 70-80 % (Shivakumar *et al.* 2011). The crop has been gaining popularity in India with the standardization of agro-techniques.

METHODOLOGY

The objective of the experiment is to study growth, yield and water use efficiency of baby corn under differentmoisture regimes and spacingand also to analyze the economics of the crop production. The experiment is conducted at BCKV, Nadia, West Bengal during 2012- 2013 in pre-*kharif* (March-June) with Golden baby (H-102) variety. The main plots 4 irrigationstreatments (IW:CPE 0.6, 0.8 and 1.0 and farmers' practice with of irrigation depth 5 cm) and sub-plots 3 plant spacing (30×30 cm, 45×20 cm, 60×15 cm) was set in split-plot design with three replications. A common dose of FYM @ 5 t/ha and N:P_2O_5: K_2O @ 120: 60: 60 kg/ ha applied to all plots.

RESULTS

The results showed thatgrowth, yield attributes and babycorn yield significantly increased with irrigation IW/CPE 1.0, which at par with farmers' practice (Table 1). The optimum spacing found in 45 cm x 20 cm produced significantly higher yield. The maximum water use efficiency (3.84 kg/ ha-mm) recorded with IW/CPE 0.6 & 45 x 20cm spacing

CONCLUSION

From the study it can be concluded that baby corn cultivation can be promoted with standardagro-techniques of irrigation scheduling at IW /CPE 1.0 and plant spacing of 45 cm × 20 cm for maximization of production in alluvial zone of West Bengal.

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Table 1. Growth and yield attributes of baby corn under different moisture regimes and spacing(mean)

Treatment	Plant height at harvest (cm)	LAI at 60 DAS	Dry matter accumulation at harvest (g/ m^2)	CGR at 40-60 DAS (g /m^2/day)	Baby corn Cob No./plant	Weight (g)	Length (cm)	Girth (cm)
IW/CPE 0.6	145.3	3.21	421.7	8.18	1.51	5.87	5.80	1.10
IW/CPE 0.8	153.6	3.39	435.6	8.45	1.62	5.91	5.85	1.16
IW/CPE 1.0	163.4	3.53	478.8	9.70	2.16	6.25	6.36	1.25
Farmers' practice	166.4	3.66	494.2	10.10	2.29	6.38	6.42	1.32
CD (P=0.05)	9.8	0.21	23.7	0.58	0.23	0.28	0.16	0.08
30 cm×30 cm	140.9	3.16	411.9	7.89	1.52	5.89	5.76	1.08
45 cm×20 cm	163.7	3.57	472.6	9.52	2.02	6.12	6.18	1.23
60 cm×15 cm	166.9	3.59	488.4	9.89	2.13	6.28	6.38	1.29
CD (P=0.05)	7.35	0.10	21.9	0.63	0.16	0.19	0.28	0.10

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Soil moisture conservation through soil conditioners in groundnut under dry farming conditions of Saurashtra region

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Improvement of soil physical condition through organic soil conditioner in heavy textured soil can helps in boosting up the productivity of groundnut. Painuli and Pagliai (1990) observed that poly vinyl alcohol improved the soil structure considerably and soils produced numerous fine cracks, smaller clods and imparted greater stability against water. Therefore, soil conditioner in medium black soil enables to check such evaporation loss and conserve the profile moisture as well as to improve physical condition of soil to make it available to the crop for its possible utilization. Keeping in view, the present experiment was conducted to study the soil moisture conservation through soil conditioners in groundnut under dry farming conditions.

METHODOLODY

The field experiment comprised of seven treatments*viz.,* FYM @ 10 t/ha, vermicompost @ 2 t/ha, castor cake @1t/ha, polyvinyl alcohol @ 25 kg /ha, polyvinyl alcohol @ 50 kg /ha, murrum @ 40 t/ha and control weretried in a randomized block design with three replications. Gross and net plot size was 5.0 m X 3.6 m and 4.0 m X 2.7 m, respectively. Groundnut (GG-5) was sown at onset of monsoon every year with 45 cm distances between row and applied 12.5 kg N + 25.0kg P_2O_5/ha. Agronomic practices and plant protection measures were followed as and when required. The total rainfall received during the crop season (June to November) was 808.2, 1236.8, 1012.8, 460.9 and 1144.5 mm in 43,43,33,17 and 46 rainy days in the year of 2006, 2007, 2008, 2009 and 2010, respectively. Productivity andsoil moisture content at 0-15 and 15-30 cm soil depth were pooled over five years.

RESULTS

Pod yield of groundnut was significantly affected due to different treatments of soil conditioners in pooled results. Application of marrum @ 40t/ha produced significantly higher pod yield of groundnut with soil moisture content at 0-15 and 15-30 cm soil depth as compared to control and poly-vinyl alcohol treatments @ 25 and 50 kg /ha, but it was remained at par with soil conditioner treatment of FYM @ 10 t /ha, vermicompost @ 2 t /haand castor cake @1 t /ha. Whereas haulm yield of groundnut was found non-significant due to soil conditioners treatments. However haulm yield was obtained higher under application of FYM @ 10 t /ha followed by murrum @ 40 t /ha as compared to control. Economics of soil conditioners was worked out on the basis of pooled results of productivity of groundnut indicated that application of murrum @ 40 t /ha gave the highest net returns of 261168 /ha with benefit cost ratio of 2.06 followed by FYM @10 t /ha(net returns24975 /ha with B:C ratio of 1.98).

CONCLUSION

On the basis of the above results, it can beconcluded that

Table 1. Productivity, soil moisture content and economics of groundnut as influenced by soil conditioners (pooled data of 5 years)

Treatment	Podyield (kg/ha)	Haulm Yield (kg/ha)	Soil moisture content (%) at soil depth		Net returns (₹/ha)	B:C ratio
			0-15 cm	15-30 cm		
Farm yard manure@ 10 t/ha	1305	3506	29.75	29.61	24975	1.98
Vermi compost@ 2 t/ha	1290	3448	29.65	29.73	22350	1.81
Castor cake@1t/ha	1267	3407	29.44	29.52	22512	1.85
Polyvinyl alcohol @ 25 kg/ha	1203	3284	29.50	29.51	14156	1.43
Polyvinyl alcohol @ 50 kg/ha	1186	3302	29.66	29.20	3657	1.09
Murrum@40 t /ha	1313	3460	29.81	29.68	26116	2.06
Control	1125	3219	29.06	28.89	21498	1.95
CD (P=0.05)	102.57	NS	-	-	-	-

the farmers of North Saurashtra Agro-climatic Zone growing bunch groundnut (GG-5) are advised to apply murrum @ 40 t /haor FYM @ 10 t /hafor getting higher yield of groundnut and net returns as well as moisture conservation under dry farming conditions.

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Production potential and economics of *rabi* sorghum (*Sorghum bicolor*) under drip irrigation

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With the advent need of food security, it is necessary to explore maximum yield potential of important cereal *rabi* sorghum. Owing to multifarious advantages of drip fertigation along with non-availability of water during dry spell in semi-arid regions of the country; justifies enormous potential for drip irrigation even for close growing crops like sorghum with some modification in crop geometry. Field experiments were conducted to assess the effect of drip irrigation on productivity of two sorghum varieties viz., 'Parbhani Jyoti' (SPV 1595) and 'Akola Kranti' (AKSV 18R) with five irrigation schedules viz., I_1-drip at 100% ETc, I_2-drip with 75% ETc, I_3-drip at 100% ETc during critical growth stages and compared with I_4-border check basin irrigation at 0.8 IW/ CPE, and I_5-rainfed (control) at AICRP on Water Management, VNMKV Parbhani, Maharashtra, India. Soil was medium textured clayey. It was low in nitrogen and phosphorus and calcareous in nature. The soil reaction was slightly alkaline. The experiment was laid out in factorial randomized block design with three replications. The inline 16 mm diameter drip laterals having drippers of 2.54 lph discharge and 30 cm spacing were laid for paired rows at 120 cm. Results indicated that drip irrigation schedule produced significantly highest *rabi* sorghum grain yield, fodder yield and 100 grain weight. The variety 'Akola Kranti' (AKSV 18R) gave higher sorghum grain and fodder yields, as compared to 'Parbhani Jyoti' (SPV 1595). Thus, it is concluded that drip irrigation is economically feasible for *rabi* sorghum which also ensure water security. Nutshell, on the basis of yield and economics, *rabi* sorghum planted in paired row at 45 x 15-75 cm spacing should be irrigated with drip irrigation at I_1 (1.0 or 100% ETc) every third day.

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Production potential of pigeonpea (*Cajanus cajan*) as influenced by plant geometry and irrigation schedules

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Pigeonpea is an important pulse crop of India. In paired row planting system each third row is removed and crops are grown in paired row cropping system. It is suitable for dryland region and objective is to conserve soil moisture and account for higher yield. It is different from skip cropping where a line is left unsown in the regular row series of sowing. Hence, it is essential to standardize a paired row planting system at a particular spacing in pigeonpea. Water is the most important inputs essential for the production of crops. Plants need it continuously during their life and in huge quantities. It profoundly influences photosynthesis, respiration, absorption, translocation and utilization of mineral nutrients. Both its shortage and excess affects the growth and development of a plant directly. The rainfall of our country is dependent on the monsoons. In order to grow food crops and agricultural products in large quantities to feed the growing millions, intensive farming with extensive irrigation is essential. Lack of irrigation facilities and improper planting patterns are the major constraints attributing to lower productivity of pulses especially pigeonpea. As a long durational crop, its reproductive growth occurs on residual moisture and lack of moisture at reproductive and terminal stages affects the stability of the yield resulting in lower productivity. In view of the above facts the present investigation was undertaken to asses the interaction effect of paired row planting systems in increasing and stabilizing the yield of BSMR-736, a wilt and sterility resistant variety of pigeonpea released by Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani under different irrigation schedules. The knowledge of row spacing in paired row planting under different irrigation schedules will help the farmers to enhance the productivity of pigeonpea by adopting appropriate combination.

METHODOLOGY

The field experiments were conducted at the Research Farm, Department of Agronomy, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani during *kharif* seasons of 2012-13 and 2013-14. The experiment was laid out in split plot design with three main plot treatments and four sub plot treatments. The main plot treatments were irrigation schedules as rainfed (no irrigation), two irrigations (at bud initiation and pod development stage) and three irrigations (at bud initiation, flowering and pod development stage). Sub plot treatments were four plant geometries i.e. 120 x 45 cm, 60-120 x 60 cm, 75-150 x 45 cm and 90-180 x 45 cm. Seeds of pigeonpea variety (BSMR-736) released by Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani were used for experimental purpose. The seeds were sown by dibbling as per treatments at 120 cm x 45 cm, 60-120 cm x 60 cm, 75-150 cm x 45 cm and 90-180 cm x 45 cm spacing during 2012-13 and 2013-14 respectively, under rainfed conditions. The fertilizers were applied as per standard dose of 25 : 50 (N : P) kg/ha. As pigeonpea is a leguminous crop, full dose of fertilizer was applied as basal dose. The sources of nutrients were urea (46% N) and diammonium phosphate (18% N, 46% P_2O_5).

RESULTS

Three irrigations in pigeonpea improved significantly all the growth attributes *viz*., plant height, number of branches/plant, functional leaves, leaf area and dry matter production/plant as compared to two irrigations and rainfed treatment during both the years. The yield attributes *viz*., number of pods/plant, weight of pods/plant and seed yield/plant were improved significantly with three irrigations as compared to two irrigations and rainfed treatment during both the year. Similarly, the improvement in yield attributes were also reflected in seed yield. The increasing trend in straw yield due to irrigation in pigeonpea was also observed and it was significantly higher than rainfed during both the year. The harvest index values were maximum in irrigated (I_1 and I_2 both) pigeonpea as compared to rainfed during both the years of experimentation. The test weight and quality parameter like protein content (%) were not influenced significantly due to irrigation treatments during both the year. The plant geometry of 75-150 x 45 cm recorded significantly higher plant height followed by plant geometry of 90-180 x 45 cm than any other plant geometry. All the growth attributing characters except plant height were improved with increase in inter and intra row plant spacing. The plant height was increased with decrease in inter and intra row spacing. The plant geometry of 90-180 x 45 cm recorded significantly higher number of pods/plant, pod weight, seed yield/plant as compared to other plant geometries except 75-150 x 45 cm plant geometry which was found at par with it. Although, seed yield/plant was higher in

Table 1. Mean weight of pods/plant, seed yield/plant and test weight of seeds of pigeonpea as influenced by different treatments during 2012-13 and 2013-14.

Treatment	2012-13			2013-14		
	Weight of pods/plant (g)	Seeds yield/plant (g)	Test weight (g)	Weight of pods/plant (g)	Seeds yield/plant (g)	Test weight (g)
Irrigation (I)						
I_0- Rainfed	87.75	55.71	102.19	105.04	66.68	103.68
I_1- Two irrigations	135.89	84.93	103.68	150.30	93.93	104.93
I_2- Three irrigations	168.40	104.05	104.67	180.68	111.90	105.78
SEm±	1.27	1.37	0.91	1.45	1.95	2.84
CD (P=0.05)	3.79	4.08	NS	4.31	5.81	NS
Plant geometry (S)						
S_1 - (120 X 45)	125.55	78.43	103.51	139.54	87.20	104.98
S_2 - (60-120 X 60)	115.01	71.50	103.49	128.10	80.04	104.71
S_3 - (75-150 X 45)	135.77	84.83	103.52	150.85	94.28	104.92
S_4 - (90-180 X 45)	146.39	91.48	103.53	162.87	101.82	104.59
SEm±	4.94	2.94	3.47	5.60	3.66	2.55
CD (P=0.05)	14.68	8.73	NS	16.62	10.87	NS
Interaction (I x S)						
SEm±	8.57	5.09	6.01	9.70	6.34	4.41
CD (P=0.05)	NS	NS	NS	NS	NS	NS

Table 2. Mean seed, straw, biological yields (t/ha) and harvest index of pigeon pea as influenced by different treatments during 2012-13, 2013-14 and in pooled analysis.

Treatments	Seed yield			Straw yield		Biological yield		Harvest index	
	2012-13	2013-14	Pooled	2012-13	2013-14	2012-13	201314	2012-13	2013-14
Irrigation (I)									
I_0- Rainfed	0.944	1.15	1.05	2.92	3.59	3.86	4.75	24.42	24.24
I_1- Two irrigations	1.48	1.65	1.56	4.11	4.64	5.59	6.29	26.42	26.21
I_2-Three irrigations	1.83	1.98	1.90	4.86	5.31	6.69	7.29	27.36	27.14
SEm±	0.03	0.03	0.01	0.08	0.90	0.11	0.13	0.68	0.51
CD (P=0.05)	0.09	0.10	0.04	0.24	0.29	0.34	0.39	2.02	1.52
Plant geometry (S)									
S_1 - (120 X 45) cm	1.38	1.55	1.46	3.89	4.43	5.27	5.98	25.89	25.69
S_2 - (60-120 X 60) cm	1.26	1.42	1.34	3.61	4.12	4.87	5.54	25.56	25.36
S_3 - (75-150 X 45) cm	1.60	1.79	1.70	4.37	4.97	5.97	6.76	26.58	26.37
S_4 - (90-180 X 45) cm	1.43	1.61	1.52	3.98	4.54	5.41	6.15	26.23	26.03
SEm±	0.05	0.06	0.04	0.12	0.13	0.16	0.19	0.10	0.09
CD (P=0.05)	0.125	0.18	0.14	0.37	0.41	0.49	0.59	0.32	0.28
Interaction (I x S)									
SEm±	0.09	0.01	0.08	0.21	0.24	0.28	0.34	0.18	0.16
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

90-180 x 45 cm plant geometry, seed yield was found significantly higher in 75-150 x 45 cm plant geometry due to higher plant population/ha than 90-180 x 45 cm plant geometry. Similarly, straw yield, biological yield and harvest index were also significantly more with plant geometry of 75-150 x 45 cm than any other plant geometry during both the year. Different plant geometries did not show any significant impact on protein content (%) and test weight (g) during both the years of study. The plant geometry of 75-150 x 45 cm was found economically viable and recorded significantly higher gross monetary returns, net monetary returns and benefit to cost ratio than 90-180 x 45, 120 x 45 and 60-120 x 60 cm plant geometries.

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Effect of irrigation levels and mulches on water use efficiency of drip irrigated summer groundnut (*Arachis hypogaea*)

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A field experiment was undertaken for two consecutive years during summer 2014 and 2015 at AICRP on Irrigation Water Management, VNMKV, Parbhani to study the effect of different irrigation level and mulches on water use efficiency of summer groundnut under drip irrigation. The soil of the experimental field was clayey (52.25%) in texture, medium in organic carbon (0.52 %), poor in nitrogen (193.32 kg/ha), medium in available phosphorus (19.28 kg/ha), high in potash (599.44 kg/ha) and slightly alkaline in reaction (pH 8.0). The experiment was framed out in split plot design with four irrigation levels (I_1 - Irrigation at 0.6 PE, I_2 - Irrigation at 0.8 PE, I_3 - Irrigation at 1.0 PE and I_4 - Irrigation at 1.2 PE) in main plots whereas four mulches [M_1 - Black polythene mulch with drip, M_2 - Transparent polythene mulch with drip, M_3 - Soybean straw mulch with drip and M_4 - Control (unmulched with drip)] were assigned in sub plots. The results revealed that during both the years of experimentation higher water use efficiency (7.3 and 7.6 kg/ha-mm) was obtained in irrigation level 0.6 PE and it decreased with increase in irrigation level. The lower WUE (4.5 and 4.8 kg/ha-mm) was observed in irrigation level 1.2 PE during both the years of experimentation. As regards to mulches WUE (8.2 and 7.1 kg/ha-mm) was observed in transparent polythene mulch followed by black polythene mulch (6.4 and 6.8 kg/ha-mm) during both the years of experimentation. The lower WUE was noticed in control (unmulched) treatment.

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Impacts of municipal wastewater irrigation on productivity of pearl millet under sole and conjunctive use with saline water

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In India, larger amounts of freshwater are diverted to domestic, commercial, and industrial sectors, due to increasing rate of urbanization and industrialization, which generate greater volumes of wastewater (Qadir *et al.,* 2007). The treatment of wastewater is given low priority in India due to the financial constraints (Akhtar *et al*., 2008). Thus, reuse of wastewater in agriculture may be an alternative option for profitable crop production. Hence, it may reduce the problem of water pollution and also provide the nutrients input to crop production. The wastewater contains nutrients of fertilizing value (Soumare *et al*., 2003) that enhances growth and yield of crop plants (Javid *et al*., 2006). Keeping in view, the

Table 1. Effect of sole and conjunctive use of wastewater and saline water irrigation on the growth and yield attributes and yield of pearlmillet

Treatment	Plant height (cm)	DM/plant (g)	Ear heads/m row length (No.)	Grain yield (t/ha)	Stover yield (t/ha)
T_1 (100%TW)	183.3	52.8	11.7	1.90	5.49
T_2 (100%WW)	193.5	61.5	13.7	2.01	6.02
T_3 (100%SW)	167.4	50.3	09.9	1.72	5.24
T_4 (50%TW+50%WW)	184.5	55.8	12.9	1.84	5.34
T_5 (50%SW+50%TW)	171.1	51.6	09.9	1.75	5.18
T_6 (50%SW+50%WW)	174.2	52.9	11.2	1.80	5.26
SEm ±	0.6	0.5	0.3	0.01	0.02
CD (P=0.05)	2.0	1.3	0.9	0.05	0.07

TW: Tubewell water, WW: Wastewater, SW: Saline water

present study was undertaken to assess the impact of wastewater irrigation in sole and conjunctive use mode on productivity of pearl millet.

METHODOLOGY

A field experiment was conducted at Water Technology Centre, ICAR-Indian Agricultural Research Institute farm, New Delhi, India to study the effect of multi quality irrigation waters on growth, yield attributes and yield of pearl millet (*Pennisetum glaucum* var. Pusa Composite-383) during *kharif* season of year 2011. Three sole irrigation treatments (viz. irrigation with 100% tubewell water (T_1), irrigation with 100% wastewater (T_2), irrigation with 100% synthetic saline water of EC-8.0 ds/m, T_3) and three conjunctive application of tubewell, wastewater and saline waters (viz. irrigation with 50% tubewell water + 50 % wastewater (T_4), irrigation with 50% saline water + 50% tubewell water (T_5) and irrigation with 50% saline water + 50% wastewater, T_6) were undertaken. These were tested under randomized block design (RBD) with four replications. At harvest, growth and yield parameters were recorded on five random plant samples representing each irrigation treatment. Crops were harvested at physiological maturity, threshed and plot-wise yields were recorded. Treatment effects were analyzed using F- test through OPSTAT software at 5 % significance level.

RESULTS

It is clear from Table 1 that plant height, dry matter accumulation per plant, number of ear heads or effective tillers per meter row length significantly higher in the irrigation with 100% wastewater and significantly lowered under irrigation with 100% saline water. However, 1000-grain weight of pearl millet was not significantly affected. In case of irrigation with 50% saline water + 50% tubewell water (T_5) and irrigation with 50% saline water + 50% wastewater (T_6), conjunctive use of saline and wastewaters (T_6) was associated with significantly higher plant height, dry matter accumulation per plant, number of ear heads or effective tillers per meter row length than those under conjunctive use of saline and tube well waters (T_5). Further, significantly higher grain and straw yields (2.01 and 6.02 t/ha, respectively) were observed in irrigation treatment with 100% wastewater. These were significantly lowered in the irrigation treatment with 100% saline water application. Conjunctive use of saline water with wastewaters (T_6) also significantly increased the grain and straw yields. These were observed to be significantly higher than those due to conjunctive use of saline with tube well waters (T_5). Presence of higher organic matter and nutrients in wastewater and their capacity to dilute saline waters, when applied in conjunction, appears to be the main reason for the dampening of adverse effects of saline water applications.

CONCLUSION

The application of wastewaters in solo or a conjunctive with saline waters appears to be a feasible strategy for enhancing pearl millet yields. However, its long term effects need to be further evaluated.

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Tillage and soybean based intercropping practices for increasing productivity under rainfed conditions in Central India

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In India, Madhya Pradesh is the largest soybean (*Glycine max* L.) producing state. The yield levels in the Bundelkhand region in Central India are very low. About 70% area is rainfed and cropping intensity is about 111% in the region. The region comprises 50% upland area in red soils and rest in black soils. The rain is very erratic and uncertain in the region, which may be virtually responsible for creating scarcity of moisture, and crop failures under rainfed conditions. Under such situations, intercropping can play a significant role to enhance the productivity and profitability per unit area and time. In intercropping efficient use of land, water and solar energy assure insurance against total crop failure due to failure of one or other crop by vagaries of weather or disease/pest epidemics in rainfed agriculture. Under limited soil moisture conditions, intercropping coupled with improved tillage can further play an important role in better intake and moisture conservation (Narayan and Lal, 2009). Information on this aspect is meager, particularly for Bundelkhand region, therefore, present study was undertaken to evolve a suitable tillage practice and soybean based intercropping system for higher rainwater conservation for augmenting the crop growth and yield.

METHODOLOGY

A field experiment was conducted during the rainy season (*kharif*) of 2006 to 2010 at ICAR-Indian Institute of Soil and Water Conservation, Research Centre, Datia (25^0 40' N, 78^0 28' E and 342.42 m above mean sea level), Madhya Pradesh, India. The climate of Datia is semi-arid with an annual average rainfall of 830 mm. Nearly 90% of the total precipitation is received in the monsoon season extending from middle of June to September. However, long dry spells during crop growth period in monsoon season, late onset and early withdrawal of monsoon, are common features. The mean rainfall received over the 5 years during the crop growth period was 384 mm and long dry spells were experienced during vegetative and reproductive growth period in all the years during experimentation. Under rainfed conditions, sorghum (*Sorghum bicolor* L.), pigeon pea (*Cajanus cajan* L.), sesame (*Sesamum indicum* L.), clusterbean (*Cyamopsis tetragonoloba* L.) and castor (*Riccinus communis* L.) perform better than other crops hence were as intercrops. The treatments consisting were two tillage practices (i. Farmer's practice - two pass harrow, one pass cultivator and planking and ii. Improve tillage - M. B. plough once, cultivator and planking) and, six sole/ intercropping systems [1. sSole soybean ('PK 1042'), 2. soybean + sorghum ('CHS 14') 2:2, 3. soybean + clusterbean ('Naveen') 2:2, 4. soybean + sesame ('Gujrat 2') 2:2, 5. soybean + pigeon pea ('IPCL 87') 2:1 and 6. soybean + castor ('Kranti') 2:1 proportion. The treatments were fitted in split plot design keeping tillage levels in main plots and intercropping systems in sub-plot, replicating 4 times. Recommended dose of nutrients (30 kg N and 60 kg P_2O_5/ha) was applied as basal to the sole soybean and soybean based intercropping treatments. No additional nutrients were given to the intercrops. Sole soybean and crops in intercropping systems were sown at 40 cm row spacing. The soybean equivalent yield was calculated by converting the yield of intercrops into the yield of soybean on the basis of existing market price of individual crop during 2009-2010. After experimentation some soil physical and chemical properties were measured. Soil analysis was done using standard chemical procedures. The soybean equivalent yield under various treatments was analyzed as per statistical procedure of the split plot design.

RESULTS

The mean results of 5 years indicated that improved tillage and intercropping systems were found more beneficial as compared to farmers practice and sole cropping of soybean, respectively, under red and black soils (Fig. 1 and 2). Higher soybean equivalent yield was recorded under improved tillage over conventional tillage in red and black soils. There were 47 and 55 per cent increase in soybean equivalent yield recorded under improved tillage over conventional tillage in red and black soils, respectively. All intercropping systems recorded significantly higher soybean equivalent yield over sole cropping of soybean under both the soils. Under red soils, soybean

+ castor intercropping system recorded the highest soybean equivalent yield (548 kg/ha) followed by soybean + clusterbean (347 kg/ha). In black soils, soybean+sesame (750 kg/ha) intercropping system recorded the highest soybean equivalent yield followed by soybean+clusterbean (536 kg/ha). Soybean-based intercropping systems also helped in the improvement of soil properties, especially in the organic carbon, which increased from 0.31 to 0.43%. The higher yield advantage under intercropping systems over sole cropping of soybean was mainly resulted probably due to efficient utilization of available resources (land, water and solar light) and improved tillage was further helpful for conserving higher rainwater into deeper soil layers which might be advantageous to the crops for a longer duration during reproductive phase after cessation of monsoon rains. These results corroborate the findings of Narayan and Lal (2009) and Patel *et al*. (2007).

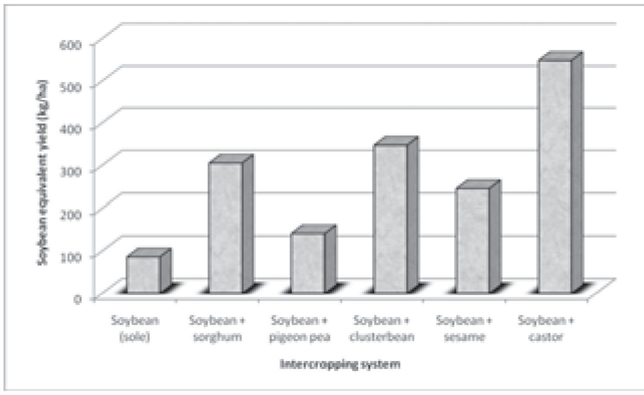

Fig. 1. Soybean equivalent yield (kg/ha) as influenced by different treatments in red soils

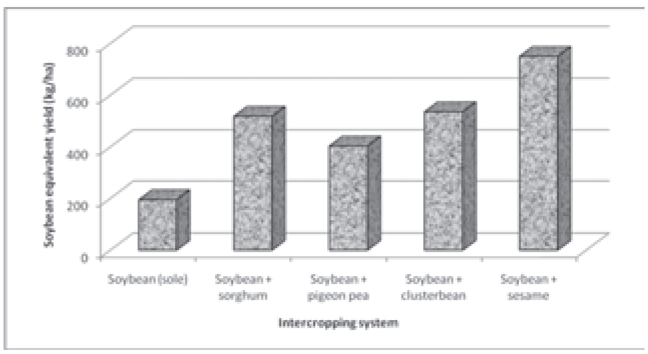

Fig. 2. Soybean equivalent yield (kg/ha) as influenced by different treatments in black soils

CONCLUSION

The experimental findings suggested that under rainfed conditions, soybean cannot be grown successfully as a sole crop, however, the farmer who wishes to grow soybean under rainfed conditions must go for intercropping coupled with improved tillage for obtaining sustainable production in red and black soils in Central India. Among different intercrops, castor and sesame performed better than other intercrops in red and black soils, respectively.

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Effect of sprinkler irrigation on the performance of different black gram (*Vigna mungo*) varieties

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Black gram is one of the important pulses grown in 41.0% of the total area under pulses in Tamil Nadu. Summer irrigated black gram is being raised after the harvest of samba/thaladi paddy, in new Cauvery delta region of Tamil Nadu, where the ground water level is sufficient.Even though black gram requires minimum water (350 – 400 mm), water scarcity during summer forced the farmers to avoid the cultivation. Excess water applied by surface irrigation method in deep clay soils causes more foliage of black gram. Hence, it is essential to find out alternate strategies to save water and increase the existing water use efficiency in black gram cultivation. One such method introduced recently is sprinkler irrigation. The research on sprinkler irrigation appears to have not much developed as compared to drip irrigation (Siddique *et al.,* 2004). Under irrigated condition, sprinkler irrigation needs to be standardized during summer season particularly the response of different black gram varieties. Now, it is right time to study the response of different black gram varieties under sprinkler irrigation system in Cauvery delta zone where water becomes scarce with availability being uncertain.

METHODOLOGY

Field experiments were conducted at Tamil Nadu Rice Research Institute, Aduthurai during Summer, 2013 and 2014 to study the response of black gram varieties under sprinkler irrigation. An experiment was laid out in strip plot design with four main plot and three sub plot treatments and three replications. The treatments consisted of four levels of irrigation: I_1 - 50 per cent Pan Evaporation through sprinkler irrigation, I_2 - 75 per cent Pan Evaporation through sprinkler irrigation, I_3 - 100 per cent Pan Evaporation through sprinkler irrigation and I_4 - surface irrigation in main plots and three black gram varieties *viz.*, ADT 5, PBG 4 and VBN BG 6 in sub pots. The soil was clay loam in texture with pH 7.14 and organic carbon 0.57%. First irrigation was given through sprinkler (50 mm) in all the sprinkler treatments for better germination. Further irrigation treatments were imposed as per the treatment and the total water used was calculated by using water meter.

RESULTS

Growth and yield parameters of black gram cultivars varied considerably under sprinkler irrigation and the results are presented in Table 1. More number of branches (2.9) was recorded under surface irrigation, closely followed by sprinkler irrigation at 100% PE. Number of pods per plant (38) was more in sprinkler irrigation at 100% PE, followed by surface irrigation. Lesser number of pods per plant (30) was obtained with sprinkler irrigation at 50% PE. Variety ADT 5 showed superior in more number of pods per plant than other two genotypes. Number of seeds per pod was not varied among black gram genotypes. However, irrigation treatments altered the number of seeds per pod and test weight. Sprinkler irrigation at 100% PE produced morenumber seeds per pod (7.2) and test weight, followed by surface irrigation (6.9).Sprinkler irrigation positively influenced the grain yield of black gram cultivars under summer irrigated condition and the results are presented in Table 2. In irrigation treatments, sprinkler irrigation at 100% pan evaporation recorded higher grain yield

Table 1. Growth and yield parameters of black gram genotypes as influenced by irrigation levels (pooled data of 2 years)

Treatment	Plant height (cm)	Number of branches/plant	Number of pods/plant	Number of seeds/pod
Irrigation level				
Sprinkler irrigation at 50% Pan evaporation	41.2	2.3	30	6.2
Sprinkler irrigation at 75% Pan evaporation	43.4	2.6	32	6.5
Sprinkler irrigation at 100% Pan evaporation	46.1	2.8	38	7.2
Surface irrigation	48.5	2.9	36	6.9
SEd±	1.9	0.09	1.5	0.2
CD (P = 0.05)	3.6	0.16	4	0.4
Genotype				
ADT 5	43.4	2.7	38	6.7
VBN (BG) 6	42.8	2.6	33	6.4
PBG 4	46.2	2.6	32	6.4
SEd±	1.4	0.08	1.2	0.3
CD (P = 0.05)	3.1	NS	3	NS

Table 2. Grain yield (kg/ha) of black gram as influenced by irrigation levels and varieties (pooled data of 2 years)

Irrigation levels	ADT 5	VBN 6	PBG 4	Mean
Sprinkler irrigation at 50% Pan evaporation	872	691	681	748
Sprinkler irrigation at 75% Pan evaporation	1028	768	739	845
Sprinkler irrigation at 100% Pan evaporation	1217	947	942	1035
Surface irrigation	1184	841	821	940
Mean	1075	812	796	
CD (P = 0.05)CD	I132	V154		

which was closely followed by surface irrigation. Among the varieties, ADT 5 produced significantly higher grain yield over other varieties. For interaction effect, sprinkler irrigation at 100% pan evaporation in ADT 5 variety recorded significantly higher grain yield of 1217 kg/ha which was on par with surface irrigation (1184 kg/ha). The lesser grain yield under surface irrigation method might be due to excess soil moisture which prolonged vegetative period even after flowering resulted in reduction of seed yield. Such findings were earlier reported by Sheoran *et al*. (2001).

CONCLUSION

Sprinkler irrigation positively influenced the grain yield of black gram cultivars under summer irrigated condition. sprinkler irrigation at 100% pan evaporation recorded higher grain yield which was closely followed by surface irrigation

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Effect of variable irrigation regimes and crop establishment techniques on performance of wheat (*Triticum aestivum* L.)

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Wheat (*Triticum aestivum* (L.) emend. Flori & Paol) is the second most important tactical cereal crop of North-Western Plains especially in Haryana and principally grown as *rabi* crop, domineering for food security of India. Haryana has a place of pride in wheat growing states of India, occupying an area of 2.5 mha with an average productivity of 4722 kg/ha during 2013-14 (*Anon*., 2014). In North-west India, it is grown in an annual sequence with rice. Scarcity and gradual decrease in the share of water for agriculture in semi-arid regions, the only option available is to produce more food per unit of available water with applied inputs. Although, it is grown under improved production practices the individual factor productivity has declined over the periods. Potential resource conservation techniques (RCTs) like FIRBS planting wheat is one of novel techniques to save water (18-35%) and enhancing the productivity of other input applied (Hari *et al*., 2010). Wheat is irrigated by surface irrigation methods where the irrigation efficiency to be as low as 30-40%. Hence well-organized, efficient technologies and approaches will impressively augment the water productivity by minimizing non-beneficial ET. Water supplied on IW:CPE basis was more economical and appropriate to achieve higher application efficiency with better crop yields. Production technologies such as scheduling irrigation and planting techniques leading to higher productivity per unit of water use need to be developed. In view, the above study was conducted to assess the behaviour of water distribution in the root zone soil and its use by the wheat crop under different crop establishment techniques and irrigation schedules.

METHODOLOGY

A field experiment was conducted at CCS Haryana Agricultural University Hisar (29^0 10' N and 75^0 46' E) during *rabi* seasons of 2012-13 and 2013-14. The soil of the experimental field was sandy loam in texture, containing 0.58% organic carbon having 1.42 g/cm bulk density of and 4.6mm/hr infiltration rate. The soil was low in available nitrogen (133.6 kg/ha), high in phosphorus (24.6 kg/ha) and medium in available potassium (276.5 kg/ha). It contained 20.5 % moisture at field capacity and 6.1 % at permanent wilting point. The experiment comprising of 12 treatment combinations with 3 replications having four crop establishment techniques *viz*. conven-

Table 1. Effect of crop establishment techniques and irrigation scheduling on pooled grain yield, biological yield and water use efficiency of wheat

Treatment	Grain yield (t/ha)	Biological yield (t/ha)	WUE (kg/ha-cm)
Crop establishment technique			
FIRBS	5.34	11.99	150.0
Conventional tillage	4.64	11.15	116.6
Minimum tillage	4.49	10.82	115.7
Zero tillage	5.10	11.59	135.3
SEm±	0.05	0.15	-
CD (P=0.05)	0.17	0.44	-
Irrigation schedule			
CRI+IW: CPE=0.90	5.12	11.78	127.9
CRI+IW: CPE=0.75	4.95	11.46	134.5
CRI+IW: CPE=0.60	4.61	10.93	124.1
SEm±	0.03	0.05	-
CD (P=0.05)	0.13	0.20	-

tional tillage (CT), minimum tillage (MT), zero tillage (ZT) and furrow irrigated raised bed system (FIRBS) in main plots with three irrigation schedules *viz*. irrigation at CRI+IW: CPE of 0.90, 0.75 and 0.60 in subplots using strip plot design. The experiment was conducted on the same layout during both the years. Wheat cv ‘WH 711’ was used during both the crop seasons.

RESULTS

Wheat planted under FIRBS produced significantly higher pooled grain yield (5.34 t/ha) as compared to other crop establishment techniques. Bed planted wheat had pronounced effect on pooled biological yield (11.99 t/ha) as compared to other crop establishment techniques but the difference between ZT was not marked significantly. Likewise, bed planting wheat (FIRBS) perceived highest pooled WUE (150.0 kg/ha-cm) followed by zero tilled wheat, conventionally tilled wheat and lowest in minimum tilled (MT) wheat. Naresh *et al*. (2014) observed lowest water use and highest WUE in bed planted wheat in comparison with other methods of sowing. Application of irrigation at higher moisture regimes resulted in significantly higher pooled grain and biological yields (5.12 and 11.78 t/ha, respectively) than lower moisture regimes. Higher grain and biological yields of wheat with higher moisture regimes was due to collective effect of dry matter production and yield attributes (Patil *et al*., 2014). Application of irrigation at CRI+IW: CPE=0.75 resulted in highest pooled WUE (134.5 kg/ha-cm) than other two moisture regimes.

CONCLUSION

From the present investigation, it may be concluded that planting of wheat under FIRBS along with application of irrigation at CRI+IW:CPE=0.90 was found better with respect to grain yield and WUE as compared to other crop establishment techniques and irrigation schedules. Adoption of bed planting in wheat saves around 12 % of total water use compared to conventional tillage.

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Evaluation of irrigation levels to commercial crops under pressurized method (drip) of irrigation in intercropping systems

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Field experiment was conducted at Irrigation water management research center, Belvatagi, University of Agricultural Sciences, Dharwad during *kharif* and *rabi* 2015-16 to study the Evaluation of irrigation levels to commercial crops under pressurized method (drip) of irrigation in Intercropping systems in Malaprabha Command area of zone III of Karnataka. The treatments comprise of three levels of irrigation with chilli as mono crop and chilli + onion and chilli + onion + cotton as intercrops with paired row system and comparing with farmers method. The results revealed that Under pressurized method of irrigation growing of chilli + onion + cotton intercropping system, the onion under raised bed (paired row 45-120-45 cm) recorded significantly higher bulb yield (48.83 t/ha) @ 1.0 ETo irrigation level as compare to farmers method and growing of onion + chilli + cotton at 0.8 ETo with a saving of 35 to 40 per cent of water compare to farmers method The yield parameters like bulb weight, bulb diameter, volume of bulb and plant height and number of leaves and were also higher with the 1.0 ETo as compared to farmer's method. The sole crop chilli recorded higher yield compare to intercropping systems the Equivalent yield and Gross and net returns were significantly higher with chilli + onion + cotton system as compare to other system.

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Effect of rice straw mulch on soil moisture, soil temperature and yield of wheat

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Wheat (*Triticum aestivum* L.) is the most important *rabi* cereal crop of India and contributes more than 30 per cent of world wheat production. Wheat crop has wider climate adaptability and highly sensitive to thermal and moisture stress. Mulch is one of the resource conserving technique that plays an important role in agronomic practices by conserving soil moisture and modifying soil and plant environment that help in maximizing crop yield. The mulch types also vary widely in terms of material used and their differential effects in producing the hydrothermal regimes in soil and plant systems. The application of mulch initially changes the soil temperature which differ with type and quantity of mulch material used along with its time and site of application. In Punjab, there is lot of problem of rice straw burning every year and approximately 18-19 million tons of rice straw is burnt every year. Keeping this in view, the experiment was planned to study the effect of rice straw mulch on soil moisture, soil temperature and yield of wheat.

METHODOLOGY

The present experiment on wheat crop (variety WH1105) was conducted during *rabi* seasons of 2014-15 and 2015-16 at the Research Farm, School of Climate Change and Agricultural Meteorology, PAU, Ludhiana. The crop was sown on 15 November during both the crop seasons. The rice straw mulch @ 5 tons/ha was applied at the time of first week of December. Recommended cultural practices were followed according to the package of practices by PAU. Gravimetric method was used for measurement of soil moisture in the soil profile. Soil moisture was measured after 15 days intervals starting from sowing to harvesting of the crop on dry weight basis and then converted into volume basis. Soil temperature during the entire growing period was recorded by soil thermometer.

RESULTS

The mean soil temperature was comparatively higher under mulch condition as compared to no mulch treatments. In the first and second year of experiment, mean soil temperature was significantly higher under mulch than no mulch. The standard deviation in mean soil temperature during 2014-15 was ± 2.37 and during 2015-16 was ± 3.23 (Fig. 1). Similarly, Fabrizzi *et al.* (2005) also observed higher soil temperature under mulch application during cold weather and lower soil temperature observed during warmer weather conditions as compared to non-mulch.

Soil moisture was significantly higher under mulch treatment during both the years as compared to no mulch (Fig.2). Evaporation recorded was comparatively low under mulch condition as compared to no mulch during early stages of the crop. It shows that more water was conserved in mulched crop than no mulch crop and mulching seems to be effective measure to conserve moisture and maintain soil temperature (Fig.

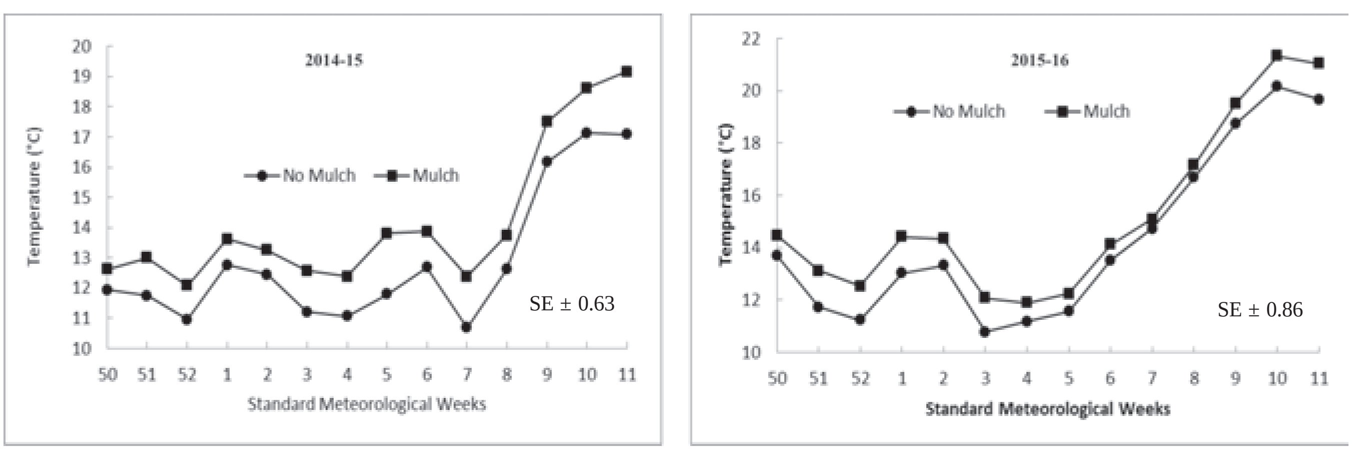

Fig. 1. Soil temperature under mulch and no mulch treatments.

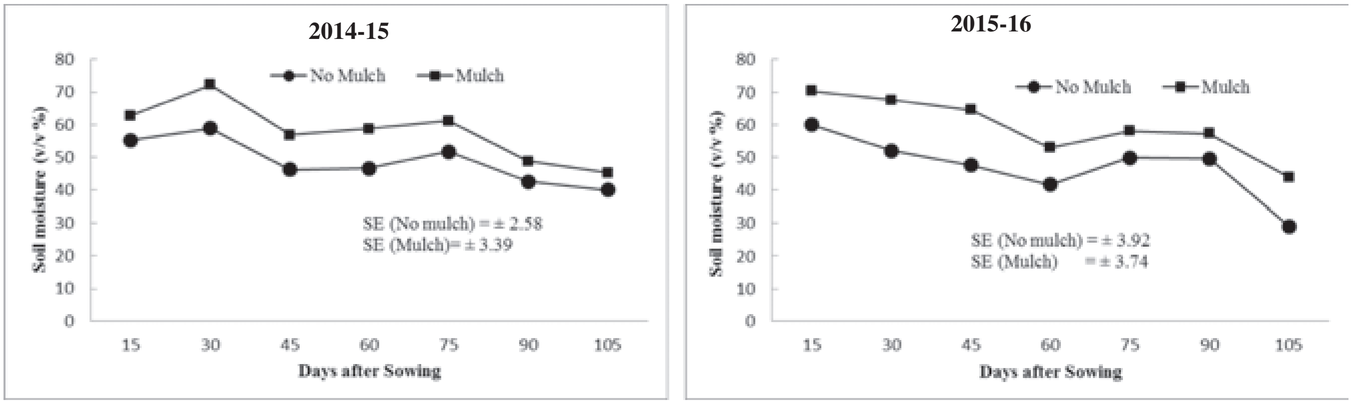

Fig. 2. Soil Moisture (v/v %) under mulch and no mulch treatments.

Table 1. Effect of application of straw mulch on grain yield of wheat during 2014-15 and 2015-16.

Treatment	Grain yield (t/ha)		Pooled
	2014-15	2015-16	analysis
No mulch	4.87	3.93	4.09
Mulch	4.23	4.23	4.264
CD (P=0.05)	0.158	0.224	0.132

2). Rahman *et al.* (2005) also reported the positive role of rice straw mulch in maintaining soil moisture. Application of mulch significantly influence the grain yield of wheat. Wheat yield recoded was 4.23 t/ha and 4.23 kg/ha higher in mulched conditions as compared to 4.087 t/ha and 3.932 t/ha non mulched conditions during 2014-15 and 2015-16 respectively (Table 1). Similar results were also reported by Qamar *et. al.* (2015).

CONCLUSION

Straw mulching in wheat crop is an effective measure to conserve soil moisture, to regulate soil temperature and increasing wheat yield. Conservation of moisture at later growth stages of wheat is helpful in avoiding terminal heat stress.

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Efficacy of hydrophilic polymer hydrogel on growth and yield of sunflower

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The experiment was conducted at Oilseeds Research unit Dr. P.D.K.V, Akola, during 2015-16 using a randomized block design with three replications along with seven treatment viz.,. RDF (80:60:30), RDF + 5t FYM/ha spreading across field, RDF + 2.5t FYM/ha in seed furrows, RDF + hydrogel @ 2.5kg/ha in seed furrows, RDF + humic acid @ 2.5 kg/ha in seed furrows, RDF + vermicompost @ 2.5t/ha in seed furrows and RDF + Fly ash @ 2.5 t/ha in seed furrows. This study was carried out with specific objectivesof higher moisture retention and slow release to tide over intermittent drought in kharif. The result showed that growth parameters viz., plant height, head diameter and 100 seed weight varied significantly due to use of moisture retentive material on sunflower. Application of 100% RDF with vermicompost @ 2.5t/ha recorded highest seed yield (1281 kg/ha) which was at par with the application of 100% RDF with hydrogel (1241 kg/ha). Remaining treatments were at par with each other. The highest gross (Rs. 42266/ha), net monetary returns (Rs. 24475/ha) and also B: C ratio (2.38) was recorded in RDF + vermicompost @ 2.5t/ha in seed furrows. Among the treatments, highest moisture (25.68%) was observed with application of 100% RDF with vermicompost@ 2.5t/ha at 30 DAS, at 45 DAS (28.24%), 60 DAS (22.47%) and at harvest (16.74%). Application of 100% RDF with hydrogel @2.5 kg/ha in seed furrows recorded highest moisture percentage at different growth stages, followed by vermicompost.

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Joint row planting – a high density planting method in sugarcane under wide row – mechanized - drip irrigated systems

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Introduction of drip and mechanization in Telangana had paved way for sugarcane planting at a wider spacing of 5 or 6 ft resulting in less no. of millable canes/ha due to reduced plant stand per unit area. Also, the wide row spacing provides poor geometry that does not intercept all the available light (Omoto *et al*., 2013). This could be overcome by high density planting within a row which by maintaining higher plant stand per unit area may compensate for more no. of millable canes/ha. Sugarcane being a C_4 plant is an efficient converter of solar energy to biomass. Further, dense planting of Sugarcane within a row with proper nourishment has a scope to realize high potential yield.

METHODOLOGY

The experiment was conducted during eksali of 2013 and 2014 at Agricultural Research Station, Basanthpur, Medak, Telangana. The soil of the experimental field was red sandy clay loam, low in available N (232.06 kg/ha) and medium in organic carbon (0.46 %), medium in available phosphorus (26.35 kg/ha) and available potassium (182.93 kg/ha) with neutral pH of 7.02. The treatments comprised of five plant row spacing methods viz., normal planting with 90 cm between the rows (P_1), wide row at 120 cm (P_2), wide row at 180 cm (P_3), paired row with 75 cm between pairs and 150 cm between rows (P_4) and Joint row planting at 210 cm between the rows (P_5). In joint row method of planting two sets/rows of seed were planted in a single furrow at a distance of 30 cm. While in the remaining methods of planting, a single set/row of seed was planted per furrow. The treatments were laid out in randomized block design in four replications with the variety Co 86032. The recommended doses of NPK were applied through urea, single super phosphate and muriate of potash, respectively.

RESULTS

The pooled mean of two year study indicated that planting a pair of seed material in a single furrow as in joint row method of planting was proved beneficial in achieving highest cane (144.16 t/ha) and sugar yields (26.87 t/ha) under mechanized and wide row spacing systems of sugarcane (Table 2). The better performance of the crop in this treatment was accounted to higher values of cane height (311.62 cm), single cane weight (1.54 kg), cane girth (cm) and sucrose content (18.39%). On the other hand, tiller count at 75 and 120 DAT was significantly at par and higher with normal planting and wide row planting at 120 cm. The number of millable canes per hectare was also significantly high with normal planting (Table 1). These results are in conformity with those of Yadav (1991) who reported that with constant seeding rate, the millable stalk number tends to decrease from narrower to wider spacings. Greater proportion of mother-shoot population with lengthy, thicker and heavier canes than that of tiller-

Table 1. Growth of sugarcane as affected by joint row planting method in comparison with the other planting methods

Planting method	Tiller population ('000 ha)		Plant height at harvest (cm)	No. of millable canes ('000 ha)	Girth (cm)
	75 DAT	120 DAT			
P_1 - Normal planting (90 cm)	89.00	182.13	202.60	105.14	2.25
P_2 - Wide row (120 cm)	91.92	184.93	247.27	97.40	2.41
P_3 - Wide row (180 cm)	69.24	126.22	319.49	72.00	3.06
P_4 - Paired row planting (75 cm between pairs;150 cm between rows)	75.44	158.34	278.25	87.11	2.52
P_5 - Joint row planting (210 cm between rows)	71.89	130.88	311.62	82.77	3.01
SEm ±	1.78	2.04	5.06	3.08	0.02
CD (P=0.05)	4.62	5.29	13.11	7.97	0.06

Table 2. Yield components and yield of sugarcane as affected by joint row planting method in comparison with the other planting methods

Planting method	Single cane weight (kg)	Cane yield (t/ha)	Sucrose content (%)	Sugar yield (t/ha)
P_1 - Normal planting (90 cm)	0.92	112.57	18.43	20.75
P_2 - Wide row (120 cm)	1.08	130.16	18.47	24.04
P_3 - Wide row (180 cm)	1.46	136.12	18.55	25.26
P_4 - Paired row planting (75 cm between pairs; 150 cm between rows)	1.21	124.86	18.48	23.08
P_5 - Joint row planting (210 cm between rows)	1.54	144.16	18.63	26.87
SEm ±	0.03	2.56	0.06	0.31
CD (P=0.05)	0.08	6.63	NS	0.80

Table 3. Cost economics of sugarcane as affected by joint row planting method in comparison with the other planting methods

Planting method	Cost of cultivation (Rs/ha)	Gross returns (Rs/ha)	Net returns (Rs/ha)	Benefit cost ratio
P_1 - Normal planting (90 cm)	126665	292682	166017	1.31
P_2 - Wide row (120 cm)	129178	338403	209225	1.62
P_3 - Wide row (180 cm)	128408	353899	225491	1.76
P_4 - Paired row planting (75 cm between pairs; 150 cm between rows)	127479	324623	197145	1.55
P_5 - Joint row planting (210 cm between rows)	122880	374816	251936	2.05

canes in joint row method of planting under wider spacing might have led to increased cane productivity per unit area. The joint row method of planting also has incurred a highest benefit of Rs. 2.05/ha due to highest gross (Rs. 374816/ha) and net (Rs. 251936/ha) returns with less cost of cultivation (Rs. 122880/ha) (Table 3).

CONCLUSION

Planting of sugarcane in joint rows with two rows of propagating material in a single furrow may compensate to the reduced stalk population and improve cane productivity by increased canopy coverage and light interception under mechanized wider row spacing systems compared to wider spaced single row planting.

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Enhancing the productivity of *rabi* castor (*Ricinus communis* L.) through drip-fertigation

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Castor is an ideal candidate for production of high value, industrial oil feeds tocks because of the very high oil content (48-60%) of the seed, the extremely high levels of potential oil production and this plant's unique ability to produce oils with extremely high levels of ricinoleic acid (Goodrum and Geller, 2005).Traditionally the crop is raised under resource poor conditions characterized by marginal soils, lowand erratic rainfall distribution, delayed sowings, little or no fertilizer application and use of poor quality seed. Consequently, the realized productivity is only 25 to 30% of actual yield potential and it's a challenging task to bridge this productivity gap in the country. Raising castor during winter (*rabi*) season with assured irrigation using hybrids is a new dimension with promise that provides greater stability and higher productivity. However, the water is becoming scarce due to competing demands including the location of research study. The study location area is a region with limited surface and ground water resources. Keeping this inview a field trial was conducted to evaluate the influence of variable water supply levels on growth, yield and WUE of DCH-519 hybrid under drip irrigation fertigation levels with water soluble conventional fertilizers.

METHODOLOGY

The treatment consisted of drip irrigation schedules at 0.6 and 0.8 EPan, fertigation of N (in the form of urea dissolved in water) and K (through water soluble $K_2 SO_4$) fertigation each at fertilizer doses (50%, 80% and 100% of recommended NPK) were compared with drip irrigation at 0.8Epan +80% N & K through soil application and surface check basin irrigation with soil application of NPK. A spacing of 120 x60 cm was adopted. Irrigation was scheduled at 3 days interval in drip method of irrigation and fertigation were scheduled as per the treatment at 10 day interval. The recommended fertilizers were applied (80-40-30 kg NPK/ha) through conventional straight fertilizers (Urea, DAP and Sulphate of Potash) in conventional irrigation/check basin method. In all the treatments the P source was applied as basal dose. Urea and $K_2 SO_4$ were mixed in water and was used as fertigation from 20 to 180 DAS. Irrigations were scheduled as per the treatments by taking daily evaporation data obtained from USWB open pan evaporimeter situated in Narkhoda farm. The quantity of water discharged for individual treatments were measured with water meters fixed to the system. The recommended agronomic practices and plant protection measures were adopted as and when required. Data on yield, yield attributes and water consumed were documented and analyzed statistically.

RESULTS

The results indicated irrigation treatments significantly influenced plant height, number of branches, capsules per plant, and primary length of spike. The drip irrigation at 0.8 Epan +100% N & K through fertigation recorded significantly highest plant height (118.3cm), number of branches (11.5), capsules per spike (75.58), length of primary spike (90.2cm) 100-seed weight (32.8 g). Significantly higher castor seed yield (3786 kg/ha) and stalk weight (6838 kg/ha) were registered when irrigations were scheduled by drip at 0.8 Epan along with supply of full amount of N& K through fertigation. It was on par with scheduling irrigation through drip at 0.6 Epan through fertigation. Studies conducted by Nagabhushanam and Raghavaiah (2005) on similar lines revealed that castor has to be irrigated at 0.8 IW/CPE ratio (wet regime). Though oil content was not significantly influenced due to different irrigation treatments, oil yield was significantly influenced and the highest oil yield (1712 kg/ha) was registered when irrigations were scheduled by drip at 0.8 Epanalong with supply of full amount of N& K through fertigation which was at par with scheduling irrigation through drip at 0.6 Epanthrough fertigation (1679 kg/ha). The highest water use efficiency of 6.44 kg/ha-mm, was registered under drip irrigation at 0.6Epan +100% N& K through fertigation followed by drip fertigation at 0.8Epan +100% N& K through irrigation (4.98 kg/ha-mm) and lowest in surface method of irrigation (2.91 kg/ha-mm).The water productivity was highest under drip irrigation at 0.6Epan +100% N& K through fertigation (0.644 kg/m^3) followed by drip fertigation at

0.8Epan +100% N& K through irrigation (0.498 kg/m^3) and lowest in surface method of irrigation (0.291 kg/m^3). The economic analysis of different drip fertigation treatments revealed that drip irrigation at 0.8 Epan +100% N & K through fertigation resulted in highest gross returns (140082 / ha), net returns (105714/ha) and B: C ratio (3.85).

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Energy use and crop productivity in agriculture

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Increasing focus on farm mechanization has changed the structure of energy consumption in the Indian agriculture, with a huge shift from animal and human labour towards tractor for different farming operations and electricity and diesel for irrigation. The share of commercial energy inputs in agriculture has gone up to 90 per cent in 2012-13. The total power availability in Indian agriculture has increased from 0.29 kW/ha in 1970-71 to 1.84 kW/ha in 2012-13. The total commercial energy input to Indian agriculture has increased from 425.4 × 10^9 Mega Joules (MJ) in 1980-81 to 3222.5 × 10^9 MJ in 2009-10. In agriculture energy is directly used as for pumping and mechanization, and indirectly in the form of fertilizers and pesticides. The consumption pattern of both direct (diesel and electricity) and indirect (fertilizers and pesticides) energy inputshas revealed that the energy consumption per hectare of net as well as gross cropped area has increased over time and therefore, the output per unit of energy use has declined. This underscores that Indian agriculture has become more energy-intensive with a concomitant shift from the use of renewable to fast-exhausting non-renewable sources. The cost of cultivation data clearly indicate that the expenses on farm inputs put together have registered a phenomenal increase since the 1990s. The contribution of cost on machine labour has increased tremendously in recent years and accounts for the second largest component after wages, in the operational costs of cultivation. The machine labour charges, which were less than 4 per cent of the operational cost in 1970-71, rose tremendously to 24 per cent in 2009-10 in the case of wheat. This has been due to widespread mechanization of agriculture, as well as frequent upward revision of diesel prices and electricity tariffs. It is worth mentioning that in states like Tamil Nadu, the average cost of cultivation of rice on machine labour was 11 per cent during 2000s as compared to only 2 per cent in 1980s. Moreover, farmers even in the poorer states depend more on machine labour.In view of the increasing share of energy in the cost of cultivation, agriculture is vulnerable to the rise in energy price. Assuming direct and indirect energy price increase by 10 per cent, then total energy cost would be 3.0 per cent higher than the original cost, considering 16 and 14 per cent share respectively in production cost of wheat. This would represent a direct reduction from farm income. In the long run, a sustained rise in energy prices may affect input use and production practices. On the output side, it will raise the output prices which have far more serious implications for food security, poverty and the cost of industrial production. The state-wise analysis of energy-use or farm mechanization and foodgrain productivity has demonstrated that energy use in the high-productivity states like Punjab and Haryana use seven-times more energy as compared to the low-productivity states like Odisha (4 GJ/ha). This clearly calls for investment on energy-related infrastructure and farm mechanization in the states having low energy consumption in order to achieve the targeted growth of four per cent. Further, the recent agricultural input survey data indicated substantial increase in the use of tractors and cultivators, especially on small and marginal farms which constitute four-fifth of the total number of operational holdings in the country.The increasing use of energy-intensive inputs and its positive correlation with agricultural output as well as rising trends toward commercialization and diversification of agriculture will certainly increase the demand for commercial energy in the coming years. The energy foresight exercise indicated that in order to achieve the national average of energy-use for the entire cropped area of the country, the energy requirement in farm sector will be double of the current consumption (21.94 million tonnes of oil equivalents). Besides, the energy requirement of the food-processing sector of India has shown a rapid growth. The total energy-use in the food processing sector has reached the level of 4.37 MTOE in the year 2010-11, which is more than tripled from 1.20 MTOE in 2005-06.

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Salinity tolerant microorganism improves rice plant growth and soil biological activity of unique coastal acid saline soils of west coast of India

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Sea water intrusion is one of the most common causes of salinity in coastal areas in India. Under such condition, co-existence of high level of salinity and acidity (low soil pH) is observed. These soils are called as ‘Khazan lands’ in Goa and Kharlands in Maharashtra. Monoculture of rice is prevalent during monsoon (rainy season) and fields are often left fallow during subsequent winter season. Abandonment of agriculture in soils affected with salinity has been observed recently as rice crop yield (1.5 – 2.0 t /ha) are very poor. Effect of salinity on physical and chemical properties is documented very well in high pH soils (Keren, 2000) and less intensively documented for microbiological properties (Reitz and Haynes, 2003).Soil microflora regulates organic matter decomposition, nutrient availability and aggregate formation and thus plays a pivotal role in maintaining and improving soil quality (Egamberdieva et al., 2010).Mahajan et al., (2016) has reported depressive effect of salinity on soil microbial activity in these areas. Thus, alleviating the salinity stress by application of the salinity tolerant microorganisms having plant growth promotion activity seems to a viable approach for crop cultivation on such soils. To study this, a pot experiments was undertaken with an objective to study the effect of application of salinity tolerant microorganisms on rice plant growth and soil biological activity in coastal acid saline soils of west coast of India.

METHODOLOGY

A pot experiment was conducted at the Institute farm, ICAR-CCARI, Old Goa during 2014. The coastal acid saline soils collected from Chorao Island, Tiswadi taluk, North Goa, Goa were processed for imposing treatments before start of the experiment. All the pots were treated with the recommended dose fertilizers. Experiment was done on salt tolerant rice variety CSR-27.The experiment involved application of two salinity tolerant microorganisms (Microbe 1 and Microbe 2) as alone and consortia. Two salinity tolerant microorganisms were selected based on primary study in laboratory conditions. These microbe had high salinity tolerance and plant growth promoting characters. The treatments of the experiment were – Microbe1, Microbe1, Consortia, control, Microbe1 + FYM, Microbe2 + FYM, Consortia + FYM, Control + FYM (Where FYM is farmyard manure applied at 0.5 kg per pot). The microbe were inoculated after establishment of the transplanted (25 days old) seedlings. Liquid formulation of the microbe were applied near the root zone of the plants. Four number of seedlings were maintained per pot. The one way analysis of variance for the completely randomized design was done for different parameters - rice plant growth, soil microbial and enzyme activities, using SAS version 9.3 (SAS 2012). Growth stage wise variation in the soil pH and EC were also recorded and analyzed.

RESULTS

The application of salinity tolerant microorganisms influenced the plant growth paramters – straw weight, root dry weight, root length and root volume significantly ($p<0.05$). Significantly ($p<0.05$) highest straw weight (39.1 g/pot), root dry weight (38.8 g/pot), root length 21.1 mm) and root volume (46.4 mL/pot) were recorded with application of Microbe1 + FYM. In general, the performance of application of salinity tolerant microorganisms was better with application of FYM compared to their alone application.The lowest plant growth characteristics were observed in the control treatment. These results are supported by the observations on the soil biological activity. The treatments affected the soil biological activity of the soils significantly ($p<0.05$). Similar to plant growth parameters, the highest soil biological activity was recorded in the treatment with application of Microbe1 + FYM. It was also noticeable that, the soil biological activity was higher in FYM treated plots compared to untreated. This reveals that the application of FYM has a complimentary effect to boost the performance of the salinity tolerant microorganisms. This could be due to higher food availability to the microorganisms. Highest dehydrogenase (242 µg TPF g^{-1} day^{-1}), urease (95 µg g^{-1} h^{-1}), phosphatase (618 µg PNP $g^{-1}day^{-1}$), basal soil respiration (0.488 mg CO_2-C $g^{-1}day^{-1}$), soil microbial biomass carbon (203 µg g^{-1}), microbial biomass carbon as a fraction of the soil organic carbon (3.96 %) were observed in the treatment Microbe1 + FYM. Interesting to notice this treatment recorded lowest metabolic quotient (0.96 µg g^{-1} h^{-1}), this indicates the lesser effect of salinity stress on the soil microorganisms. The microorganisms was identifies as *Bacillus methylotrophicus* strain STC-4. It was isolated from rhizosphere soil of cowpea. The strain is a plant growth promoter and salt tolerant (upto 1.5M). The strain was identified based on morphological, biochemical and 16S rRNA sequence (NCBI Acc. N. KU682846). Morphological description: Irregular colony with undulate margin. Surface: rough, Appearance: dull; Opaque, Gram positive rods with terminal spore. Biochemical characteristics: Positive to VP test, Citratetest, Casein test, Starch hydrolysis, Esculine Hydrolysis, Nitrate reduction, Cytochrome oxidase, Catalase and Gelatin hydrolysis. Negative to MacConkey, Indoletest, Methyl red test, Urea hydrolysis and H2S gas production. The cultureis deposited in the national repository of NBAIM, Mau (Acc.N. NAIMCC-B-01890) (Ramesh and Mahajan, 2015).

CONCLUSION

The results of the study reveals that application of salinity tolerant microorganisms (*Bacillus methylotrophicus* strain STC-4) promotes the plant growth and soil biological activity in rice under controlled conditions in coastal acid saline soils of Goa. Furthermore, its field evaluations are needed to test its viability under natural conditions.

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Effect of irrigation water salinity on growth and yield of fodder pearl millet varieties

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Inadequate supply of good quality water for irrigation is a major factor limiting grain as well as fodder crop production in arid and semi-arid regions of our country. It has become imperative to use suitable crop like pearl millet and its genotype for sustainable and economically sound production systems that can use poor quality water and withstand drought on saline lands. Increasing the productivity of water and making safe use of poor quality particularly saline and alkali water will play a vital role in easing competition for scarce water resources, prevention of environmental degradation and provision of food and fodder security. The green fodder of pearl millet is leafy, palatable, HCN free and very nutritious feed stock for cattle ensuring good milk yield. Pearl millet has been reported to have high tolerance to salinity and drought thus it can serve as an important fodder cum cereal crop in the arid and semi-arid regions of India.

METHODOLOGY

The experiment was conducted during *Kharif* season of 2015 at Experimental Farm, Nain (Panipat), ICAR -CSSRI, Haryana. The experiment was laid out Randomized Block Design consisting of eight treatment combinations of four Irrigation water salinity (Control, 3, 6 and 9 dS/m) and two pearl millet genotypes viz., AVKB-19, ICMV-15111 with four replications. Application of 72 g Urea/plot and 72g DAP/plot at the time of sowing as per recommendation. Next split doses of urea application at the time of first cutting and then after first cut. The seeds of pearl millet 2 varieties *viz* AVKB-19 and ICMV-15111 were sown in 12 rows with a distance of 30 cm between the rows. First cut was taken at 50 days after sowing (DAS) with seed rate of 12 kg/ha and spacing 30 cm×10 cm. Irrigation was applied with 1.2 ID/CPE ratios. Data for green fodder yield were taken at I cutting and statically analysed.

RESULTS

Ultimate objective of any technological intervention is to get maximum productivity per unit area. Green fodder yield is a function of various growth and yield contributing parameters like plant height, number of leaves per plant, number of tillers per plant etc. The data on green fodder yield of pearlmillet are presented in Table 1. The data indicated that the main effect of irrigation water salinity on green fodder yield of pearlmillet was significant. The maximum green fodder yield (37.55 and 34.74 t/ha) was observed with the application of good quality water and water having EC 3.0 dS/m respectively, at 1st cut at 50 DAS. The minimum green fodder yield (23.97 t/ha) was recorded from the plants irrigated with saline irrigation water having EC 9.0 dS/m (36.17 % reduction from good quality water), while in case of irrigation water with EC 6.0 dS/m the green fodder yield was found (30.52 t/ha) at 1st cut at 50 DAS. The statistical results for performance of pearlmillet cultivar showed that AVKB-19 which produced 32.74 (t/ha) significantly high mean green fodder yield as compared to ICMV-15111(30.65) 1st cut at 50 DAS.

Table 1. Effect of irrigation water quality and varities on green fodder yield (t/ha) of pearl millet.

Irrigation water quality (dS/m)	Varieties ICMV 15111	AVKB 19	Mean
Control	36.24	38.87	37.55
3 dS/m	33.78	35.70	34.74
6 dS/m	29.12	31.92	30.52
9 dS/m	23.46	24.47	23.97
Mean	30.65	32.74	
Factor	V	I	VxI
SEm±	0.70	0.99	1.40
CD at 5%	1.46	2.06	NS

CONCLUSION

With successive increase in salinity levels the green fodder yield decreased from 37.55 to 23.97 t/ha. The variety AVKB 19 gave significantly higher green fodder yield at Karnal.

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Evaluation of different basmati varieties at different time of transplanting in Punjab conditions

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The basmati rice is a vital crop diversification module to hault depleting underground water that is guzzled by the coarse rice varieties grown on 24 lakh ha in Punjab. But basmati's transplanting time coincides with arrival of monsoon that reduces its irrigation demand. But the grain yield of Basmati rice is comparatively low than the coarse rice. Basmati rice is also known for its unique aroma which is due to acetyl 2 praline compound present in it. This aroma develops only when basmati rice matures in low temperature and shorter day length. The Punjab climatic conditions are suitable for producing good quality basmati rice. Early transplanting of basmati results in less quality grains due to high temperature during ripening and late transplanting also is not much favorable in Punjab conditions due to delayed harvesting resulting late sowing of succeeding wheat crop in basmati rice – wheat cropping system. The yield potential of basmati rice can be increased by manipulating the time of transplanting and selection of high yielding genotypes. Therefore, a field experiment was planned to find the optimum time of transplanting for different basmati varieties for obtaining high grain yields.

METHODOLOGY

A field experiment to find the suitable time of transplanting of promising genotypes for obtaining higher grain yield was carried at the research farms of rice section of department of plant breeding and genetics, Punjab Agricultural University Ludhiana during *kharif* 2014. The soil of the experimental site was loamy sand with low in available nitrogen, Phosphorous and organic carbon but medium in available Potassium. The experiment was carried with three dates of transplanting in main plots viz. 5th July, 15th July and 25th July where as eight promising genotypes were kept in subplots viz. Pusa Basmati 1509, Punjab Basmati 3, Pusa Basmati 1121, RYT 3382, RYT 3390, Pusa 1612, Pusa 1592 and Punjab Mehak 1 with three replications. The nursery of different genotypes was raised on broad beds with 1.3 kg Urea/100m^2 and 1.5 kg Single Superphosphate /100m^2 as per the different dates of transplanting. The nursery of the different genotypes transplanted in the field as per different dates of transplanting. The crop was raised with the application of 36 kg Urea/acre in two equal splits at 3 weeks and 6 weeks after transplanting. The weed control is done with 15 days continuous stagnation of water in the field after transplanting and with the application of Pretilachlor 50 EC @ 600 ml /acre. For insect and pest control 10 kg Cartap hydrochloride was applied after 45 days of transplanting and one spray of chloropyriphos was done to control stem borers and leaf folders. Irrigation was applied two days after the drying of water in the field and irrigation was stopped 15 days prior the harvesting of the crop. The data was recorded pertaining to the yield attributes and yield as per the treatments. Recorded data was statistically analysed .

RESULTS

The plant height, number of days taken for 50% flowering and grain yield and yield influenced significantly at different dates of transplanting. The plant height and grain yield was significantly higher when transplanting was done at 5th July but these attributes were not good when the crop was transplanted on 25th July. The data in the Table 1 showed that Plant height and number of days taken for 50 % flowering was maximum at 5th July transplanting and it reduced significantly with further delaying the transplanting. The grain yield was significantly higher at early transplanting than the late transplanting but statistically at par with 15th July transplanting. Among the varieties, Pusa basmati 1121 attained significantly more plant height than all other varieties, whereas RYT 3390 attained significantly smaller plant height. The variety Pusa basmati 1509 took significantly lesser and RYT 3390 took significantly more number of days for attaining 50% flowering. The variety Pusa 1592 gave significantly higher grain yield (47.51 q/ha) than all other varieties but statistically at par with Punjab Mehak 1 and Pusa basmati 1509.The varieties Punjab Mehak 1, Pusa basmati 1509, Pusa basmati 1121 and RYT 3390 all were statistically at par for obtaining grain yields.

Table 1. Effect of date of transplanting on the productivity of Basmati Varieties

Treatment	Plant height (cm)	No. of days taken for 50 % flowering	Grain yield (q/ha)
Date of transplanting			
July 5	102.2	108.2	49.60
July 15	98.3	103.9	48.40
July 25	95.1	101.5	33.94
CD (p=0.05)	0.9	1.0	1.39
Varieties			
Pusa Punjab Basmati 1509	97.3	94.0	45.82
Punjab Basmati 3	98.3	112.7	39.03
Pusa Basmati 1121	115.6	110.2	45.34
RYT 3382	89.1	111.3	40.76
RYT 3390	85.5	116.0	44.79
Pusa 1612	102.8	98.8	42.59
Pusa 1592	97.8	98.3	47.51
Punjab Mehak 1	101.7	95.0	46.02
CD (P=0.05)	1.3	0.6	1.73

CONCLUSION

From this experiment it was concluded that optimum time of transplanting for basmati is first fortnight of July. The varieties Pusa 1592, Punjab Mehak 1, Pusa basmati 1509 and RYT 3390 gave high grain yields in lesser number of days under Punjab conditions.

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Irrigation management in mentha (*Mentha arvensis* L.) under different growing conditions of *tarai* region of Uttarakhand

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India is a leading producer of mint oil, contributes approximately 85% of the total world production (Anwar *et al.,* 2010). In India, it is cultivated on 1.75 lakh ha area with a production of 55000 tonnes. Mint cultivation is mainly confined to northern states of Punjab, Haryana, Uttar Pradesh, Bihar and *tarai* belt of Uttarakhand (Kumar *et al.,* 2001). These areas, which are pre-dominated by rice-wheat cropping system, mint crop could a remunerative pre-position for the farmers. In Tarai region, it could be a better substitute of high water requiring summer rice crop which is exhausting the ground water table at an alarming rate. After paddy harvest and before next paddy transplanting, there is a gap of about 6-7 months. In this period, taking only wheat or mentha alone leaves about 2 months fallow period which may result in poor system and water productivity. In this regard, relay planting of mint in wheat and late mint transplanting after wheat are the viable options to improve the crop and water productivity. Under different menthol mint growing systems, crop experiences variable climatic conditions across the growing period. Therefore, it may affect the irrigation requirement and application time. Hence, the present study was undertaken to find out suitable irrigation schedule (IW:CPE ratio) as well as to assess its impact on crop and water productivity of mentha under different growing situations.

METHODOLOGY

The field experiment was conducted at the Norman E. Borlaug Crop Research Centre, G.B. Pant University of Agriculture and Technology, Pantnagar; district U.S. Nagar (Uttarakhand) during *rabi*-summer season of 2014-15. Soil of the experimental site was sandy loam in texture, neutral in reaction, rich in organic carbon, low in available nitrogen and high in available phosphorus and potassium. During the crop season (wheat sowing to till mint harvesting), a total 218.6 mm rainfall was received. Out of that, 155.8 mm rainfall was received by timely planted sole mint period. PBW-550 and Sim sarayu varieties of wheat and menthol mint, respectively were used in the study. Sole and intercropped mint was planted at optimum sowing time, i.e. in January. For mint after harvest of wheat, 30 days old nursery was transplanted. Wheat was sown 20 cm apart. For relay cropping of mint in wheat, after every two rows of wheat (20 cm apart), one row was skipped which was later used for relay cropping of mint. In sole mint, the suckers were placed in end to end fashion at a depth of 4 to 5 cm in furrows spaced 40 cm apart and covered immediately with fine loose soil. Similarly, for relay cropping of mint, a furrow was opened between two paired rows of wheat and suckers were planted. Crop was raised as

Table 1. Yield and water use parameters of mint as influenced by different treatments

Treatment	Wheat grain yield (t/ha)	Mentha oil yield (kg/ha)	MEY (kg oil/ha)	Irrigation depth (cm)	Irrigation WUE (kg oil/ ha-cm)
Cropping system					
Sole mint	-	196.9	196.9	21.0	9.38
Wheat + mint (2:1)	3.76	171.2	235.4	49.5	4.76
Wheat-transplanted mint	3.56	124.3	185.1	52.5	3.53
CD (P=0.05)	NS	6.7	7.6	-	-
Irrigation schedule					
IW:CPE 0.6	-	126.5	167.1	30	5.57
IW:CPE 0.8	-	158.8	202.9	38	5.33
IW:CPE 1.0	-	178.6	219.5	44	4.99
IW:CPE 1.2	-	192.7	233.7	52	4.49
CD (P=0.05)	-	7.7	8.8		

per recommended package of practices. IW: CPE based treatments were executed after the establishment of crop. In wheat-transplanting system, irrigation was applied just after the harvesting of wheat and then the respective plots were subjected to irrigations according to IW:CPE ratio based treatments. In each irrigation , 6 cm water depth was maintained by using Parshall flume.

RESULTS

Mint oil equivalent yield was the highest with wheat + mint (2:1) followed by sole mint and lowest with wheat-transplanted mint crop (Table 1). The mint oil equivalent yield increased with increased irrigation supply being the maximum in IW: CPE 1.2 ratio. It produced significantly higher mint oil equivalent yield than remaining IW: CPE ratios. Irrigation water use efficiency was found to be the maximum with timely plated sole mint crop. It recorded 97.1 and 165.7% higher IWUE than intercropped and transplanted mint, respectively. It was due to producing higher MEY by consuming less irrigation water. Crop rose under 0.6 IW: CPE ratio was superior to others irrigation schedules when irrigation WUE was concerned as in a good rainfall year, irrigation frequency was too less in this treatment. IWUE deceased gradually with increase in frequency of irrigations. This was attributed to more depth of irrigation water required at higher moisture regimes.

CONCLUSION

Findings of present study indicate that either intercropping of mint in wheat in 2:1 row pattern or timely planted sole mint crop are good options to get higher productivity and profitability. Mint should be irrigated at 1.2 IW: CPE ratio.

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Performance of chickpea under planting techniques and irrigation levels

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Chickpea is the most important winter pulse crop of India occupying 6.93 million ha with an annual production of 5.6 million tonnes (FAO, 2006). It is predominantly grown on residual soil moisture as is evident from the fact that of the total area in the country, only 1.96 million ha (28.3%) is irrigated (FAI, 2005). Hence, its production is largely depends on the availability of residual soil moisture. The cultivation of chickpea in clay soil on flat beds faces the problem of water logging and poor aeration and adversely affects the productivity under over irrigated conditions. Under such circumstances, a small change in flat field condition through planting techniques may help in improving the productivity of chickpea. Further, the moisture stress at some of the critical stages of growth often leads to its lower productivity. But, irrigating the crop at most critical stages, appropriate quality and through suitable method is the key factor for high and economical yield. Therefore, the present investigation was undertaken to ascertain beneficial effects of irrigation and land configuration treatments on performance of chickpea.

METHODOLOGY

The field experiment was conducted at the Agricultural Research Station, NAU, Tanchha, during the *rabi* season of 2009-10 and 2010-11. The experiment was conducted on clayey soil having organic carbon (0.38 %), available nitrogen (209 kg/ha), available phosphorus (30 kg/ha) and available potassium (354 kg/ha). The soil was slightly alkaline in reaction. Total 12 treatment combinations consisting of three lev-

Table 1. Yield and economics of chickpea as influenced by irrigation levels and planting techniques

Treatment	Grain yield (kg/ha)	Stover yield (kg/ha)	Harvest index (%)	Net return ($x10^3$/ha)	B:C ratio
Irrigation (Main plot)					
One irrigation at branching stage	986	1718	36.5	34.1	1.8
One irrigation at pod development stage	1046	1796	36.8	37.3	2.0
Two irrigations at branching and pod development stages	1137	1899	37.4	41.7	2.2
CD (P=0.05)	63	72	NS		
Planting techniques (Sub plot)					
Flatbed sowing	1005	1739	36.6	35.4	1.9
Furrow after two rows	1039	1784	36.8	36.8	2.0
Furrow after three rows	1057	1800	37.0	37.8	2.0
Furrow after four rows	1125	1894	37.2	41.5	2.2
CD (P=0.05)	53	58	NS		

els of irrigation as main plot treatment (*viz*., I_1: One irrigation at branching stage, I_2: One irrigation at pod development stage and I_3: Two irrigations at branching and pod development stages) and four planting techniques as sub plot treatment (*viz*., P_1: Flatbed sowing, P_2: Furrow after two rows, P_3: Furrow after three rows and P_4: Furrow after four rows) and with one control was laid out in split plot design with three replications. Chickpea *var*., GG-2 was sown on 21 and 22 November during 2009 and 2010 respectively. The seed was sown 30 cm row apart by bullock drawn seed drill. The crop was fertilized with 20-40 kg NP/ha through urea and diammonium phosphate, applied as basal. The crop was raised as per the recommended package of practices except the treatment.

RESULTS

Significantly higher seed (1122, 1152 and 1137 kg/ha, respectively) and stover (1960, 1838 and 1899 kg/ha, respectively) yields were recorded, when crop irrigated twice at branching and pod development stages during both the years and pooled (Table 1). The might be expected as sufficient amount of available moisture present in the upper soil layer with low tension. However, harvest index was remained unchanged. Adoption of either furrow after four rows or furrow after three rows techniques of sowing were found equally effective by producing significantly higher grain yield during individual years. However, in pooled, furrow after four rows methods of sowing recorded significantly the highest grain yield. Further, it increased grain yield by 12.43, 11.47 and 11.95%, respectively during first and second year and in pooled data compared to flatbed sowing. Whereas, stover yield was found significantly the highest under the treatment furrow after four rows. The increase grain and stover yields was due to the cumulative effect exerted from better improvement in drainage, soil environment, aeration, soil microbial activity, root development and optimum moisture-air equilibrium throughout the crop growth besides supply of available nutrients to the crop resulting in better growth and development ultimately reflected into better grain yield. Significantly higher grain and stover yields were recorded under treatment mean over control during both the years as well in pooled. It might be due moisture availability during different growth stages of crop which enhance the metabolic activities in terms of higher rate of cell division and cell enlargement and favourable environment in the root zone resulting in absorption of more water and nutrients from soil because of cumulative effect exerted from better improvement in drainage, soil environment, aeration, soil microbial activities, root development. Thus, enhance availability of nutrients, water, light and space which might have accelerate the photosynthetic rate, thereby increasing the supply of carbohydrates, which finally improved growth and yield of crop. Furrow after four rows technique of sowing secured maximum net realization of 41513/ha with BCR of 2.24 and lowest net realization of 35442/ha with BCR of 1.94 was obtained under flatbed sowing treatment. The data further revealed that the maximum net realization of 41725/ha with BCR of 2.21 were obtained in treatment two irrigations at branching and pod development stages.

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Performance of transplanted pigeonpea through drip fertigation

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Pigeonpea (*Cajanus cajan)* is one of the protein rich legume of the semi-arid tropics grown predominantly under rainfed condition. Among the different agronomic practices, planting techniques, irrigation methods, imbalanced fertilization and delayed sowing *etc*. are limiting the yield. Precise nutrient management is important factor to obtain desired results in terms of productivity and nutrient use efficiency (NUE) in pigeonpea. The advantages of the fertigation technique include a slow-release of fertilizer, higher N uptake by the plant. Raising pigeonpea seedlings well in advance and transplanting in the field would help in getting higher yield and profits.

METHODOLOGY

The studies were conducted in 2015 rainy season at Agriculture College Farm, UAS, Raichur ($16^0$12' N, $77^0$20'E, and 389 m MSL). The experiment was laid out in RBD and replicated three times, treatment combinations consists of soil application of Normal fertilizer (NF) at 100% RDF without irrigation, surface irrigation with soil application of 100 % RDF (NF), drip fertigation of NF at 75% RDF in 3, 4, 5 splits, drip fertigation of NF at 100 % RDF in 3, 4, 5 splits, drip fertigation of WSF (water soluble fertilizer) at 100% RDF in 3, 4, 5 splits at 30, 45, 60, 75 and 90 days after transplanting. Each plot has ten rows with 10.8 m × 6 m area transplanted at 150 x 60 cm. The seeds were sown on 19^{th} June, 2015 in polythene bags (8' x 5') having 3/4th of soil and 20 g of vermicompost. The polythene bags were watered regularly. After one month, the seedlings were transplanted in the main field by opening the furrow at 15-20 cm depth. The drip system includes pump, filter units, fertigation tank, main line and sub line for each replication and a lateral for each plot. The drip line was passed in between two consecutive rows, which includes six laterals were placed per plot for each row, 10 emitters in each row at a distance of 60 cm with a total of 60 emitters per plot. In this experiment, normal fertilizer (NF) and water soluble fertilizer (WSF) were used for the study. For soil application, 100 per cent nitrogen and phosphorus *i.e.,* only normal fertilizer (NF) was applied in the form of DAP and urea, at the time of planting as basal dose. In drip fertigation methods, according to treatments, required quantities of fertilizer (NF and WSF) were given in 3 to 5 equal splits at 15 days interval starting from 30 DAT to 90 DAT.

RESULTS

Experimental results revealed that drip fertigation of WSF at 100% RDF in 5 splits recorded significantly higher dry matter production per plant at harvest (415.2 g/plant), pods per plants (693.3), seed yield (3340 kg/ha). Improvement in pigeonpea grain yield with drip fertigation was 7.5 to 60.5 per cent with normal fertilizers and 98.4 to 134.1% with water soluble fertilizers over surface application. Further, improved yield was observed with increased split application of fertilizers. The improvement in productivity is due to significant increase in the number of branches, leaf area and leaf area index. Significantly higher net returns (Rs. 141983/ha) were recorded by providing drip fertigation of WSF at 100 per cent RDF in 5 splits as compared to other treatments. Significantly lower seed yield was recorded with soil application of Normal fertilizer (NF) at 100% RDF without irrigation. Drip fertigation of WSF at 100 per cent RDF in 5 splits recorded higher yield and other parameters over soil application .It was mainly due to increased solubility and availability of nutrients as they were supplied at 5 equal splits, thus minimizing the loss to a considerable extent. Higher gross, net returns and BC ratio could be obtained when 100 per cent RDF applied through WSF through fertigation in 5 splits over conventional method of irrigation.

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An alternate for conventional inline drip lateral to small and marginal farmers

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Technological innovations are to be exploited to achieve the objective of higher productivity and better water use efficiency. In this regard, drip irrigation is one of the best alternative in delivering water near to the root zone of the plant. But it cannot be afforded by and are not appropriate for the smallholder farmer. Smallholder farmers require affordable, robust and simple drip system for them to adopt and realize the benefits that drip can offer. In this context, the present study was under taken to evaluate the comparative performance of low cost drip tape irrigation system with conventional inline drip system on growth and yield of sweet corn.

METHODOLOGY

Field experiment was conducted at Tamil Nadu Agricultural University, Coimbatore during 2013-14. The experiment was laid out in RBD. There were seven treatments with three replications. Raised beds were formed in a well prepared field with a bed width of 120 cm and furrows of 30 cm. Conventional inline drip laterals (900 micron wall thickness with a size of 16 OD, Rs. 12.25/m, 7 years of life system, dripper spacing 40 cm with a discharge rate of 4 lph) and low cost drip tape laterals (250 micron wall thickness with a size of 16 OD, Rs. 2.40/m, 3 years of life system, dripper spacing 45 cm with a discharge rate of 8 lph) were fixed in the sub mains with a lateral spacing of 150 cm. Emission uniformity of conventional inline drip laterals and low cost drip laterals were 96 and 94%, respectively. Sweet corn hybrid (Sugar 75) from Syngenta company was used for field experiment. It is a short duration (80-90 days) with higher yielding hybrid.

RESULTS

Generally, increased levels of irrigation regime through drip system favoured plant growth positively (Table 1). Drip irrigation (DI) at 125% PE with conventional inline drip system (T_4) registered higher plant height and DMP of 241.40 cm and 18785 kg/ha, respectively followed by DI at 125% PE with drip tape system(T_1) and it is significantly different from surface irrigation at 0.8 IW/CPE (T_7). Higher frequency of irrigation and increased availability of soil moisture under drip irrigation might have led to effective absorption and utilization of available nutrients and better proliferation of roots resulting in quick canopy growth (Ayotamuno, 2007). The Vegetative growth was lower in surface irrigation because of unfavorable moisture regime in the soil. The increase in sweet corn green cob yield in T_4 was 46.6% and 45.58% in T_1 over T_7. Drip irrigation scheduled at 125% PE registered significantly higher green fodder yield in both conventional inline drip system (22.93 t/ha) and drip tape system (22.58 t/ha),

Table 1. Effect of drip tape and conventional inline drip irrigation system on growth and yield of sweet corn

Treatment		Plant height (cm)	DMP (kg/ha)	Green cob yield (t/ha)	Green fodder yield (t/ha)
T_1	DI at 125% PE with drip tape system	238.10	18703	19.74	22.58
T_2	DI at 100% PE with drip tape system	219.28	17207	17.21	20.97
T_3	DI at 75% PE with drip tape system	192.29	15747	15.34	18.97
T_4	DI at 125% PE with conventional inline drip system	241.40	18785	19.88	22.93
T_5	DI at 100% PE with conventional inline drip system	225.95	17364	17.68	21.52
T_6	DI at 75% PE with conventional inline drip system	198.16	15917	15.59	19.18
T_7	Surface irrigation at 0.8 IW/CPE	184.09	15312	13.56	17.30
	SEd	8.74	748	0.74	0.87
	CD (P = 0.05)	19.03	1630	1.61	1.90

*DI-Drip irrigation, PE- Pan Evaporation

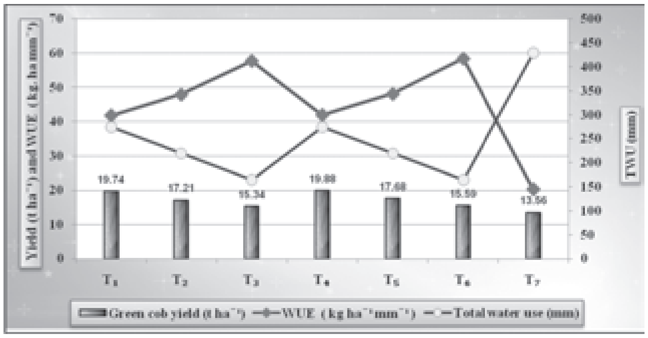

Fig. 1. Relationship between green cob yield (t/ha), WUE (kg/ha mm) and total water use (mm) under both drip irrigation systems

which was 32.54 and 30.52% more than surface irrigation, respectively. The increase in green fodder yield was mainly due to significant increase in dry matter accumulation in leaf and stem and total dry matter production of plant. The total water requirement under both conventional inline drip and drip tape system was 274.42, 220 and 165 mm at 125, 100 and 75% PE, respectively which leads to water saving of 36, 49 and 61% compared to surface irrigation. The drip irrigation scheduled at 75% PE in both conventional inline drip and drip tape system has recorded higher water use efficiency of sweet corn over drip irrigation scheduled at 125% PE and 100% PE and were better than surface irrigation (Fig.1). Surface irrigation registered lower water use efficiency over both drip irrigation systems. The increase in WUE in all drip irrigated treatments over surface irrigation was mainly due to considerable saving of irrigation water, greater increase in yield of crops and higher nutrient efficiency (Anitta Fanish and Muthukrishnan, 2011).

CONCLUSION

From the above study it was concluded that, besides cheaper in cost, drip tape system produced growth and yield on par with conventional inline drip system. Water saving benefits and distribution uniformity were also equivalent with that of conventional inline drip system. Hence drip tape system is technically feasible and economically viable for small and marginal farmers.

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Response of fodder oat (*Avena sativa*) to irrigation and nitrogen

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Among the fodder crops, oat (*Avena sativa* L.) is one of the most important cereal fodder crop of *rabi* season in North, Central and West zone of country. It provides soft, palatable and nutritive fodder to all categories of livestock in any form-green, dry fodder, silage or hay-covering some scarcity periods of the year. Its fodder on dry matter basis contains 10-11.5% crude protein, 55-63% neutral detergent fibre, 30-32% acid detergent fibre, 22.0-23.5% cellulose and 17-20% hemicelluloses when harvested at 50% flowering stage of crop. Adequate and timely availability of irrigation water to crop is realized for higher and quality yield. Among nutrients, nitrogen being an essential element play an important role in crop development, it is an important constituent of protoplasm and chlorophyll and is associated with the activity of living cells. The management of irrigation and nitrogen requires a new approach as these aspects of oat cultivation have received very little attention, particularly in semiarid regions. On aforesaid aspect, a field experiment was planned during *rabi* 2013-14 at Instructional farm (Agronomy), Rajasthan College of Agriculture, Udaipur. To find out the proper irrigation schedule to study the effect of irrigation management and nitrogen fertilizations on production of fodder oat.

METHODOLOGY

The experiment consisted of 12 treatment combinations, comprising four irrigation levels (Two-20 and 60 DAS, Three-20, 40 and 60 DAS, Four-20, 40, 60 & 80 DAS and Five-20, 40, 60, 80 & 100 DAS) and three nitrogen levels (70, 90 and 110 kg N/ha) tested in split-plot design with three replications keeping irrigation in main and nitrogen in sub plots. Nitrogen in form of urea was applied 1/3 at sowing time + 1/3 at 30 DAS + 1/3 after first cutting. The oat variety- kent were used with seed rate of 100 kg /ha at row spacing 20 cm. The soil of the experimental field was clay loam in texture, slightly alkaline in reaction pH (8.0), high in organic carbon (0.84), medium in available nitrogen (295.3 kg/ha), low in available phosphorus (16.60 kg/ha) and high in potassium (275.70 kg/ha). The samples of oat were taken for treatment evaluation from all the treatments and were sun-dried. Then they were dried in the oven at 70 ^oC for 40 hours till constant weight attained. The dried samples were then grinded and analyzed for crude protein and mineral matter, Crude fat (EE) and nitrogen free extract, crude fibre and total digestible nutrients by using the digestible coefficient of CP, CF, EE and NFE.

RESULTS

The results of experiment revealed that five irrigations gave significantly higher plant height, dry matter accumulation, number of tillers/m row length, total green 60029 kg/ha and total dry fodder 19561 kg/ha yield. Irrigations failed to show any significant variation in plant height and dry matter accumulation at 30 DAS,RGR between 30-60 and 60-90 DAS and nitrogen free extract at both first and second cuttings. The quality parameters viz., crude protein, crude fat, mineral matter and nitrogen content also increased, whereas, these parameters were found statistically at par with four irrigations. The maximum crude fibre content 30.34 and 30.03%; total digestible nutrient content 72.62 and 72.44% at first and second cuttings; and soil available nitrogen 276.94 kg/ha after harvest of crop were recorded under two irrigations over rest of the irrigations. Similarly application of five irrigations resulted in crude protein production 939.88 and 994.03 kg/ha; crude fat production 147 and 158.9 kg/ha; mineral matter production 631.9 and 658.4 kg/ha and nitrogen production 150.3 and 159 kg/ha; at first and second cuttings, respectively as well as it fetched the highest net returns of ₹69032.12 /ha with B: C of 3.28. Among the nitrogen levels 110 kg N/ha gave significantly highest plant height 29.9, 56.9, 106.3 and 97.2 cm; dry matter accumulation 28.5, 34.1, 98.6 and 139.6 g 0.5/m; at 30 and 90 DAS, as well as both first and second cuttings; CGR 70.1 and 34.1 g/m^2/day; between 30-60 and 60-90 DAS, respectively; number of tillers/m row length 165.6 and 191.7; total green 53768 kg/ha; total dry fodder yield 18333 kg/ha; The quality parameters viz., crude protein content 10.96 and 11.23%; crude fat content 1.74 and 1.75%; mineral matter content 7.41 and 7.29% and nitrogen content 1.75 and 1.80%. Whereas, maximum crude fibre content 30.30 and 29.72% and total digestible nutrient content 72.41 and 72.42% at both first and second cuttings were recorded with the application of 70 kg N/ha over 90 and 110 kg N/ha. Similarly application of 110 kg N /ha resulted in crude protein production 956.75 and 982.54 kg /ha; crude fat production 151.78 and 153.46 kg /ha; mineral matter production 647.58 and 639.62 kg /ha; nitrogen free extract production 4451.71 and 4465.44 kg/ha; total digestible nutrient production 6277.45 and 6315.02 kg/ha; nitrogen production 153.08 and 157.21 kg/ha; at first and second cuttings, respectively and also soil available nitrogen 280.29 kg/ha after harvest of crop. This treatment also gave significantly highest net returns of Rs. 60651.91 /ha with B:C of 3.01. Five irrigations and application of 110 kg N /ha recorded higher total green and dry fodder yield, net returns as well as maximum B: C.

Table 1. Effect of irrigation and nitrogen on green and dry yield of fodder oat

Treatment	Green fodder yield (kg/ha)			Dry fodder yield (kg/ha)		
	First cutting (60 DAS)	Second cutting (120 DAS)	Total	First cutting (60 DAS)	Second cutting (120 DAS)	Total
Irrigation level						
Two	18126	16064	34813	7213	7098	14311
Three	25897	24448	50413	8426	8252	16678
Four	25818	30199	55201	8416	9706	18122
Five	25772	34257	60029	8405	11156	19561
SEm±	668	873	1395	272	254	414
CD (P=0.05)	2313	3021	4825	941	881	1433
Nitrogen level (kg /ha)						
70	22153	24343	45889	7405	8328	15734
90	24235	25963	50690	8229	9206	17436
110	25322	28421	53768	8709	9624	18333
SEm±	572	657	950	207	211	365
CD (P=0.05)	1716	1972	2850	621	635	1096

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Scheduling last irrigation and use of bioregulators in wheat in context to changing climate situations

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Wheat is the most important staple food crop of about 36% of the world population. Worldwide this crop provides nearly 55% of the carbohydrates and 20% of the food calories. It is grown in all the continents of the world covering an area of 218.5 million ha with production of 713.2 milllion tones and productivity of 3265 kg/ha during 2013. Wheat is the second most important cereal crop after rice in India and during 2013-14 it was cultivated on 30.5 million ha area with production of 93.5 million tones and productivity of 3145 kg/ha. Yield of wheat crop is influenced by improved production technology and water management practices (Sharma *et al.,* 2007). In command area, method of irrigation and time of application plays an important role in increasing water productivity. Declining availability of irrigation water, needs sustainability in crop production and increasing demand of food can be achieved through adoption of improved irrigation water management technology.In recent years, use of bioregulators has offered new avenues for enhancing productivity of several crops. Partitioning of dry matter to yield storage organs is considered to be a major determinant for agricultural yield and this is dependent on the efficiency of photosynthate translocation in crop during grain filling period when developing grains are the storing sink. It has been reported that bioregulators plays important role in greator partitioning of photosynthates towards reproductive sink thereby improves the harvest index. Foliar applications of thiourea (Sahu and Singh, 1995) have been reported to be effective for enhancing wheat productivity under different environmental conditions. Keeping this in view, experiment was conducted at Agricultural Research Station, Kota under AICRP on Irrigation Water Management to improve productivity and water use efficiency of wheat.

METHODOLOGY

Field experiment was conducted during two consecutive years from 2014-15 and 2015-16 at Agricultural Research Station, Kota. The experiment was laid out in split plot design with four replications. The bulk density, pH and cation exchange capacity of these soils varies between 1.30-1.60 Mg/m^3, 7.75-8.50 and 30-40 Cmol/kg, respectively. The soils of the region are poor in organic carbon (0.50±0.08) and available nitrogen (275±5 kg/ha) but are low to medium in available P_2O_5 (24.2± 1.0 kg/ha) and medium to high in available K_2O (290 ± 8 kg/ha). In this experiment, treatments comprised combinations of five irrigation schedule (Early milk, late milk, early soft dough, late soft dough and IW/CPE 0.8 control) and three bio-regulators foliar spray at tillering and heading stage (thiosalicylic acid 100 ppm, thiourea 500 ppm and control) thereby making twelve treatment combinations were replicated four replications. Wheat were sown using 100 kg/ha seed rate with improved technology in second week of November and harvested in second week of April every year. Total four irrigations were applied including pre sowing irrigation during the crop season. Data were recorded under experiment during crop season and analyzed for different parameters.

RESULTS

Pooled data shows that under last irrigation at late milk stage was recorded significantly the highest grain yield (5.3 t/ha) and straw yield (7.0 t/ha) as compare to early milk, late soft dough stage and control but at par with early soft dough stage. Under thelast irrigation at late milk stage was recorded significantly the highest net return (₹86.5 thousand/ ha) and B:C ratio (4.27) as compare to early milk, late soft dough stage and control but at par with early dough stage. Application of foliar spray of thio salicylic acid (100 ppm) at tillering and booting stage gave higher grain yield and fodder yield rest control but it was found at par with the foliar spray of thiourea (500 ppm). The maximum grain yield (5.2 t/ha) and straw yield (7.0 t/ha) of wheat were recorded under application of foliar spray of thio salicylic acid (100 ppm) in pooled analysis. The maximum net returns (83.7 thousand/ ha) and benefit cost ratio (4.05) were recorded under foliar spray of thio salicylic acid (100 ppm) over control. Efficiency indices for water use were estimated in terms of water use efficiency. Pooled data (Table 1) of two years indicated that higher water use efficiency (157.20 kg/ha-cm) under last irrigation at late milk

Table 1. Effect of irrigation scheduling and bio regulators on test weight, yield, water use efficiency, and economics of wheat.

Treatment	Test Wt. (gm)	Grain yield (t/ha)	Straw yield (t/ha)	WUE (kg/ha-cm)	Net return (x 1000)	B:C ratio
Irrigation scheduling						
Early milk stage	41.09	4.8	6.3	139.93	74.9	3.69
Late milk stage	41.93	5.3	7.0	157.20	86.5	4.27
Early soft dough stage	41.71	5.2	6.8	152.92	83.5	4.11
Late soft dough stage	40.18	4.5	5.9	131.07	68.7	3.38
IW/CPE 0.8	40.48	4.6	6.1	165.95	73.2	3.70
SEm ±	0.22	0.14	0.17	4.31	2.76	0.14
CD (P=0.05)	0.68	0.43	0.54	13.27	8.52	0.43
Bio-regulators (Two spray)						
Thiourea (500 ppm)	41.20	5.0	6.8	156.03	81.0	3.90
Thiosalicylic acid (100 ppm)	41.44	5.2	7.0	159.36	83.7	4.05
Control	40.60	4.3	5.5	132.86	67.3	3.55
SEm ±	0.17	0.18	0.13	3.33	2.14	0.10
CD (P=0.05)	0.50	0.34	0.39	9.63	6.19	0.30

stage and (159.36 kg/ha-cm) foliar spray of thiosalicylic acid were observed over control.

CONCLUSION

On the basis of our investigation it could be concluded thatlast irrigation at late milk stageand two foliar spray of thiosalicylic acid at 100 ppm in wheat crop, gave higher yields, net return, B:C ratio and water use efficiency.

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Effect of summer rice to spacing of laterals and drippers with interval of irrigation in drip irrigation system

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The area of rice was 39.47 million ha during *kharif* season with average productivity of 2217 kg /ha, whereas, it was 4.83 million ha with average productivity of 3174 kg /ha during summer season of 2011-12 in the country. The rice plays a very vital role in the national food security and is the backbone of the Indian agriculture. Chhattisgarh is known as “Rice Bowl of India”. The state consists of three agro-climatic zones viz. Chhattisgarh plains, Northern hills and Bastar plateau. Net and gross sown area of the state was 4.828 m ha and 5.788 m ha, respectively. Out of these areas rice was grown in 3.687 million ha during *kharif* season with average yield of 2020 kg /ha during 2013-14. Out of the total area of *rabi* crops (1.758 million ha), the share of summer rice is 45 per cent (0.197 million ha) with average productivity of 3847 kg /ha. Summer rice occupied sizeable area in the state and with increasing availability of water; area of summer rice is increasing gradually. Flood irrigation is only method of irrigation to summer rice. This causes huge losses of water from rice field due to seepage and percolation and surface evaporation at one end and unproductive loss of ground water or surface water on the other end. Due to this, major area remains uncropped and farmers do not have enough employment opportunities during *rabi* and summer season. Drip irrigation may save huge quantity of water in summer rice that will help in enhancement of area of summer rice crop even under available water resources. The main objective of the study was to find out the optimum spacing of drippers and laterals and irrigation intervals for irrigation to summer rice through drip system

METHODOLOGY

The experiment "Effect of summer rice to spacing of laterals and drippers with interval of irrigation in drip irrigation system" was conducted at Research cum Instructional Farm, IGKV, Raipur (C.G.) during summer season 2012 and 2013. Treatment consisted of three Dripper and lateral spacing (Main plot) viz. Lateral and dripper spacing at 50 cm (50L50D), Lateral at 50 cm and dripper at 40 cm spacing (50L40D) and Lateral at 60 cm and dripper at 50 cm spacing (60L50D) and four Interval and time of irrigation (Sub plot) viz. Irrigate one hour daily (1H1D), Irrigate two hour every 2nd day (2H2D) Irrigate three hours every 3rd day (3H3D) and Irrigate two hours every 3rd day (2H3D) with rice varieties IR-64. Treatments were laid out in strip plot design by replicating thrice. The come up irrigation was given just after sowing. Irrigation treatments were imposed from 10 days after sowing (DAS). Irrigation was scheduled as per the treatments mentioned above using dripper of 4 lph. In this treatment plot, six paired rows were sown with row spacing of 15 cm. Thereafter, 45 cm open space was left un-cropped in order to minimize the number of laterals. After leaving 45 cm again six rows crop were grown at same row spacing and repeated the same for five times. Thus, the total number of crop lines is 30 in a single plot. Each lateral was placed in the central row amongst the three rows, thus two laterals were placed in six rows planted at 15 cm spacing. With lateral spacing of 50 cm, the plot can accommodate 10 laterals. Similarly, with 50 cm dripper spacing, each lateral can hold 20 drippers. Thus, it consisted of total 200 drippers in each such plot. Drippers used in this treatment are of 4 lph which discharged 800 liters of water in each such plot. In this treatment plot, six paired rows were sown with row spacing of 15 cm. Thereafter, 45 cm open space was left un-cropped in order to minimize the number of laterals. After leaving 45 cm again six rows crop were grown at same row spacing and repeated the same for five times. Thus, the total number of crop lines is 30 in a single plot. Each lateral was placed in the central row amongst the three rows, thus two laterals were placed in six rows planted at 15 cm spacing. With lateral spacing of 50 cm, the plot can accommodate 10 laterals. Similarly, with 40 cm dripper spacing, each lateral can hold 25 drippers. Thus, it consisted of total 250 drippers in each such plot. Drippers used in this treatment are of 4 lph whichdischarged1000 liters of water in each such plot. In this treatment plot, eight paired rows were sown with row spacing of 15 cm. Thereafter, 45 cm open space was left un-cropped in order to minimize the number of laterals. After leaving 45 cm again eight rows crop were grown at same row spacing and repeated the same for four times. Thus, the total number of crop lines is 32 in a single plot. Each lateral was placed in the central row amongst the four rows, thus two laterals were placed in eight rows planted at 15 cm spacing. With lateral spacing of 60 cm, the plot can accommodate 8 laterals. Similarly, with 50 cm dripper spacing, each lateral can hold 20 drippers. Thus, it consisted of total 160 drippers in each such plot. In this treatment, 640 liters of water was discharged by using 4 lph drippers in each such plot. There were 3 set of same size plots in each configuration. All the 9 sub plots were irrigated simultaneously. The discharge capacity (7320 lph) of sub-main pipe was worked out by keeping the value of discharge rate (4 lph) and total number of drippers (1830). There were 4 sub-main pipes, however, only 1 sub main pipe was operated at a time for irrigation. Therefore, the discharge of main line was also 7320lph. Each sub-main pipe was operated as per the sub treatments.

RESULTS

A perusal of the data presented in Table 1 indicate that grain yield of rice showed significant variation due to dripper and lateral spacing and interval and time of irrigation. Narrow dripper and lateral spacing treatment of 50L40D resulted significantly higher grain yield during 2012 and 2013, respectively which, was statistically at par to dripper and lateral spacing of 50L50D. Lowest grain yield was recorded in dripper and lateral spacing of 60L50D during 2012 and 2013 respectively. It is quite clear from the data presented in the Table 1 that significantly higher grain yield was produced when daily one hour water (1H1D) was applied followed by 2H2D, compared to other treatments during both of the years. The least grain yield was obtained from the treatment 2H3D. In general the grain yield of year 2013 was numerically higher than the year of 2012. The grain yield showed significant variation due to interaction between dripper and lateral spacing and interval and time of irrigation options. Significantly highest yield was recorded in 50L40D x 1H1D during both the years which was at par to 50L40D x 2H2D and 50L50D x 1H1D during 2012 and 50L50D x 1H1D, 50L50D x 2H2D and 50L40D x 2H2D during 2013. This indicates that irrigation for one hour daily or two hours in two days in laterals placed at 50 cm interval having drippers at 40 or 50 cm dia produced higher yield as sufficient water received to the crop with this arrangement in the drip irrigation system. The volume of water applied throughout the crop period, soil moisture contribution and effective rainfall received was considered as total water use (Table 2). The total water used ranges from 1374 mm to 5634 mm during 2012 and 1021 mm to

Table 1. Grain yield, straw yield and harvest index of summer rice as influenced by spacing of drippers and laterals interval of irrigation in drip irrigation system

Treatment	Grain yield (t/ha)		Straw yield (t/ha)		Harvest Index (%)		Water use (mm)	
	2012	2013	2012	2013	2012	2013	2012	2013
Dripper and lateral spacing								
50L50D	4.20	4.44	4.58	4.91	48.06	47.06	1447	1421
50L40D	4.66	4.74	4.75	5.20	49.97	47.56	1452	1421
60L50D	3.75	4.06	4.18	4.70	47.61	46.55	1435	1417
Sem±	0.12	0.12	0.09	0.08	0.99	0.53	21	12
CD (P=0.05)	0.45	0.46	0.35	0.32	NS	NS	NS	NS
Interval and time of irrigation								
1H1D	4.82	5.25	5.49	5.73	46.81	47.54	1562	1517
2H2D	4.55	4.82	5.17	5.38	46.75	47.20	1530	1512
3H3D	3.99	3.81	4.00	4.54	50.02	45.62	1539	1521
2H3D	3.46	3.77	3.36	4.10	50.61	47.86	1148	1130
SEm±	0.11	0.13	0.20	0.10	1.20	1.32	15	13
CD (P=0.05)	0.39	0.47	0.70	0.35	NS	NS	53	45

4216 mm during 2013. Highest amount of water was used in WSR-conventional irrigation (5634 mm during 2012 and 4216 mm during 2013) followed by TPR-conventional irrigation (4435 mm during 2012 and 3318 mm during 2013) and DSR-conventional irrigation (4396 mm during 2012 and 3290 mm during 2013). Whereas the lowest amount of water used by plants when irrigated through WSR- sprinkler (1374 mm during 2012 and 1022 mm during 2013) and WSR-drip irrigation (1386 mm during 2012 and 1030 mm during 2013). Among the establishment methods, the maximum water was used in TPR *viz.* 2117 mm and 2050 mm during 2012 and 2013, respectively which was statistically at par with WSR during 2013 (1957.7 mm). Minimum water was used by DSR *viz.* 1909.8 mm during 2012 and 1775.5 mm during 2013. Among the method of irrigation, significantly maximum water was used under conventional irrigation (3792 mm and 3617 mm during 2012 and 2013, respectively) followed by recommended practice. The irrigation counts in micro sprinkler and drip irrigation was almost same. Govindan and Grace (2012) reported higher consumptive use of water to the extent of 1027 mm and 822 mm in drip irrigation during 2008 and 2009, respectively. The micro irrigation technique saved 55 to 74 per cent water. Water saving by 74 per cent and 73 per cent was achieved by using drip and sprinkler irrigation, respectively over conventional irrigation. This indicates that cropped area under summer rice can be doubled with same quantity of available water by using drip irrigation without sacrificing grain yield over conventional irrigation.

CONCLUSION

The findings clearly visualized that among the both spacing of laterals and drippers and interval & time of irrigation, treatment combination of 50L40D with 1H1D proved comparable and better followed by 50L50D with 2H2D than rest of the other treatments, which gave higher growth, yield attributes and yield of summer rice.

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Modification in sugarcane planting geometry by introducing intra-row spacing to ensure higher population and productivity

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The field experiment was conducted during 2013-14 at ICAR-Indian Institute of Sugarcane Research, Lucknow to ensure higher population of sugarcane by introducing intra-row spacing in planting geometry for higher cane productivity.

METHEDOLOGY

The experiment comprising 16 treatment combinations was laid out in RBD (factorial) with three replications. The treatments combinations were: 1. Planting material viz.; three budded setts and two budded setts; 2. Planting geometry (intra- row spacing) viz.; placing setts in pair at intra- row spacing of 20 cm (end to end), placing setts in pair at intra-row spacing of 30 cm (end to end), placing three setts together at intra-row spacing of 30 cm (end to end) and conventional (end to end placement); 3. Sett treatment *viz.*; setts treatment (overnight soaking) with Resorcinol @0.1% and control (conventional) was done. The soil of the experimental site was sandy loam in texture, low in organic carbon (0.33%), available nitrogen (219.8 kg/ha), medium in phosphorus (23.7 kg P_2O_5/ha) and potassium (202.8 kg/ha) and slightly alkaline in reaction (pH 7.9).

RESULTS

The experimental findings revealed that germination in sugarcane was not affected by planting materials used (two budded and/or three budded setts) and planting geometry (different intra-row spacing). However, sugarcane planting with three budded setts registered significantly higher tiller population resulting into more number of millable canes (103.1 thousand/ha) as compared to two budded setts (90.7 thousand/ha). Dry matter accumulation and leaf area index (LAI) were also significantly higher in sugarcane planted with three budded setts as compared to two budded setts. Whereas, improvement in plant height in sugarcane planted with three budded setts was not to the level of significance over two budded setts. Sugarcane yield was enhanced to the level of 83.7 t/ha with planting three budded setts over two budded setts (77.6 tonnes/ha) due to higher, heavier and lengthy millable canes. Introduction of intra-row spacing in sugarcane planting significantly augmented tiller population. The highest tiller population (141 thousand/ha) was recorded in the month July in the treatment of placing three setts together at intra-row spacing of 30 cm (end to end) that was significantly higher than conventional method (125 thousand/ha). Plant height, dry matter accumulation and LAI improved significantly in sugarcane planted with three setts together at intra-row spacing of 30 cm (end to end) as compared to conventional method (end to end sett placement). The cane yield of 88.3 tonnes/ha was recorded in the treatment of sugarcane planting with placing three setts together at intra-row spacing of 30 cm (end to end) that was significantly higher than conventional (72.7 tonnes/ha) and other planting methods due to higher in number and heavier canes. The highest cane yield (91.8 tonnes/ha) was recorded in sugarcane planting with placing three setts (three budded) together at intra-row spacing of 30 cm. Sugarcane planting with two setts in pair keeping intra-row spacing 20 cm or 30 cm also significantly enhanced cane yield over conventional method due to higher and heavier millable canes. Cane diameter and juice quality parameters were not affected by different treatments.

CONCLUSION

Sugarcane planting after setts treatment (overnight soaking) with Resorcinol @ 0.1 % significantly augmented germination to the tune of 15.7 % over conventional planting. Tiller population, dry matter accumulation and LAI and cane yield was improved significantly in setts treatment with Resorcinol @ 0.1% as compared to conventional planting.

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Enhancing water productivity in irrigated echosystem at ORP Malaprabha command of Karnataka state

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Attempts were made to intervene through proven technologies developed irrigation management strategies to educate farmers to avoid excess irrigation. The objective of the research on the farmers fields is to prevent excessive irrigation, maintain proper nutrient balance, check the process of soil erosion and reduce head tail difference so that farmers are educated on proper on–farm water resource management. Operational research programme (ORP) on irrigation water management was conducted for two years (2013 and 2014) in the 12-L of 23rd distributary of Malaprabha Right Bank Canal (MRBC) at Hebsur village, Hubli taluka of Dharwad district (Karnataka state) and the study area was 288.94 ha. The Maize, wheat and chickpea grain yield was enhanced about 10.26%, 11.54% and 14.67% when compared with the normal irrigation practiced by farmers. The enhanced WUE recorded in maize, wheat and chickpea was 35.33, 22.01 and 13.5% when compared to normal method of irrigation respectively. The amount of irrigation water saved in maize, wheat and chickpea was 28.57, 13.4 and 8.7% when compared to normal method of irrigation respectively.

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Root architecture of groundnut as influenced by drip and micro sprinkler fertigation

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The root system is the major link between the plant and soil. It is responsible for the absorption of water and nutrients, anchorage, synthesis of some plant hormones and storage. Groundnut being a most important oilseed crop in India and in order to achieve proper growth and yield, the root zone of a crop must be well supplied with water, nutrients and oxygen. In view of the above, an investigation was undertaken to assess the effect of drip and micro sprinkler fertigation on root architecture of groundnut.

METHODOLOGY

A field experiment was carried out at Tamil Nadu Agricultural University, Coimbatore, during 2015 (January-April). The soil was sandy clay loam type and rainfall received during crop growing period was 4.3mm only. The experiment was laid out in a randomized block design and replicated thrice with 11 treatments. The recommended dose of fertilizer (RDF) @ 25: 50: 75kg NPK/ha was applied to crop and crop was sown at row spacing of 30 cm x 10cm. Drip and micro sprinkler irrigation was based on daily pan evaporation (PE) and fertigation based on nutrient uptake pattern at different growth stages of groundnut. Surface irrigation at 0.8 IW/CPE ratio with 5cm depth of water.The required quantity of water soluble fertilizers (WSF) *viz.,* N,P_2O_5 and K_2O were applied as urea (46:0:0), all 19 (19:19:19), MAP (12:61:0) and SOP (0:0:52) and normal fertilizers (NF) as urea, MAP and MOP

Table 1. Root architecture as influenced by drip and micro sprinkler fertigation with different levels of irrigation and fertigation in groundnut

Treatment	Root length (cm)		Root volume (cm^3)		Root dry weight (g)	
	60 DAS	At harvest	60 DAS	At harvest	60 DAS	At harvest
T_1-DI at 100% PE + fertigation at 100% RDF with WSF	14.79	17.01	4.75	4.98	1.80	2.45
T_2-DI at 75% PE + fertigation at 100% RDF with WSF	13.17	15.22	4.29	4.45	1.64	2.21
T_3-DI at 100% PE + fertigation at 75% RDF with WSF	12.83	14.92	4.12	4.34	1.48	1.96
T_4-DI at 75% PE + fertigation at 75% RDF with WSF	10.14	13.92	3.59	3.87	1.32	1.72
T_5-DI at 100% PE + fertigation at 100% RDF with NF	11.05	14.28	4.11	4.33	1.46	1.93
T_6-MS at 100% PE + fertigation at 100% RDF with WSF	13.43	15.51	4.20	4.39	1.56	2.07
T_7-MS at 75% PE + fertigation at 100% RDF with WSF	12.37	14.62	4.01	4.21	1.42	1.87
T_8-MS at 100% PE + fertigation at 75% RDF with WSF	12.01	14.38	3.80	4.16	1.39	1.82
T_9-MS at 75% PE + fertigation at 75% RDF with WSF	10.07	13.31	3.52	3.59	1.21	1.63
T_{10}-MS at 100% PE + fertigation at 100% RDF with NF	10.83	14.13	3.80	4.01	1.36	1.80
T_{11}-SI + soil application at 100% RDF with NF	14.22	16.38	3.03	3.22	1.15	1.49
CD (P=0.5)	1.27	1.40	0.39	0.45	0.14	0.21

DI - Drip Irrigation; MS- micro sprinkler; WSF- Water soluble fertilizers; NF- Normal fertilizers; SI-Surface irrigation.

(0:0:60) were used under drip and micro sprinkler whereas, for surface application urea, MOP and SSP (0:16:0) were used. The observations on root length, volume and dry weight were recorded using standard method at 60days after sowing (DAS) and harvest stage respectively.

RESULTS

The root architecture *viz.,* root length, volume and dry weight of groundnut were significantly influenced by drip and micro sprinkler fertigation with different sources and levels of fertilizer during cropping period compared to surface irrigation and mean data is given on Table 1. Higher root length was recorded under DI at 100% PE + fertigation at 100% RDF with WSF (T_1) which was on par with SI + soil application at 100% RDF with NF (T_{11}), whereas lower under MS at 75% PE + fertigation at 75% RDF with WSF (T_9) at 60 DAS and harvest stage. Roots under drip fertigation were adequately provided with sufficient moisture, nutrients, soil aeration that finally resulted in higher root length while under surface irrigation, depth of water increases at the time of irrigation resulted long root however, under micro sprinkler root length was less due to the lesser depth of water and more evaporation loss. Whereas, higher root volume and root dry weight were recorded under DI at 100% PE + fertigation at 100% RDF with WSF (T_1) followed by DI at 75% PE + fertigation at 100% RDF with WSF (T_2), least in SI + soil application at 100% RDF with NF (T_{11}) at 60 DAS and harvest stage, respectively. This might be due to the crops under drip and micro sprinkler fertigation were provided with adequate quantity of nutrients and moisture might have resulted in higher root proliferation finally higher root growth. Whereas, under surface irrigation with soil applied fertilizer, excess irrigation leached off the available nutrients along with it beyond the effective root zone which may therefore not be available to the roots due to that affecting the root growth of the crop and ultimately crop yield (Ali *et al.,* 2014).

CONCLUSION

From the study, it can be concluded that drip and micro sprinkler irrigation cum fertigation recorded improved root architecture which will helps in improve growth, yield and quality of groundnutcompared to surface irrigation and among all treatments drip irrigation at 100% PE with fertigation at 100% RDF as WSF was performed best.

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Effect of tillage practices on physiological stress indicators of pearl millet cultivars under rainfed conditions of western Rajasthan

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Pearl millet [*Pennisetum glaucum* (L.) R. Br] commonly known as *bajra*, is a prominent crop of local food system of arid and semiarid regions. It is an important drought hardy coarse grain crop that provides staple food for the poor in a short period. Its grain contains about 11.6% protein, 5% fat, 67% carbohydrate, 2.7% minerals and 12.4% moisture. The Crop is also valued as an important source of green and dry fodder (*karbi*) for cattle in this belt. A small proportion of grains is used for poultry feed. The major pearl millet growing states *i.e.* Rajasthan, Maharashtra, Gujarat, Uttar Pradesh and Haryana in India, together contribute about 95 per cent of total area and production of the country. Rajasthan alone constitutes about 50% area and 42% of production of pearl millet in the country. Minimizing the cost of production under rainfed conditions is of logical importance. On the basis of numerous reports, practice of zero/minimum tillage can understandably be incorporated owing to its positive effects. Choice of suitable variety is a prerequisite for successful crop production. In western Rajasthan, drought tolerant and early maturing varieties (to escape terminal drought) are always preferred due to weather abnormalities often experienced in this region. Prolonged dry spells during crop growth period are commonly experienced in rainfed regions. Under such a situation, modification in surface configuration by making ridge after sowing may help in conserving available soil moisture for a longer period. Choice of suitable variety is a prerequisite for successful crop production. In western Rajasthan, drought tolerant and early maturing varieties (to escape terminal drought) are always preferred due to weather abnormalities often experienced in this region.

Table 1. Effect of tillage practices on physiological stress indicators at flowering stage of pearl millet cultivars

Treatment	Relative water content (%)	Proline content (mg /g fresh weight)	Membrane stability Index (%)
Tillage practice			
Conventional tillage	62.00	0.67	45.68
Zero tillage	60.27	0.70	44.61
Conventional tillage + Ridging	66.99	0.64	48.90
Zero tillage + Ridging	63.89	0.66	46.71
SEm±	0.95	0.02	1.13
CD (P=0.05)	3.05	0.05	3.63
Cultivar			
Pusa composite-443	62.56	0.65	45.94
CZP 9802	61.99	0.64	45.84
MPMH-17	64.11	0.70	47.59
RHB-177	64.50	0.68	46.52
SEm±	0.89	0.01	0.60
CD (P=0.05)	NS	0.03	1.72

NS= Non-significant

METHODOLOGY

A field experiment was conducted on loamy sand soil at Agronomy Farm, College of Agriculture, SKRAU, Bikaner during *Kharif* 2014. The sixteen treatment combinations comprising of four tillage practice *viz.,* conventional tillage, zero tillage, conventional tillage + ridging, and zero tillage + ridging in main plot treatments and four pearl millet cultivars *viz.,* Pusa composite 443, CZP 9802, MPMH 17 and RHB 177 as sub plot treatments. The treatments were laid out in split plot design and replicated four times. The pearl millet cultivars were sown at 45 cm x 10 cm spacing using seed rate of 4 kg/ ha for each. Physiological stress indicators such as Relative water content (RWC), proline and membrane stability index (MSI) were estimated at flowering time of the crop. RWC of fresh leaves were measured by the method given by Barrs and Weatherly (1962). The RWC was calculated by the formula RWC (%) = [(Fresh weight - Dry weight)/ (Turgid weight – Dry weight)] × 100. Free proline in fresh leaves (mg/g fresh weight) was extracted and determined by the method of Bates *et al.* (1973). The MSI was determined as per method prescribed by Sairam, 1994. The MSI was calculated as MSI (%) = 1- [C1/C2] × 100.

RESULTS

The tillage practice as conventional tillage + ridging significantly increased the RWC (%) and MSI (%) over rest of the treatment (Table 1). Results further indicated that pearl millet cultivars were significantly influenced proline content (mg/g fresh weight of leaf) and membrane stability index (%) but relative water content (%) was at par among pearl millet cultivars. The hybrid cultivar MPMH-17 recorded maximum proline content (0.70 mg/g fresh weight of leaf) and membrane stability index (47.59%) as compared to other cultivars. It is also noticed that hybrid cultivars have higher RWC, MSI and proline content as compared to composite cultivars.

CONCLUSION

It can be concluded on the basis of results obtained in the present study that the tillage practices and ridging operation at 30 DAS enhanced the drought tolerance capacity of the crop. Hybrids also have more drought tolerance capacity than composites.

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Management of water in a canal command: Study on rainfall-runoff relationship and water storage in auxiliary ponds and and dug-wells

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India accounts for only about 2.4% of the world's geographical area and 4% of world's renewable water resources, but the country has to support about 18% of the world's human population and 15% of livestock (DES, 2013). Hence, water resources development and its management is essential to meet the increasing food demand and sustain agricultural production systems. Per capita availability of water per year is steadily declining from 5177 m^3 in 1951 to 1820 m^3 in 2001, 1588 m^3 per year in 2010 and is expected to decline further to 1341 and 1140 m^3 by the years 2025 and 2050, respectively (CWC, 2013). Though there has been a significant achievement in water resources development, a wide gap still exists between irrigation potential created (123.3 M ha) and irrigation potential utilized (91.5 M ha); hence, it has become a great challenge to bridge the gap by evolving innovative as well as adopting existing technologies. Most of the canal projects suffer from inadequate supply and poor reliability of water, especially at the tail end during lean season. Hence, attempts were made to study the rainfall, runoff and water storage in water harvesting tanks and open wells and development of integrated farming system in a canal command in Odisha, India.

METHODOLOY

The study has been carried out under the Kuanria Medium Irrigation Project (KIP) at Daspalla, Nayagarh district of Odisha, India (20^0212 N, 84^0512 E, 122 m above msl). The irrigation command serves two blocks viz. Daspalla and Nuagaon. This study site comes under Agro-Eco Sub-Region 12.2 (AESR 12.2) according to the classification by NBSS & LUP (ICAR). KIP is a medium irrigation project. Intercepting river 'Kuanria', a right tributary of river Mahanadi and a nallah named 'Khalakhala' by an earth dam form the reservoir of KIP. The catchment area of the reservoir is 124 sq km. The project has two number of head regulators such as right and left distributary (RD and LD). RD and LD run for a length of about 18.2 and 16.5 km. The GCA is 4800 ha and CCA is 3780 ha. There are 10 water users' association (WUA) distributed over the entire area of the KIP. The rainfall pattern in the project site was analysed (Mandal *et al*., 2015). The total annual rainfall ranged from 1304 to 1895 mm; most of the rainfall occurred during the SMW 27 through 41 i.e., within three and half months; afterwards, there is no or very less rainfall during 42 through 52 SMW (Fig. 1). Runoff was estimated by using SCS curve number method. Intervention was made in different sites viz. Odasar sub-minor (S/M), Mangalpur S/M, Khamarasahi S/M, Khairapankalsahi S/M, Madhyakhanda S/M (two sites), Lunisara S/M and Soroda S/M-II with fish culture in ponds, and crop cultivation in commands for improving water productivity. The impact assessment was made on water availability in ponds, groundwater fluctuation, fish & crop production and water productivity in different sites.

RESULTS

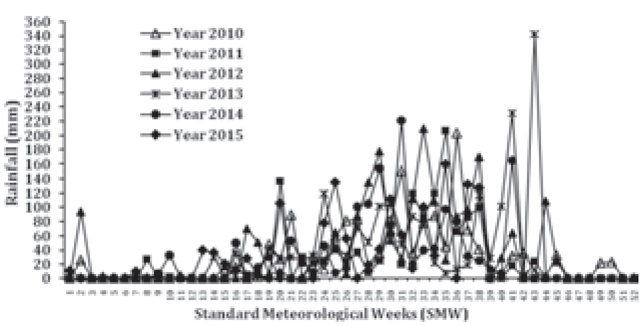

Fig. 1. Rainfall distribution trends over standard meteorological weeks in the project site (2010-2015)

On an average of 20 years, the area receives 1532 mm of rainfall annually; out of this, it is estimated that 386 mm i.e., 25.2% of rainfall is the runoff amount in each year; again about 24% of annual runoff occurs during monsoon months. Average annual seepage losses from the reservoir and canal during study period (2011-2015) was 305.56 ha m with the range of 246.25 to 362 ha m. Monthly seepage losses was the maximum i.e., about 85% of the total, during months of January to June every year. Hence, there is the need for storage of runoff and seepage water.

The availability i.e., the depth of water in the auxiliary ponds and the groundwater was monitored for eight different study sites in head-, mid- and tail-ends under the command. For every site (Fig. 2), the trend is that the depth of pond water increased to above 2.5 m and even beyond 3.0 m with the receipt of monsoon rain during July to October; it remains higher than 2.0 m up to the month of December for every ponds; then it decreased during post-monsoon and summer months. The trend of decrease varied in different sites; three of the total eight ponds got dried up faster than others. Depth of groundwater was monitored for five representative sites (Fig. 3) viz. one in head reach in the RD under Odasar s/m, one in mid-reach in the RD at Khamarsahi s/m, one in mid-reach in the LD at Mangalpur s/m, one in tail-end in the RD

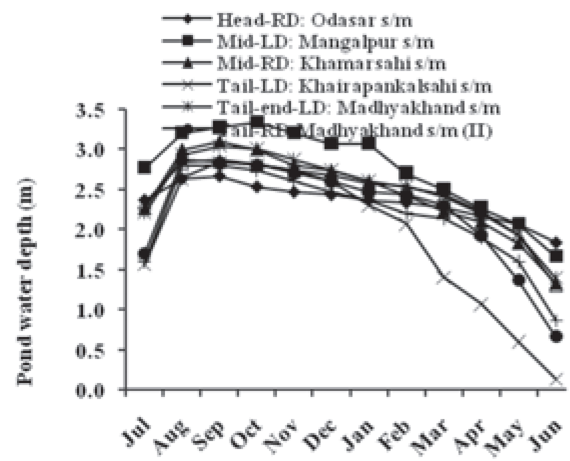

Fig. 2. Temporal variation of pond water depth in eight study sites under different canal commands

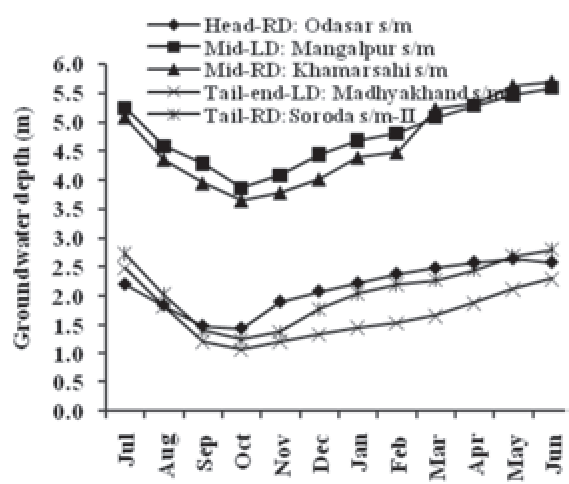

Fig. 3. Temporal variation of groundwater depth in five representative study sites

at Soroda s/m-II and one in tail-end in the LD at Madhyakhanda s/m. Depth was within 3-5 m for every site. Overall trend is that the depth of groundwater decreased during rainy season due to monsoon rainfall and then it increased from December to June. Out of five sites, two sites under the mid-reach showed greater depth of groundwater. Hence, there is huge potential of groundwater development in the command area.

Conjunctive use of water facilitated development of integrated farming systems viz. rice + (fish in pond)-maize, rice + (fish in pond)-vegetables (bhindi/ tomato/ cauliflower/ onion/ pointed gourd/ brinjal/ pumpkin etc.), rice + (fish in pond) + on-dyke vegetables/ papaya/ banana/ arhar - green gram/ black gram/ ragi etc., rice + (fish in pond)-green gram, rice + (fish in pond)-black gram, rice + (fish in pond)-arhar, rice + (fish in pond)-sesame and rice + (fish in pond)-ragi. The excess canal water and rain water stored in tanks and dug wells provided irrigation to post-monsoon crops, and thereby enhanced productivity of dry season crops and improved livelihood of farmers.

CONCLUSION

The estimated water through runoff and seepage indicates a large potential to improve water resources through storage in auxiliary ponds and dug-wells and enhancing water productivity through multiple use of water. The harvested water can be used for growing on-dyke crops, fish culture and duckery during monsoon season and life saving irrigation in dry/lean period. Further, infrastructure development under the canal command in a participatory mode and adopting appropriate integrated farming system will improve both land and water productivity through augmented water resources. There will be definite social and economic impact of the beneficiary farmers through the integration of multi-enterprise components.

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Impact of wastewater irrigation and different land-water management strategies on growth and yield of brinjal (*Solanum melongena)*

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Drivers of global change like industrialization, urbanization, rising population, increasing living standards, and water and energy demand will illustrates the future of wastewater. Wastewater being the immense source of nutrients and organics can be a viable and alternate option for water scarce semi arid countries. The reuse of wastewater for agricultural irrigation purposes offers increase in crop yield and biomass (Mendoza-Espinosa *et al.* 2008) along with potential solution to reduce the freshwater demand for zero water discharge avoiding the pollution load in the receiving sources (Ladwani *et al.,* 2012). The extensive use of untreated wastewater for urban agriculture has led to various consequences on crop produce quality, population health and soil quality that have been reported by several studies. To reduce the pollutant threat associated with wastewater irrigation, practicing better management strategies can be a viable option for resource poor urban farmers. Among this water application methods and land management measures offer most acceptable and feasible ways. Drip irrigation, coupled with wastewater use may offer improved water and nutrient management, potential

Table 1. Growth and Yield parameters of Brinjal

Treatments	Plant length (cm)	No. of leaves/plant	No. of branches/plant	Avg. Diameter (cm)	Fruit wt. (g)	No. of fruits/kg
W1I1L1	79.7	137	20	9.25	261	3.90
W1I1L2	76.2	147	32	8.92	248	4.15
W1I2L1	74.7	159	43	9.38	254	3.95
W1I2L2	69.7	121	46	9.67	266	3.79
W2I1L1	69.7	100	37	10.00	354	2.85
W2I1L2	82.2	170	41	10.75	350	2.87
W2I2L1	84.5	155	45	9.50	281	3.59
W2I2L2	93.5	173	53	9.82	312	3.22

for improved yields and crop quality, greater control over applied water resulting in less water and nutrient loss through deep percolation, and reduced total water requirements. In this view we have formulated the objective to assess the effect of wastewater irrigation along with different land and water management strategies on the growth and yield of brinjal.

METHODOLOGY

The study was conducted at 12 C field of ICAR-IARI farm during 2014-15. The treatments undertaken in study include two irrigation sources ie; wastewater and ground water, two land management measures ie; ridge & furrow and basin method and two methods of irrigation ie; drip irrigation and flood irrigation. The design of the experiment was Split- Split plot design and the replications were 4. The variety selected for the study was Supriya and sowing of the crop was done 20[th] August, 2014 and transplanting was done 20[th] September, 2014. The observations related to growth (plant length (cm), no. of leaves per plant, no. of branches per plant) and yield parameters (average fruit diameter, fruit weight and number of fruits per kg) were taken.

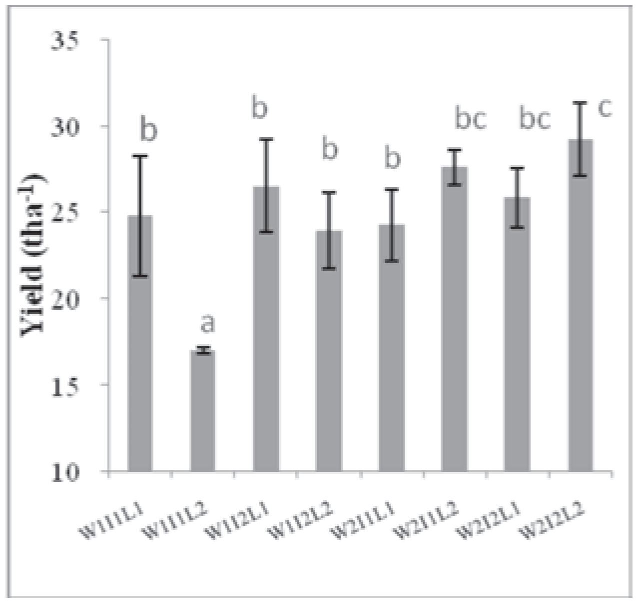

Fig. 1. Brinjal fruit yield (t /ha)

RESULTS

The wastewater used for irrigation had pH 7.9 ±0.3, EC 2.0 ±0.5 dS m^{-1}, RSC 1.5 ±0.3 meq/l and SAR was (7.0 ±1.2)). These parameters were within the range for irrigation usage. However; BOD was very high (300 ppm) and above the maximum permissible limit for irrigation. The concentration of Ni (0.28 ±0.08) and Cr (0.26 ±0.14) were above their respective safe limits (0.2, and 0.1 ppm) given by FAO (1985), however, concentration of Pb (1.03 ±0.05) was within the permissible limit (5.0 ppm). The soil analysis revealed that pH was 7.8 ±0.2, EC was 0.57 ±0.1 dS/m, OC- 0.89%, N- 277 kg/ha, P- 38 kg/ha, and K-290 kg/ha. The heavy metal contents (Cu, Fe, Zn, Mn, Cr, Ni and Cd) were within the safe limits except for Pb (2.93 ppm). Wastewater irrigated plots have shown higher plant height (69.7cm to 93.5 cm), number of leaves per plant (100- 173) and number of branches per plant (33-55) as compared to ground water irrigated plots (Table 1). The yield parameters (fruit weight, average diameter) also showed the same pattern, while the number of fruits per kg was observed more in ground water irrigated plots (3-4 number of fruits per kg). The yield data revealed that wastewater irrigation has resulted 18% higher yield when compared to groundwater irrigated plots (Fig. 1). Maximum yield was obtained in the treatment containing wastewater with flood method of irrigation and basin land configuration (30 t/ha) which was significantly different from all other treatments. While wastewater irrigated with drip method has recorded 25% more yield when compared with groundwater irrigated with drip system. The bacterial load in fruits showed that wastewater applied through flood method has 100 times more contamination than applied through drip irrigation.

CONCLUSION

Waste water irrigation increased the yield up to 18 % when compared to ground water. While Waste water applied through drip has recorded less yield compared to flood method, but it significantly (100 times) reduced the pathogen load in fruits.

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Influence of water regimes and NPK levels on rice (*Oryza sativa*) under aerobic production system

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Rice is the mainstay Indian Agriculture and forms major staple for the large population of it. Rice is the major user of water. Increased competition for water and climate change is reducing the amount of water available for agriculture. The Aerobic Rice System is one of the new ways to produce more rice with less water. Balanced nutrition of the crop, more particularly with the major nutrients NPK, is equally important to obtain higher yield. Substantial yield and water- use- efficiency gains are possible with the application of appropriate nutrients in combination with optimum water management adapted to the target environments. Hence, this research was under taken to: (1) assess the performance of 'Luit'-a HYV under different water regimes and NPK levels and (2) determine water economy under aerobic rice production systems.

METHODOLOGY

The experiment was conducted at Assam Agricultural University in the summer seasons of 2012 and 2013 to study the influence of water regime and NPK levels for rice (*Oryza sativa*) under aerobic production system using 'Luit'-a HYV of rice. The treatments consisted of four water regimes viz., rainfed (I_1), irrigation to keep the soil saturated (I_2), irrigation at 80% available soil moisture stage (I_3), irrigation at 60% available soil moisture stage(I_4) in main plot and four NPK levels viz., control (F_1), 40-20-20 kg /ha of N, P2O5, K_2O (F_2), 50-25-25 kg /haof N, P2O5, K_2O (F_3), 60-30-30 kg /haof N, P2O5, K_2O (F_4) in sub-plots.The experiment was laid out in split –plot design with three replications. The soil of the experimental plot was acidic in reaction (pH 4.76), low in organic carbon (0.43%) and available P2O5 (21.52 kg/ha) content and medium in available N (287.78 kg/ha) and available K_2O (185.2 kg/ha). The amount of irrigation water was measured volume basis by multiplying area and depth of irrigation and then area – volume method was followed to irrigate the field with required time for each plot under irrigation.

RESULTS

The results revealed that water regimes influenced the growth performance of rice. Irrigation applied to keep the soil at saturation being at par with irrigation at 80% available soil moisture (I_3) recorded the highest values for all those growth characters except for dry matter accumulation. The highest values for yield attributing characters, grain and straw yield were recorded under irrigation applied to keep the soil at saturation (I2). The maximum water use efficiency was observed under irrigation at 80% available soil moisture stage (I3) followed by rainfed condition (I1) in both the years. Different NPK levels brought about significant differences in plant height, plant population, dry matter accumulation, yield attributing characters, grain and straw yield, N, P, K-uptake and the highest values were recorded under application of 60:30:30 kg/haof N, P_2O_5, K_2O (F4) and were closely followed by 50:25:25 kg/ha of N, P_2O_5, K_2O (F3). These two treatments also recorded higher water use efficiency.In terms of economics, among all the treatment combinations, application of irrigation at 80% available soil moisture stage with 50-25-25 kg/

ha of N, P_2O_5 and K_2O. Water regimes and NPK levels significantly affected growth and yield of 'Luit' under aerobic rice production systems. Water inputs and productivity with the tested water regimes showed comparable results. The rice variety "Luit" gave the highest grain yield in the treatment combination (I_2F_4) i.e. irrigation applied to keep the soil moisture at saturation with 60-30-30 kg/ha of N, P_2O_5 and K_2O among all the treatment combinations. However, the benefit-cost ratio was the highest in the treatment combination (I_3F_3) that encompasses irrigation at 80 % available soil moisture stage with 50-25-25 kg /ha of N, $P_2O_5$and K_2O and this was considered to be the best treatment.

CONCLUSION

It can be concluded that NPK fertilizer level i.e. 50:25:25 kg/ha of N, P_2O_5, $K_2$with irrigation at 80% available soil moisture stage was beneficial. This resultshould be tested through experiments in farmersfield and demonstrations in a wide range of locations.

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Efficient water management in wheat using micro irrigation

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Wheat is a high water demanding crop. Water is one of the scare and limiting factors for crop production. Water management is key issue for economizing the irrigation water use efficiency of the wheat crop. Drip has proved its superiority in widely spaced crops, but wheat is a close spaced crop. For exploiting the possibilities of using drip and to optimize the water requirement for yield maximization in wheat, a special trial was conducted at Wheat Research Station, S.D. Agricultural University, Vijapur (Gujarat) during 2014-15. The experiment was laid out in split plot design having three replications. The treatments consisted of three irrigation system *viz.* conventional flood (60mm depth), drip irrigation with 20mm depth (40 cm lateral distance with 4 LPH) and drip irrigation with 50 mm depth (80 cm lateral distance with 4 LPH) and four irrigation schedules *viz.* IW/CPE of 1.2, 1.0, 0.8 and 0.6. Significantly higher grain yield was recorded with drip irrigation at 50 mm CPE (3.70 t/ha) as compared to other methods of irrigation. The IW/CPE ratio of 1.2 produced highest grain yield (3.63 t/ha), which was significantly higher than 0.6 and 0.8 IW/CPE and being at par with 1.0 IW/CPR ratio. Interaction between irrigation methods and irrigation regimes for grain yield was non-significant.

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Quality and yield of vegetables irrigated with constructed wetland treated sewage

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Increased pace of urbanization resulted in higher abstraction of freshwater and consequently generated huge volumes of sewage to dispose. In water scarcity situations, wastewater use in agriculture is inevitable. It is a cheap source of plant nutrient and assured source of irrigation therefore, largely used in vegetables and other high value crops (Minhas *et al.,* 2015). Contrary to the benefits, wastewater contains salts, pathogens, heavy metals and other pollutants. Unregulated use of wastewater affects quality of natural resources, contaminates food chain and poses serious health hazards (Murtaza *et al*., 2010). Sewage treatment using sewage treatment plants generates toxic sludge and is prohibitively expensive. In India, only 31% of sewage generated is treated (CPCB, 2009). Moreover, sewage treatment plants are housed in large cities; apparently there is no option for small towns and villages. Constructed wetlands which utilize vegetation, soils and the associated microbial assemblages could be the low cost, ecologically sound wastewater treatment alternate. Before devising a treatment technology, produce quality and consequential consumer health hazards using treated v/s untreated sewage for irrigation must be evaluated.

METHODOLOGY

Impacts of untreated v/s treated sewage were assessed on okra (variety A-4) – cabbage (variety Indu) during 2014-15 at IARI, New Delhi research farm. Both the crops were irrigated by municipal sewage treated through constructed wetlands in form of mesocosms which were filled with gravel/soil and planted with *Pharagmites karka* (PW)*, Typha latifolia* (TW)*, Acorus calamus* (AW) and control (without vegetation). The results were also compared with untreated sewage and groundwater irrigation. Therefore, as a whole there were six irrigation treatments replicated thrice in a randomized block design. The irrigation waters were analyzed at monthly interval for biological oxygen demand (BOD_5), NPK and trace metals using standard methods. The appropriately matured vegetables were picked /harvested manually. The lots were weighed individually and then pooled for total yields. Oven dried plant samples were digested in acid and analyzed for N, P, K and trace metals.

RESULTS

The fruit yield of okra (15.3 t /ha) was the highest when grown on soils irrigated with untreated sewage followed by sewage passed through an un-vegetated mesocosm (13.9 t /ha) and lowest in case of groundwater (12.3 t /ha). The fruit yield of okra irrigated with sewage passed through mesocosmic wetlands planted with *Phragmites karka, Typha latifolia, Acorus calamus* were similar with an average of 13.5 t /ha. Cabbage irrigated with untreated sewage also produced significantly higher boll yield (160 t /ha) compared to groundwater irrigation (138 t /ha). Boll yields of cabbage irrigated with PW, TW, AW were similar to GW with an average of 141t /ha. Nutrient contents were the highest in fruits of okra irrigated with untreated sewage compared to other treatments. These ranged from 3.1 to 3.4% in case of N, 0.58 to 0.68% in P and 1.1 to 1.4% K and the contents of N, P and K. Similar pattern was observed in case of cabbage boll. The coliform counts ($5.37X10^4$ cfu g^{-1}) and heterotrophs ($8.43X10^5$ cfu g^{-1}) on okra fruits were also the highest when the crop was irrigated with untreated sewage in comparison to the mean value of coliform counts $2.09X10^3$ cfu g^{-1} and $4.67x10^4$ heterotrophs found in case of treated wastewater. The total bacterial load both in the internal and outer layers of cabbage boll was also the highest when irrigated with untreated sewage compared to groundwa-

Table 1. Okra and cabbage yield (t /ha) obtained with treated and untreated sewage irrigation

Tr.	Okra		Cabbage	
	Fruit	Shoot	Boll	Shoot
CW	13.9	2.1	146	60
SW	15.3	2.4	160	63
PW	13.2	1.9	142	58
TW	13.5	1.9	138	52
AW	13.7	1.9	143	53
GW	12.3	1.7	138	52
TOTAL	1.7	0.4	19	8

Table 2. Health risk index posed due to consumption of okra and cabbage irrigated with treated and untreated sewage

	Okra			Cabbage		
	Pb	Cd	Zn	Pb	Ni	Mn
GW	0.62	0.39	0.07	0.79	0.08	0.57
CW	0.71	0.50	0.06	0.97	0.11	0.57
VW	0.66	0.46	0.06	0.67	0.12	0.53
PW	0.54	0.36	0.06	0.85	0.09	0.57
TW	0.82	0.35	0.06	0.90	0.07	0.51
SW	1.17	0.58	0.08	1.21	0.13	0.60

ter or treated sewage use. In both the crops, Pb was found to be higher than the permissible limits whereas Cr was in traces. Okra and cabbage irrigated with untreated sewage might pose consumer health risk in particularly mainly due to lead contamination. By using treated sewage for irrigation health risk due to lead contamination could be lowered by 30-54% in okra and 26-45% in cabbage.

CONCLUSIONS

The fruit yield and the nutrient contents of okra and cabbage were significantly higher when irrigated with untreated wastewater than those irrigated with the groundwater or the treated wastewaters yet the crop irrigated with untreated sewage was heavily infested with pathogens and might pose health risk due to lead contamination. Use of treated sewage reduced the pathogen load by more than 10 times and health risks due to heavy metal contamination by 26 to 54%.

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Effect of mulching on the yield of potato (*Solanum tuberosum* L.) – local cultivar *Thangal Alu*

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A field experiment was conducted during *rabi* of 2011-2012 at Central Agricultural University with the objective to find out the effect of rice husk mulching on potato yield. The experiment was laid out in randomized block design and replicated thrice with 6 (six) levels/doses of rice husk mulching. Treatment consisted seven rice husk mulching viz., without rice husk (control), 6 t/ha of rice husk, 7 t/ha of rice husk, 8 t/ha of rice husk, 9 t/ha of rice husk, 10 t/ha of rice husk, 11 t/ha of rice husk. Results revealed that tallest plant height at 90 DAP was recorded (with 10 t/ha of rice husk followed by 9 t/ha of rice husk and the lowest was recorded in without rice husk. After harvesting, the tubers were graded in to three category i.e. large (>35 g), medium (20-35 g) and small (<20 g). Application of 10 t/ha rice husk recorded the maximum number of large size and medium size tubers per hill which was followed by 9 t/ha rice husk. The maximum number of small size tuber per hill was recorded by 9 t/ha rice husk mulching. The highest potato yield (9.57 t/ha) was recorded with 10 t/ha of rice husk and control recorded the lowest tuber yield (2.54 t/ha). Among different treatments, the highest gross return, net return and benefit cost ratio (4.2) were recorded with the mulching of rice husk @10 t/ha. The lowest gross and net incomes were recorded in control treatment. From the above findings it may be concluded that mulching with 7 t/ha of rice husk increased yield statistically on par with 8, 9, 10 and 11 tonnes/ha. However, high net return can be obtained by using mulch @ 10 t/ha of rice husk.

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Influences of mulch and irrigation levels on barley yield

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Barley (*Hordeum vulgare* L.) is an important crop of India cultivating an area of about 671.1 lakhs hectare with annual production of 1752 lakhs tonnes with productivity of 2580 kg/ha (Anonymous, 2014). Water is the most crucial input in agriculture as major share of water resources is used in agriculture and food requirements are increasing while water resources are shrinking. Mulching is one of the important agronomic practices in conserving the soil moisture and modifying the soil physical environment. Mulching not only conserving the soil by preventing evaporation but also control weed, moderate soil temperature, reduce runoff and increase infiltration. The use of different mulching materials is an efficient way to reduce the exchange of water vapor between the soil surface and the atmosphere. Consequently, the evaporation of water from a mulched soil decreases relative to a bare soil, and more water is available for beneficial crop transpiration (Sarkar and Singh, 2007). Keeping the above facts in mind, the present experiment was carried out to determine the optimum level of mulching and irrigation for ensuring higher productivity of barley.

METHODOLOGY

The field experiment was conducted at the Agricultural Research Farm of Banaras Hindu University, Varanasi, Uttar Pradesh (83°03' E and 25°18' N; 81.71 m above mean sea level) during *rabi* seasons (November–April) of 2013-14 to find out the effect of mulch and irrigation levels on barley. Nine treatments consisting of different mulching and irrigation levels were arranged in a randomized block design with three replications. Barley variety '*RD 2552*' was grown in the experimental field with recommended package of practices. Fertilizers were applied uniformly through urea, diaammonium phosphate and muriate of potash @ 60 kg N, 30 kg P_2O_5 and 20 kg K_2O/ha, respectively. Data on growth and yield performance were recorded.

RESULTS

Significantly higher number of tillers per meter running row were found in 6 t/ha mulching + two irrigation at 35 DAS

Table 1. Effect of mulching and irrigation levels on number of tillers/m row, number of grains ear/ head and grain yield of barley

Treatment	Number of tillers/m row			Number of grains/ear head	Grain yield (t/ha)
	30 DAS	60 DAS	90 DAS		
6 t/ha mulching + no irrigation	66	76	72	25	3.06
6 t/ha mulching + one irrigation at 35 DAS	74	97	92	26	3.46
6 t/ha mulching + two irrigation at 35 DAS & 85 DAS	79	106	102	28	3.58
4 t /ha mulching + no irrigation	59	65	61	24	2.92
4 t/ha mulching + one irrigation at 35 DAS	61	66	63	25	3.24
4 t/ha mulching + two irrigation at 35 DAS & 85 DAS	72	94	87	25	3.38
No mulching + no irrigation	55	63	60	23	2.67
No mulching + one irrigation at 35 DAS	57	65	62	24	2.78
No mulching + two irrigation at 35 DAS & 85 DAS	68	83	78	25	3.26
SEm±	2.53	3.38	2.86	0.77	0.57
CD (P=0.05)	7.59	10.13	8.56	2.31	1.55

and 85 DAS (T_3) as compared to other treatments except the 6t/ha mulching + one irrigation at 35 DAS (T_2) and 4 t/ha mulching + two irrigation at 35 DAS and 85 DAS (T_6) to which it was at par at all the stages of observation (Table 1). No mulching + no irrigation (T_7) recorded significantly minimum number of tillers at all the stages of observation. Mulching at 6 t/ha recorded significantly higher number of tillers than no-mulching as well as mulching at 4 t/ha at 60 and 90 DAS of crop. Towa *et al.* (2013) also observed increase of tillers due to application of mulch and attributed to the increase in soil moisture contents and reduction in evaporation from soil. The maximum number of grains per head were recorded in 6 t/ha mulching + two irrigation at 35 DAS and 85 DAS (T_3) which was found at par with 6 t/ha mulching + one irrigation at 35 DAS (T_2). Significantly minimum numbers of grains earhead were recorded under no mulching + no irrigation (T_7) treatment. The level of mulching failed to cause significant difference in grains/ear under no irrigation. The significantly higher grain yields (3.58 t/ha) was obtained in 6 t/ha mulching + two irrigation at 35 DAS and 85 DAS (T_3) over the remaining treatments except 6 t/ha mulching + one irrigation at 35 DAS (T_2). Significantly minimum grain yield (2.67 t/ha) was recorded under no mulching + no irrigation treatment (T_7). No irrigation treatment gave significantly higher grain yield with 6 t/ha mulching than no mulching treatment whereas, it remained at par with 4 t/ha mulching.

CONCLUSION

The mulching at 6 t/ha + two irrigations at 35 DAS and 85 DAS has been found most effective towards the maximum productivity of barley in Varanasi region of Eastern Uttar Pradesh.

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Extended Summaries Vol. 1 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Effect of different agro-technique in rice- fallow lands on productivity and profitability of subsequent crops and residual soil fertility in Eastern Himalayan Region

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The shrinkage of agricultural resources like arable land, irrigation water and energy, there is a dire need to design and develop new methods and techniques of crop production to meet the increasing demand for food, feed and forage through effective utilization of available agricultural input resources. Under the present system of sole cropping, small farmers are unable to address their diversified domestic needs to sustain normal livings from their limited land, water and economic resources. This necessitates going for appropriate alternative and more efficient production systems such as multicropping (inter/relay cropping) which can ensure proper utilization of resources to obtain increased production per unit area and time on a sustainable basis (Trenbath, 1986).

METHODOLOGY

The field experiment was conducted at the Research farm of ICAR Research complex for North Eastern Hill Region (NEHR), Manipur Centre, Langol farm during *kharif* season of 2014 and 2015. The farm is located at 24.49^0 N, 93.55^0 E with an altitude of 760 m above mean sea level. The Experimental area falls under the monsoon belt of eastern Himalayan region with an average annual rainfall of 1450- 2000 mm. Due to varied level of altitude and slopes the climatic situation of the region varies subtropical to semi-temperate condition (prevailing at higher altitudes). The winter season (November to February) can be characterized by low temperature, heavy dew fall and occurrence of frost. The temperature varies from

0 °C in winter to 36 °C in summer months. In general the soil of the experimental sites were sandy loam in texture, acidic in reaction (pH 5.2), medium to low in Nitrogen (117± 2.8 kg/ha), medium in phosphorus (14.3 ± 0.67 kg/ha) and low in potassium 170 ±8.9 kg/ha). The experiment was consisted of three diversified crops (Rapeseed & Mustard, Lentil and Pea) in rice fallow lands with three varieties of each Crop, rapeseed and mustard (M-27, TS-36 and TS-38), Lentil (PL-4, DPL-15 and HUL-57) and Pea (Rachna, Azad and Makhayatmubi) and three agro-techniques; Farms practice (control), Minimum Tillage, Minimum Tillage + Mulching. A total numbers of 9 nine treatment combination for each sequential crops was laid out in a RCBD with three replications. The fertilizer dose for Rapeseed and mustard was 50-60-30 kg N, P_2O_5 and K_2O/ha along with 2 t/ha of FYM; lentil 30-60-40 kg N, P_2O_5 and K_2O/ha along with 2 t/ha of FYM and pea 30-60-40 kg N, P_2O_5 and K_2O/ha along with 2t/ha of FYM were maintained for each sequential crops. However, the dose of fertilizers was reduced to half in case of farmer's practices as farmers are using very less amount of fertilizers. The remaining crop management practices were followed as and when required for the crops. The crops were harvested at maturity. The price of different commodities was considered as par prevailing market rate economics for all the crops were calculated.

RESULTS

Rapeseed and Mustard: The experimental result reveals that the highest growth and yield of Rapeseed & Mustard was found in the variety, TS-36 (801 kg/ha) which was significantly superior over by TS-38 and M-27. Among all the agro-technique the crop receiving minimum tillage with mulching recorded the highest yield (1045 kg/ha) irrespective of crop varieties. The pooled data over the two years experiments reveals that growing of rapeseed variety, TS-36 with minimum tillage and mulching recorded the highest yield (1145 kg/ha) and this technology can be recommended for rice fallow terrace lands of NEH hill region for cultivation of lentil. The soil fertility status after harvest of the crops was found to be improved in the agro- technique with minimum tillage and mulching. The N, P_2O_5 and K_2O was found to increased by 32%, 31.7% and 13.9 % respectively over farmers practices. However, the status of organic carbon was not improved significantly. *Lentil:* The result reveals that among all the varieties the lentil variety HUL-57(730.47 kg /ha) recorded the highest yield which was followed by DPL-15 significantly superior over PL-4. The growing of lentil with minimum tillage and mulching recorded the highest yield (908.2 kg/ha) irrespective of crop varieties. The pooled data over the two years experiments reveals that growing of lentil variety, HUL-57 with minimum tillage and mulching resulted the highest yield (1037.4 kg/ha). The soil fertility status after harvest of the different lentil varieties were found to be improved in the agro- technique, minimum tillage and mulching. The N, P_2O_5 and K_2O was found to increased by 6%, 23.3% and 25.8 % respectively over farmers practices. However, the status of organic carbon was not improved significantly. *Pea:* Three varieties of pea were studied with three different agro-techniques, the result reveals that among all the varieties the pea variety Makhayatmubi (2228.3 kg /ha) recorded the highest green pod yield which was followed by Rachna irrespective of all management practices. On the other hand, growing of pea with minimum tillage and mulching recorded the highest yield (2506.3 kg/ha) irrespective of crop varieties. The pooled data over the two years experiments reveals that growing of lentil variety, Makhayatmubi with minimum tillage and mulching resulted the highest green pod yield (3347.5 kg/ha). The soil fertility status after harvest of the different lentil varieties were found to be improved in the agro- technique, minimum tillage and mulching. The N, P_2O_5 and K_2O was found to increased by 15.5%, 63 % and 12 % respectively over farmers practices. However, the status of organic carbon was not improved significantly. *Economics:* The Economics of different diversified crops Rapeseed & Mustard, Lentil and Pea was compared in rice fallow terrace lands of Manipur. Among all the agro-techniques, growing of different crops in rice fallow lands with minimum tillage and mulching recorded highest net return Rs.71.28 X 10^3, Rs. 72.65 X 10^3, Rs. 29.26 X 10^3 in case of Pea, Lentil and Rapeseed & Mustard. The same treatment recorded highest return per Re invested Rs. 3.46, Rs. 2.75 and Rs. 2.27, respectively.

CONCLUSION

From the above experiment it can be concluded that the agro-technique minimum tillage and mulching is most suitable for higher crop productivity in rice fallow lands of hill terraces of NEH region. The growing of pea, Makhayatmubi, Lentil, HUL-57 and rapeseed-mustard, TS-36 were found to be more profitable.

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Precision water management in conservation agriculture based cereal systems: wheat yield and water productivity on a sandy loam soil in north-western IGP

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Rice-wheat cropping systems (RWCS) of north-western Indo-Gangetic plains (NW-IGP) of India contribute bulk of share in national food basket. However, its sustainability especially in the light of high water use, declining factor productivity, diminishing farm profits; intensive tillage and residue burning led soil and environmental health hazards have been major concerns (Yadvinder-Singh *et al*., 2014). The challenges will be further intensified and multiplied under projected climate change induced variability and resultant future high demand for irrigation water (Jat *et al*., 2016). Efforts have been made to address these issues through developing conservation agriculture based management practices for RWCS; diversification options for rice, improved water management practices *etc* but in isolation. We therefore, initiated an innovative research platform to develop portfolios of layering modern management practices and strategies for sustainable intensive cereal based systems for future food security in NW-IGP of India.

METHODOLOGY

A strategic research experiment was established during monsoon 2015 at Barloug Institute for South Asia (BISA) farm (30.99°N latitude, 75.74°E longitude), Ladhowal, Ludhiana, India. The actual treatments were imposed in wheat 2015-16 considering monsoon season a zero cycle ensuring tillage, crop establishment and residue management effects are captured in first test crop. Six management scenarios involving layering of cropping systems, tillage energy source for irrigation and irrigation management were evaluated (Table 1) in large plot size (400 m^2; 20 x 20 m) in a randomized complete block design with four replications. All the other standard management practices were used irrespective of the management scenarios.

RESULTS

We present the results related to grain yield, irrigation water use and water productivity in wheat under 6 different scenarios (Fig.1). The results revealed that all the three parameters mentioned above differed significantly under different scenarios. RWZT-SSD resulted in highest wheat grain yield (5.56 t /ha) which was *at par* with MWPB-SSD and MWPB-Fu; producing 15.4% higher yield over RWCT-FP (4.82 t /ha). Both RWCT-FP and MWCT-FP recorded similar and significantly lower grain yield over all other 4 scenarios.

Tillage and cropping systems	Method of irrigation	Treatment symbols
Zero till direct seeded rice + wheat residue (25-30%) (ZTDSR)- Zero till wheat + rice residue (100%) (ZTW)	*[a]Sub surface drip (SSD)	RWZT-SSD
Zero till direct seeded rice + wheat residue (25-30%) - Zero till wheat + rice residue (100%)	*[b]Flooding (Fl)	RWZT-Fl
Puddled transplanted rice (PTR) -Conventional till wheat (rice residue removed) (CTW)	[b]Farmers practice (FP)	RWCT-FP
Permanent bed maize + wheat residue (25-30%) (PBM)- Permanent bed wheat + maize residue (50%) (PBW)	**[a]Sub surface drip (SSD)	MWPB-SSD
Permanent bed maize + wheat residue (25-30%) (PBM)- Permanent bed wheat + maize residue (50%) (PBW)	**[b]Furrow irrigation (Fu)	MWPB-Fu
Fresh bed maize + wheat residue (25-30%) incorporated (FBM)- Conventional till wheat (maize residue removed) (CTW)	[b]Farmer practice (FP)	MWCT-FP

* Irrigation at 20 kPa in DSR and 40 kPa in wheat, **Irrigation at 50 kPa in maize and 40 kPa in wheat,[a]Solar power operated, [b]Electric power operated

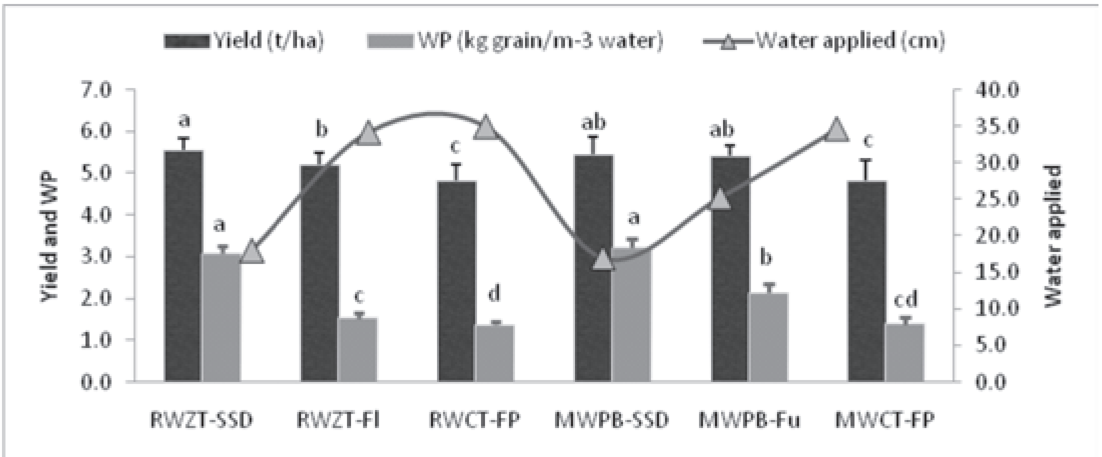

Fig. 1. Grain yield, irrigation water use and water productivity of wheat under different scenarios of conservation agriculture based cropping systems with precision water management

The irrigation water use under zero tillage and SSD based RW and MW scenarios was almost 50% lower compared to conventional tillage based farmer's flood irrigation management practices. The irrigation water productivity of wheat under ZT based RW and MW systems coupled with SSD was twofold compared to CT based systems with flood irrigation (1.5—1.6 kg/m^3).

CONCLUSION

The results of first year of study indicate that layering portfolios for tillage & crop establishment, residue recycling and irrigation for the two crop rotations (RW and MW) can help improving productivity by 15% while saving almost 50% irrigation water. The CA based management practices along with precision irrigation system have large potential for long term sustainability of the intensive cereal based systems of NW-IGP.

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Use of anti-transpirant and mulches for enhancing water stress tolerance in soybean

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Soybean has already established as one of the substitute crop for major Kharif cash crop in Vidarbha. The improved production technology has increased the productivity of soybean in Vidarbha. But uncertain rains and dry spell is one of the major constraint in production of soybean.Use of anti-transparent and mulching is one of the technology which may helps in increasing the productivity of soybean even if insufficient rainfall and prolong dry spell occurs at its critical growth stages.Straw mulch ameliorates environment stresses (Macilwain, 2004) and improves the food quality and safety.

Table 1. Number of pods/plant, straw yield (kg/ha), seed yield (kg/ha), and economics as influenced by different treatments of anti-transpirant and mulch on soybean (pooled)

Treatment	Pods/ plant	Straw yield (kg/ha)	Seed yield (Kg/ha)	Net returns (Rs/ha)	B:C ratio
Wheat mulch	21.90	24.33	20.09	32957.97	1.98
Control	23.17	21.80	18.37	31133.30	2.04
SE(m) $\pm$	0.43	0.53	0.45	1495.60	—
CD (P=0.05)	1.27	1.59	1.35	4483.79	—
Anti-transpirant					
$MgCO_3$ @ 5%	20.42	21.59	17.98	27781.70	1.87
Glycerol @ 5%	24.12	25.85	21.30	37896.23	2.16
Na_2CO_3 @ 2%	21.84	22.01	18.15	28718.66	1.92
KNO_3 @ 1%	24.18	23.59	20.11	34223.44	2.04
Control (Water spray)	22.12	22.29	18.59	31608.14	2.05
SE(m) $\pm$	0.65	0.85	0.70	2339.52	—
CD (P=0.05)	1.94	2.53	2.95	6951.06	

So the present investigation was undertaken, for management of water stress through use of anti-transpirant and mulching in prominent soybean variety.

METHODOLOGY

An investigation were carried out for three years from 2012-13 to 2014-15. The experiment was laid out in factorial randomized block design and the treatment were comprised of four anti-transparent *viz*., $MgCO_3$ at 5 per cent, glycerol at 5 per cent, Na_2CO_3 at 5 per cent, KNO_3 at 1 per cent and water spray with wheat straw mulching and without mulching which were replicated thrice.

RESULTS

From three years pooled data (Table 1), it is revealed that, maximum number of pods per plant (23.17) was observed in control treatment proves significantly superior over mulching treatment but in respect of straw yield, application of mulch resulted better. In respect of seed yield resulted that, amongst mulching and control treatment, significantly highest yield was recorded in mulching treatment. Better development of roots and proliferation depending on soil moisture under mulching helps in producing yield and yield attributes. In respect of different anti-transpirant spray, significantly highest number of pods per plant (24.18) was recorded in application of KNO_3 @ 1% while highest seed index and straw yield was recorded in application of glycerol @ 5% i.e. 12.64 g and 2585 kg/ha respectively. Significantly highest yield was observed in application of glycerol @ 5% but was found at par with treatment KNO_3 @ 1%. Pooled data over the three years indicates that significantly net monetary returns observed in mulching treatment i.e. Rs. 66799 and Rs. 32957/ha respectively but highest B:C ratio was observed in control treatment. This may be due to higher expenses over the mulching. In respect of anti-transpirant treatments, highest gross monetary returns, net monetary returns and B:C ratio was observed in application of glycerol @ 5% i.e. Rs. 70917, 37896 and 2.16 respectively.

CONCLUSION

From three years data it may be concluded that, mulching in soybean was found beneficial for getting higher yield. In respect of different anti-transpirant spray, significantly highest yield was observed in application of glycerol @ 5% but was found at par with treatment KNO_3 @ 1%.

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Sustainable practices of soil moisture conservation through tillage based soil manipulation systems

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Over the last few decades, there has been increasing interest in environmentally sound and sustainable soil management. When the soil is compacted, deep loosening gave higher yield and quality. The black cotton soils of Vidarbha region (vertisols) have the tendencies toward swelling and shrinkage depending on the availability of the moisture. Further, the continuous cultivation of soil creates a hard plough-pan beneath the soil surface. Apart from poor condition of sub-soil drainage, plough-pan offer obstacles to the root penetration, and thereby reduces overall growth and productivity of the crop. Hence, it was thought inevitable to break this plough-pan through tractor drawn plough and record the soil physical behaviour with soybean crop, being most popular among the cultivators.

The prevailing national agricultural research has inclined towards the new concept of zero tillage, minimum tillage and conservation tillage practices on a sustainable basis. In view of testing these tillage practices separately and in combination with conventional deep tillage practices on Vertisol soil types of Vidarbha region; and further to evaluate its effect on conserving the restraining natural resource, i.e. soil moisture, the field investigation was undertaken at the Research Farm of Department of Agronomy, Dr. P.D.K.V. Akola during *Kharif* season of 2015-2016 with the following objectives.

METHODOLOGY

The experiment was laid out in randomized block design with seven tillage treatments replicated three times having net plot size of 8.1 m × 5.4 m. The tillage treatments were- 1) 1Rotavator + 1 PE Herbicide Application + 1 PoE Herbicide Application (HR), 2) 1 Blade Harrow + 1Rotavator (BR), 3) 1 Tyne Harrow + 1Rotavator (TR), 4) 1 Tyne Harrow + 1 Blade Harrow + 1 Rotavator (TBR), 5) 2 Tyne Harrow + 1 Blade Harrow + 1 Rotavator (TtBR), 6) 1 Ploughing + 1 Tyne Harrow + 1 Rotavator (PTR), 7) 1 Ploughing + 2 Tyne Harrow + 1 Blade Harrow (PTtB).

The soil of experimental field was fairly levelled and uniform in depth, well drained, clayey in texture, moderately high in available nitrogen, moderate in available phosphorus, rich in available potassium with slightly alkaline in reaction. Soybean crop (Var. JS-335) was sown on 22nd June, 2015. Prior to sowing, the seven tillage treatments were applied to the selected site of experimentation. Fertilizer application to the crop was made as per recommended dose of fertilizer. Crop was harvested on 14th October, 2015.

Rainfall received during various crop growth stages viz., sowing to flowering, flowering to pod formation, pod formation to pod filling and pod filling to maturity was 50.2, 338.3, 42.4 and 138.3 mm, respectively with total being 569.2 mm. In general, the status of rainfall was quite lower than the normal (593.4 mm) during the crop period.

The physical properties of soil over cropped area were explored by adopting international standard methodology.

RESULTS

A. Rate of infiltration (cm hr^{-1})

As observed from the mean values, it is evident that the rate of infiltration decreased to a higher extent at harvest (1.67 cm hr^{-1}) when compared to its initial status (2.06cm hr^{-1}). The data reveals significant effect of various tillage practices over IR. At the time of sowing significant reduction in IR was noted with the treatment HR (0.87 cm hr^{-1}) and BR (0.80 cm hr^{-1}), both being similar with each other. However, maximum improvement in IR at sowing was observed with tillage treatment of PTtB (2.81 cm hr^{-1}). It was closely followed by treatments PTR, TtBR, TBR and TR with respective IR values of 2.78, 2.40, 2.37, and 2.38 cm hr^{-1}, all being statistically similar with each other. As far as IR at the time of harvest is concerned, though the IR values were lower than that of sowing, at all the treatments, the treatment differences were found to be differed to a level of significance. At this stage maximum improvement in IR was noted with tillage treatment of PTR by registering the value of 2.33 cm hr^{-1}. However, it was closely followed by treatment PTtB (2.30 cm hr^{-1}) and TtBR (2.17 cm hr^{-1}), all being statistically non significant with each other. The tillage treatment where soil bed was prepared with single application of rotavator (HR and BR) did not improved the IR, thus recorded the lowest IR values of 0.81 and 0.78 cm hr^{-1} respectively. The remaining tillage treatment (TR, TBR) were found to be intermediate with IR values of 1.17 and 1.13 cm hr^{-1} respectively.

This improvement in infiltration potential with treatments PTtB and PTR at the time of sowing and at harvest might be ascribed to higher degree of soil manipulation (up to the depth of 25 cm), indicating long lasting effect of deep tillage practices in improving water infiltration at air soil interface. The contribution of mean weight diameter and hydraulic conductivity also could not be ignored, as improvement in these soil properties might have improved the rate of IR with deep tillage treatments. Further, the significant decline in rate of IR with shallow tillage treatments (HR and BR) could have been the result of higher degree of soil strength due to reduced depth (10-12 cm) of tillage and probable formation of hard pan under the depth of operation.

Potter *et al.* (1995) also concluded that water infiltration rates can be large soon after tillage. Khan *et al.* (1997) reported greater infiltration in the plots ploughed by the mouldboard plough and the least in the plots ploughed by the cultivator. Abdullah and Al Ghazal (2000), Kergas *et al.* (2012) and Ahuchaogu *et al.* (2015) also reported greater rate of infiltration with greater tillage intensity and depth.

Table 1. Rate of infiltration (cm hr^{-1}) as affected by various tillage practices.

Treatments	Rate of Infiltration (cm hr^{-1}) At sowing	At harvest
HR	0.87	0.81
BR	0.80	0.78
TR	2.38	1.17
TBR	2.37	1.13
TtBR	2.40	2.17
PTR	2.78	2.33
PTtB	2.81	2.30
SE (m)±	0.370	0.305
CD at 5%	1.064	0.957
GM	2.06	1.67

Soil moisture content (%)

Marked changes in soil moisture were recorded during the period of investigation as revealed from the data presented in Table 2. As observed from the general mean it is obvious that the moisture content values never decline up to the lower limit (16%) of water potential, nor rose to the status of higher water potential (36%) throughout the investigational period. However the distribution of moisture was often uneven, affecting the various crop growth stages.

Tillage practices significantly affected the mean moisture content. Remarkable improvement in conserving the rainfall was noted with deep tillage consisting of ploughing + tyne harrow + rotavator operation (PTR) and ploughing + two tyne harrows + blade harrow operation (PTtB) throughout the investigational period. At the time of sowing except HR and BR the remaining deep tillage treatments improved the status of soil moisture by recording the values from 30.17 to 31.84 percent. However, at 20 DAS, significantly highest (in the range of 27 percent) moisture conservation was noted with tillage treatments of PTR and PTtB, even though this was the period when there was dry spell of about 20 days. Under this period of dry spell treatments HR and BR significantly reduced the soil moisture content by recording 20.43 and 19.81 per cent soil moisture. Remaining tillage treatments of TR, TBR and TtBR were found to be intermediate in conserving the soil moisture at the depth of 0-15 cm. It is noteworthy to mention that the soil moisture content with HR and BR were reduced to such an extent that the crop was showing the symptoms of wilting. Subsequently at 40 DAS with receipt of sufficient rainfall the soil moisture content at all the tillage prepared plot was improved to a satisfactory level. However the deep tillage treatments (PTR and PTtB) proved its superiority in conserving the soil moisture to significantly higher (31.99 and 32.35 per cent) extent. At this stage all the remain-

Table 2. Soil moisture content (%) at the depth of 0-30 cm as affected by various tillage practices.

Treatments	Soil moisture content (%) at 0-30 cm depth					
	At Sowing	20 DAS	40 DAS	60 DAS	80 DAS	At harvest
HR	27.29	20.43	29.83	26.41	19.47	16.32
BR	26.49	19.81	28.74	25.95	19.62	16.49
TR	30.63	24.23	29.46	28.79	23.53	20.37
TBR	30.17	24.17	29.37	30.72	24.18	20.28
TtBR	31.16	24.66	30.13	30.61	24.84	20.83
PTR	31.72	27.15	31.99	32.05	26.19	22.37
PTtB	31.84	27.00	32.35	31.78	26.52	22.41
SE (m)±	0.674	0.648	0.502	0.582	0.436	0.459
CD at 5%	2.172	2.037	1.485	1.836	1.321	1.428
GM	29.90	23.92	30.27	29.47	23.48	19.87

ing tillage treatments did not differ significantly with each other by recording the soil moisture to the tune of 28.74 to 30.13 per cent. At 60 DAS treatments PTtB, PTR, TtBR and TBR recorded significantly higher values of soil moisture than that of HR and BR. Thereafter again there was short dry spell reflecting over the soil moisture content at 80 DAS. Though there was less receipt of rainfall at this stage the deep tillage treatment i.e. PTR and PTtB significantly conserved the soil moisture to a higher extent of 26.19 and 26.52 per cent respectively. Whereas the lowest soil moisture content (19.47 and 19.62 per cent) was observed with treatments HR and BR. Similar trend was recorded at the time of harvest.

Thus it can be inferred that deep tillage practice with or without rotavator operation consistently improves the status of soil moisture not only under adequate rainfall condition but also under the condition of inadequate receipt of rainfall. This improvement in higher water conservation PTR and PTtB may attribute to loosening of soil to a higher depth coupled with increased porosity and higher mean weight diameter. The soil compaction below the operational depth of rotavator in case of treatments HR and BR may have resulted in less percolation of water up to the depth of 30 cm. reflecting in lowest availability of soil moisture for the plant growth.

Helenius and Saarinen (2013) noted that the main problem in rototilling seems to be the loose and porous structure of the seedbed resulting in decreased availability of capillary water. Barua *et al.* (2014) reported significant reduction in soil moisture with the reduction in depth of operation. Such noting was also reported recently by Karuma *et al.* (2014) and Meidani (2014).

CONCLUSION

Infiltration rate get significantly improved with tillage treatment of ploughing + 2 tyne harrow + 1 blade harraow while treatment of blade harrow + rotavator recorded lowest rate of infiltration i.e. 0.80 cm hr^{-1}. There was alternately higher moisture content in treatments ploughing + 2 tyne harrow + 1 blade harraow and ploughing + 1 tyne harrow + rotavator, as compared to other tillage treatments. The lowest conservation of moisture was recorded with blade harrow + rotavator.

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Effect of different soil moisture regimes and sources of nutrients on growth attributes and yield of wheat + chickpea

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Intercropping is an age old practice of growing two or more crops simultaneously on the same piece of land. Intercropping has been recognized as a potentially beneficial system of crop production and evidences suggest that it can provide substantial yield advantage over sole cropping (Tsubo *et al*., 2005). Under mid-hill conditions of Himachal Pradesh intercropping of chickpea in wheat provides additional source of income to the poor farmers, more efficient use of land and

Table 1. Effect of treatments on growth attributes and yield of wheat (pooled of 2 years)

Treatment	Growth attributes at maturity			
	Plant height (cm)	Dry matter accumulation (g/m^2)	Number of tillers/m^2	Grain yield (t/ha)
Soil moisture regime				
Rainfed	89.8	597.8	156	2.33
Irrigated	98.1	612.6	169	2.82
SEm±	2.4	4.8	3	0.05
LSD (P=0.05)	7.3	14.3	10	0.19
Nutrient Management				
Organic	92.4	600.2	158	2.60
Inorganic	97.7	611.5	168	2.78
Integrated	98.0	620.2	171	2.86
Farmer’s practice	87.8	589.0	154	2.05
SEm±	3.4	5.4	4	0.07
LSD (P=0.05)	NS	16.1	12	0.21

Table 2. Effect of treatments on growth attributes and yield of chickpea (pooled of 2 years)

Treatment	Growth attributes at maturity			
	Plant height (cm)	Dry matter accumulation (g/m^2)	Number of plants/m^2	Grain yield (t/ha)
Soil moisture regime				
Rainfed	61.6	104.9	14	0.28
Irrigated	66.5	116.0	16	0.37
SEm±	3.3	3.0	0.7	0.02
LSD (P=0.05)	NS	9.1	NS	0.06
Nutrient Management				
Organic	70.6	120.9	16	0.41
Inorganic	62.3	110.1	14	0.28
Integrated	66.9	113.7	17	0.34
Farmer’s practice	56.5	97.0	13	0.25
SEm±	7.1	3.6	1.6	0.02
LSD (P=0.05)	NS	10.9	NS	0.07

labour, better control of weeds, insects/pests, and pathogens than the sole crops. Main objective of this study was to find out the effect of different soil moisture regimes and sources of nutrients on production of crops.

METHODOLOGY

A field experiment was conducted during winter (*Rabi*) seasons of 2012–13 and 2013–14 at Model Organic Farm, Department of Organic Agriculture, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur. The experiment was laid out in split plot design with three replications. The experiment consisted of two irrigation treatments *i.e.* irrigated and rainfed in main plots and 8 treatments comprising of combinations of four nutrient management practices i.e. organic (soil treatment with jeevamrit + seed treatment with *Azospirillum*/ *Rhizobium* and PSB + vermicompost (VC) 10 t/ha + 3 sprays of vermiwash), inorganic (recommended NPK), integrated (5 t VC + 50% of recommended NPK) and farmer’s practice (2.5 t VC + 25% of recommended NPK) in sub plots. Wheat and chickpea were sown in the ratio of 1:1 and the row spacing was 25 cm between two crops.

RESULTS

In wheat, irrigated condition significantly increased plant height, dry matter accumulation, number of effective tillers/m^2 and grain yield over rainfed condition might be due to sufficient availability of moisture in root zone and better utilization of plant nutrient by wheat (Table 1). Among nutrient management, integrated nutrient management (INM) increased dry matter accumulation, number of effective tillers/m^2 and grain yield and remained statistically at par with inorganic nutrient management. INM produced 39.5% higher grain yield of wheat over farmer's practice, respectively. In chickpea, dry matter accumulation and seed yield were significantly higher in irrigated condition over rainfed condition (Table 2). Among nutrient management, higher dry matter accumulation and seed yield were obtained with organic nutrient management and was statistically at par with INM. The increase in the chickpea yield with organic nutrient management was 64.0% over farmer's practice. The increased seed yield in organic condition might be due to availability of nutrients throughout the crop growth that ultimately improved the growth and yield contributing characters of chickpea and hence resulted in higher seed yield.

CONCLUSION

Irrigated condition and INM recorded higher productivity in wheat + chickpea intercropping system. Therefore, for higher productivity from wheat + chickpea system irrigation and INM may be used in silty clay loam soil of mid hill region of Himachal Pradesh.

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Effect of crop geometry and drip irrigation on growth rate, yield attributes and quality of groundnut (*Arachis hypogaea* L.)

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Oilseeds occupy an important place in the Indian economy and contribute about 6 per cent to the gross national product and 9 per cent of the value of all agricultural commodities. Among oilseeds, Groundnut (*Arachis hypogaea* L.) is one of the most important crops of Indian economy, which belongs to the sub–family papilionaceae of the family leguminosae. It is popularly known as peanut, earthnut, monkey nut and locally called as "moongphali". Groundnut oil is used as a cooking medium. Groundnut seed (kernel) contains 44–50% oil, 26% protein and 10-20% carbohydrate. Kernels are important source of vitamin E, calcium, phosphorus, magnesium, zinc, iron, riboflavin, thiamine and potassium. The groundnut oil cake, which is generally used as animal feed, contains 7 to 8 % N, 1.5 % P_2O_5 and 1.2 % K_2O and can also be used as organic manure. It has been envisaged that with the establishment of better irrigation facilities (IGNP and Tube wells) in north-western Rajasthan, the region has offered welcome boost for further expansion of groundnut cultivation. However, soils of this region are coarse textured with low soil fertility status and poor in water holding capacity. Moreover, hot winds with high velocity at initial establishment stage (May-June) further restrict exploitation of full genetical potential of available varieties, all together results in low yield levels of this crop in this region. Such a situation calls for renewed efforts for analyzing production constraints in the prevailing agro-climatic condition and to evolve location specific production technology for increasing production. Therefore the present study was carried out for enhancing production potential and quality of groundnut under arid region.

METHODOLOGY

A field experiment was conducted on groundnut during *Kharif* season of 2014 at Niche Area Excellence Farm, S K Rajasthan Agricultural University, Bikaner situated in arid western hyper arid zone of Rajasthan. The soil of experimental field was loamy sand in texture, having field capacity 6.60%, PWP 1.52%, bulk density 1.52 g /cc, pH (1:2) 8.4 and electrical conductivity (1:2) 0.2 dS/m. The soil was very low in organic carbon (0.11%) and available nitrogen (86.41 kg/ha) medium in available P_2O_5 (33.4 kg/ha) and high in available K_2O (337.0 kg/ha). The experiment was laid out in randomized block design using group comparison method with three replications (Gomez and Gomez, 1976). The treatments consist of four crop geometry *viz*. normal sowing (30cm x 10cm) in 90 cm drip line spacing, normal sowing (30cm x 10cm) in 120 cm drip line spacing, paired row sowing in 90 cm drip line spacing and paired row sowing in 120 cm drip line spacing; three levels of drip irrigation (0.6, 0.8 and 1.0 ETc) and compared with surface irrigation at 30cm x10cm crop geometry.Groundnut variety 'HNG-10' was sown using 100 kg/ha seed with row to row 30 cm and plant to plant 10 cm spacing in normal sowing both in 90 and 120 cm drip line spacing whereas, in paired row sowing, crop was sown with 6-8 cm plant to plant spacing to get equal plant population in each geometry. Pre sowing irrigation (25 mm) was given before sowing to get proper germination and growth of the crop and thereafter irrigations were applied at alternate days as per the treatment. The quantity of water was calculated by the formulae**,** Irrigation water (mm) = PE × Kp × Kc; Where, PE = Pan evaporation (mm)**,** Kp = Pan factor and Kc = Crop factor**.** The lateral drip lines are laid on the soil surface as per treatment. Dripper to dripper spacing was 30 cm with 4 lit hr^{-1} discharge.The crop was harvested manually by uprooting the whole plant when leaf veins started yellowing and about 80 per cent pods became fully mature. For recording the dry weight, sample plants were dried in sun for ten days and then in an oven at $70^{O}C$ to a constant weight. The mean crop growth rate was calculated and expressed in g/m/day. The mean RGR is calculated expressed in g/g/day. Oil content in kernel was determined by Soxhlet apparatus using petroleum ether (60-$80^{0}C$) as an extractant (A.O.A.C., 1960).

RESULTS

Highest yield attributes yield *viz.*, test weight (450 g), harvest index (38%), shelling percentage (70%) and pod yield (3.31 t/ ha); and quality parameters *viz.,* oil content (47.79%) and oil yield (1.11 t/ ha) were recorded with normal sown crop at 90 cm drip line spacing, which was at par with paired row sown crop at 120 cm drip line spacing. However, harvest index and oil content of groundnut not influenced by different crop geometries (Table 1).Crop geometry did not affect oil content of groundnut (Khati *et al*., 2000). Patel and Patel (2013) also opined that spacing failed to exert any significant effect on oil content in castor. Significantly, higher oil yield was obtained from normal sown crop (30 cm x 10 cm) at 90 cm drip line spacing. Irrigation levels had significant effect on dry matter accumulation, crop growth rate, relative growth rate, yield attributes, yield and quality of groundnut (Table 1 and 2). Highest dry matter accumulation (4.08, 22.45 and 52.83 at 40, 80 DAS and at harvest, respectively), crop growth rate (3.42, 15.40 and 18.53 g/m/day at 0-40 and 40-80 DAS and 80 DAS-harvest, respectively), relative growth rate (18.53 g/g/day at 0-40 DAS), yield attributes yield *viz*., test weight (451.61 g), harvest index (38.28%), shelling percentage (70.17%) and pod yield (3.39 t/ha); and quality parameter *viz.,* oil yield (1.11 t/ha), was recorded with drip irrigation at 1.0 ETc, but highest oil content (48.09%) was recorded with 0.8ETc. However, all these parameters gave at par values both with 0.8 and 1.0 ETc. Further, there was no difference between drip irrigated and surface irrigated groundnut with respect to dry matte accumulation and crop growth rate at initial stages, relative growth rate, test weight, harvest index, shelling percentage and oil content of groundnut. This was in confirmation with Santosh *et al*., 2012 in okra. Irrigation based on crop ET produced significantly higher yield components *viz*. pods per plant, seed yield and shelling out turn etc.

Table 1. Effect of crop geometry and irrigation levels on yield attributes and quality parameters of groundnut

Treatments	Test wt. (g)	Pod yield (t/ ha)	Harvest index (%)	Shelling percentage (%)	Quality parameters: Oil content (%)	Quality parameters: Oil yield (t /ha)
Geometry						
G_1	450.85	3.31	38.00	70.00	47.79	1.11
G_2	431.58	2.69	36.98	69.27	45.91	0.86
G_3	449.44	2.98	37.18	69.68	46.63	0.98
G_4	450.37	3.19	37.70	70.01	46.91	1.05
SEm±	5.35	0.042	0.33	0.15	0.73	0.019
CD (P=0.05)	15.63	0.125	NS	0.46	NS	0.055
Irrigation levels						
0.6 ETc	435.68	2.45	36.25	69.08	45.76	0.78
0.8 ETc	449.39	3.29	37.86	69.97	48.09	1.11
1.0 ETc	451.61	3.39	38.28	70.17	46.58	1.11
SEm±	4.63	0.037	0.28	0.13	0.64	0.016
CD (P=0.05)	13.53	0.108	0.84	0.40	1.87	0.048
Control (Surface irrigation)	447.00	2.77	37.63	69.43	46.53	0.89
SEm±	9.27	0.074	0.57	0.27	1.28	0.033
CD (P=0.05)	NS	0.216	NS	NS	NS	0.096

$G_{1,}$ Normal sowing in 90 cm drip line spacing; $G_{2,}$ Normal sowing in 120 cm drip line spacing; $G_{3,}$ Paired row sowing in 90 cm drip line spacing; $G_{4,}$ Paired row sowing in 120 cm drip line spacing in groundnut. Patel and Patel (2013) who recorded higher oil content in castor seed under drip irrigation at 0.8 ETc at alternate days. Irrigation x crop geometry interaction was found significant statistically for oil yield in groundnut. Normal sown crop at 90 cm drip line spacing gave highest oil yield in all the drip irrigation levels and also recorded at par oil yield with paired row sown crop at 120 cm drip line spacing (Table 2).

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Effect of depth and interval of drip irrigation on growth and yield of chickpea (*Cicer arietinum* L.)

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Chickpea is a *rabi* season pulse crop grown over an area of 11.97 million hectares, producing 10.89 million tonnes with an average productivity of 764 kg/ha in the world. It represents 17 per cent of world pulse area and 17.68 per cent of world's pulse production (Anon., 2012). India is one of the important chickpea growing countries in Asia with an area of 9.93 million hectares and production of 9.53 million tonnes with a productivity of 960 kg/ha (Anon., 2014). Irrigated agricultural development has a high priority in the present world where production of food must keep pace with a rapidly increasing population. It is clear that with high yielding varieties in hand, higher agricultural production is expected from efficient use of available water resources. Irrigation plays an important role in chickpea productivity. Average chickpea yield under rainfed condition is 1.2-1.5 t /ha, while irrigated chickpea is 1.8-2.3 t/ha. Lack of irrigation and suitable variety under delayed sowing were the hindrances for higher productivity. It is an established fact that crop production suffers not only from moisture stress but also from over irrigation or unscientific use of water, as it affects crop growth and yield. It also spoils the land by way of increased salt accumulation, deteriorating the soil physical condition and leaching out the nutrients. Scientific irrigation scheduling, according to developmental rhythm of plant and in accordance with climatic demand is one of the ways to increase water use efficiency. Recently high yielding varieties responded to higher levels of irrigation and nutrients are evolved and therefore, better irrigation scheduling and intervals have prime importance in chickpea production. Drip irrigation system offer great promise for exploiting the yield potential of chickpea. In this backgroundthe a field investigation entitled "Effect of depth and interval of drip irrigation on growth and yield of chickpea" (*Cicer arietinum* L.) was undertaken during *rabi* 2014-15 in the Zonal Agricultural Research Station, GKVK, UAS, Bengaluru.

METHODOLOGY

The experiment was conducted at Zonal Agricultural Research Station, GKVK, University of Agricultural Sciences, Bengaluru. Geographically it is situated in the Eastern Dry Zone (Zone-5) of Karnataka, and the experimental site is located between 12º 51' N Latitude and 77º 35' E Longitude at an altitude of 930 m above Mean Sea Level (MSL). The experiment conducted in factorial RCBD with three replications. The treatments consist of two factors viz., irrigation depth and irrigation interval at different levels. The evaporation loss is recorded through USWB class A pan evaporator, according to the pan evaporation readings irrigation was scheduled at 100,

Table 1. Effect of depth and interval of drip irrigation on seed yield, haulm yield of chickpea

Treatments	No. of pods/plant	100 Seed weight (g)	Seed yield (kg/ha)	Haulm yield (kg/ha)
Irrigation depths (D)				
D_1	24	19.00	1264	1831
D_2	29	22.31	1449	2064
D_3	34	22.72	1723	2300
D_4	37	24.96	1780	2414
SEm±	1.26	0.66	41.67	58.08
CD at 5%	3.70	1.96	122.23	170.35
Irrigation intervals (I)				
I_1	27	20.61	1397	1950
I_2	31	23.18	1593	2204
I_3	34	24.45	1671	2303
S.Em±	1.09	0.57	36.09	50.30
CD at 5%	3.21	1.69	105.86	147.52
Interactions				
SEm±	2.19	1.16	72.19	100.60
CD at 5%	NS	NS	NS	NS

80, 60 and 40 per cent pan evaporation at 3, 5 and 7 days interval. The experimental data recorded was analysed statistically by adopting the standard procedures.

RESULTS

The results (Table 1) indicated that seed yield of chickpea differed significantly due to depth and interval of drip irrigation. Among the different irrigation depths, significantly higher seed yield (1780 kg/ha) was recorded with scheduling of drip irrigation at 100 per cent E_{pan} than all other treatments except scheduling of drip irrigation at 80 per cent E_{pan} which had recorded on par seed yield (1723 kg/ha). Lower seed yield was recorded when drip irrigation was scheduled at 40 per cent E_{pan} (1264 kg/ha). Among the irrigation intervals, drip irrigation scheduled at 7 days interval had recorded significantly higher seed yield (1671 kg/ha) and it was on par with the drip irrigation scheduled at 5 days interval (1593 kg/ha) and the lower yield was recorded at 3 days interval (1397 kg/ha). Similarly, haulm yield differed significantly due to depth and interval of drip irrigation. Significantly higher haulm yield (2414 kg/ha) was recorded with scheduling of drip irrigation at 100 per cent E_{pan} and was on par with scheduling of drip irrigation at 80 per cent E_{pan} (2300 kg/ha). Lower haulm yield was recorded with scheduling of drip irrigation at 40 per cent E_{pan} (1831 kg/ha). Among the irrigation intervals, drip irrigation scheduled at 7 days interval was recorded higher haulm yield (2303 kg/ha) and it was on par with drip irrigation scheduled at 5 days interval (2204 kg/ha). However, lower haulm yield was recorded with 3 days interval (1950 kg/ha). The interaction effect was found non-significant for both seed yield and haulm yield. Significantly higher seed yield of chickpea due to drip irrigation scheduling at different depths and intervals was mainly due to more number of pods/plant, higher test weight (Table 1). The higher values of yield attributes recorded could be attributed to higher availability of nutrients in optimum level throughout the crop growth period.

CONCLUSION

From this study it can be concluded that chickpea performed equally better with scheduling of drip irrigation at 100 per cent E_{pan} and 80 per cent E_{pan} along with 7 days interval with regard to growth, yield, quality and economics. Hence, Scheduling of drip irrigation at 80 per cent E_{pan} along with 7 days interval would be sufficient to meet the crop water requirement.

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Influence of tillage practices on growth, yield attributes, yield and economics of pearl millet cultivars under rainfed situations

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Dryland agriculture contributes only 42% to the national food grain production where more than 90% of sorghum and millets as well as 75% of pulses are grown. Therefore, dryland areas are important for the economy of the country and likely to continue till turn of the century and even beyond. Pearl millet [*Pennisetum glaucum* (L.) R.Br.] commonly known as bajra, is an important drought hardy millet crop, cultivated mostly in the arid and semiarid areas with rainfall ranging from 150 to 600 mm. It provides staple food for the poor in a short period in the relatively dry tracts of the country. The nutrient content of pearl-millet compares very well with other cereals and millets. Its grain contains about 12.4% moisture, 11.6% protein, 5% fat, 67% carbohydrate, and about 2.7% minerals. It also contains higher amount of carotene, riboflavin (Vit B_2) and niacin (Vit B_4). It is also used as feed for poultry and green fodder or dry karbi for cattle. It can provide economical grain yield (600–700 kg/ha) under marginal and low management conditions. Tillage is as old as agriculture. It helps in loosening the soil, improving the aeration, creating optimum tilth for sowing particularly for small grain crops as pearl millet. In conventional tillage, the soil is opened with mouldboard/disc plough for primary tillage with first rain of monsoon and a fine seedbed is prepared by secondary tillage in which crushing of clods, incorporation of plant residues, fertilizers, smoothing of soil surface etc., is done. Indian agriculture is a gamble of monsoon and crop failure due to erratic rainfall is most common in rainfed areas. To minimize the cost of production, peasants are adopting zero tillage. In zero tillage, there are no land preparation operations (primary tillage) and secondary tillage is restricted to seed bed preparation in row zone only. In rainfed areas, crop variety plays an important role in production because yield is directly influenced by crop variety. Some varieties are mostly suitable for the specific climate and soil. So, in rainfed and dry lands region, selection of suitable varieties like drought tolerant, early maturity is the key of successfully crop production.

METHODOLOGY

Therefore, in view of above mentioned facts, the research work entitled " Influence of Tillage Practices on Growth & Yield Attributes, Yield and Economics of Pearl Millet Cultivars under Rainfed Situations" was undertaken at Agricultural Research Station, Bikaner during kharif 2014 and kharif 2015. Experiment comprising of four tillage practices in main plots (conventional tillage, zero tillage, conventional tillage + ridging and zero tillage + ridging) and four cultivars of pearl millet in sub plots (Pusa composite 443, CZP 9802, MPMH 17 and RHB 177) was laid out in split plot design with four replications.

RESULTS

On the basis of pooled analysis, it was observed that practice of conventional tillage + ridging (T_3) and zero tillage + ridging (T_4) was at par from each other in respect of growth and yield attributes (plant height, DMA at 45, 60 DAS and at harvest, effective tillers/plant) and grain yield of pearl millet. Conventional tillage + ridging and zero tillage + ridging significantly increased the grain yield by a magnitude of 11.17 and 10.06%, respectively, over zero tillage. The treatment zero tillage + ridging recorded the highest net return (₹25,546/ha) and B: C ratio (3.69:1) among all the tillage practices so investigated. Significantly higher effective tillers/plant, grain yield and harvest index were observed in pearl millet hybrids in comparison to composite cultivars and the hybrid cultivar MPMH-17 recorded the highest grain yield (1423 Kg/ha) and harvest index (30.4%). However, plant height (cm), straw yield and nitrogen uptake by straw were found higher in composites than hybrids. The hybrid cultivar MPMH-17 also fetched the highest net return (₹25,482/ha), however, it was at par with that of Cv. RHB 177. The maximum B: C ratio (3.44:1) was also observed with Cv. MPMH 17. MPMH 17 in combination with conventional tillage + ridging resulted in higher DMA at harvest, effective tillers/plant, grain yield, harvest index, total N uptake, FWUE and net returns over other treatment combinations. Hybrid MPMH 17 gave the highest net return of ₹28,932 under conventional tillage + ridging treatment and remained at par where Cv. Pusa composite 443 or MPMH 17 was grown under zero tillage + ridging.

CONCLUSION

Therefore, on the basis of one year experimentation, it may be concluded that higher grain yield and net return of pearl millet can be obtained by growing MPMH-17 in combination with zero tillage + ridging or conventional tillage + ridging in rainfed areas of western Rajasthan.

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Effect of hydrogel and NP fertilizers on growth and yield of summer groundnut under controlled and assured irrigated conditions

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Of the agronomic factors known to contribute to productivity, water and nutrient management are the most important ones as these affect the productivity directly. Judicious management of available soil moisture and nutrients is crucial for improving the crop productivity. During summer, groundnut is totally dependent upon external supply of water and its requirement is also quite high due to high temperature and evaporation of water from the soil and plant surfaces. Hence, it is very essential to reduce the number of irrigations with use of some superabsorbent polymers. One of such developed product is 'Pusa hydrogel' which is an indigenous semi-synthetic superabsorbent technology for conserving water and enhancing crop productivity and thereby increases the water use efficiency (IARI, 2012). Further, the irrigation can give maximum benefits to the crop only if supply of nutrients during plant growth is maintained in the soil and vice-versa is also true. Among mineral nutrients, nitrogen and phosphorus are considered to be of prime importance for proper growth and development of crop plants. Nitrogen is the major constituent of proteins, amino acids, nucleic acids and chlorophyll, which direct and control the metabolic activities in the plant. Phosphorus occupies a key place in intensive agriculture and considered as backbone of fertilizer management programme. As the information on use of such superabsorbent in groundnut along with NP fertilizers under controlled and assured irrigated conditions is lacking, hence the present investigation was undertaken.

METHODOLOGY

A field experiment was conducted during summer, 2011 at ICAR-Directorate of Groundnut Research, Junagadh, Gujarat. The soil of the experimental site was clay loam, having pH 8.1, medium in organic carbon, available phosphorus and potassium status and low in available nitrogen status. The experiment, consisting of 24 treatment combinations comprising 2 irrigation schedules i.e. assured irrigation (as per crop requirement, 12) and controlled irrigation (8), allotted to main plots, 3 levels of hydrogel (0, 2.5 and 5.0 kg/ha) allotted to sub-plots, and combinations of two levels each of nitrogen (12.5 and 25 kg/ha) and phosphorus (11 and 22 kg P/ha) allotted to sub-sub plots, was laid out in split-split plot design with three replications. Nitrogen and phosphorus were applied through urea and DAP after adjusting the quantity of nitrogen supplied by DAP at the time of sowing. Groundnut 'TG 37 A' was sown during last week of February. Plot size under each treatment was 25.2 $m^2$with a spacing of 30 cm x 10 cm. Weeds were controlled by pre-emergence spray of pendimethalin @ 1 kg a.i./ha followed by one hand weeding at 25 DAS. The crop was evaluated in terms of plant dry weight (60 DAS), SPAD Chlorophyll Meter Reading (SCMR, 75 DAS), plant height (at harvest), relative water content in leaves (75 DAS), number of nodules/plant (75 DAS), number of pegs/plant (75 DAS), root weight (0-20 cm, 75 DAS), number and weight of mature pods/plant, shelling out-turn, 100-kernel weight, pod-and-haulm yields, andharvest index.

RESULTS

Raising of groundnut under assured as well as controlled irrigation supply did not affect the growth attributes [Plant dry weight (60 DAS), SPAD Chlorophyll Meter Reading (SCMR, 75 DAS), root weight (75 DAS) and plant height], relative water content in leaves (75 DAS), and yield attributes [Number of nodules/plant (75 DAS), weight of mature pods/plant, shelling out-turn and 100-kernel weight], pod-and-haulm yields, and harvest index significantly. However, number of pegs/plant (75 DAS) and mature pods/plant were significantly higher under assured irrigation schedule. There was saving of about 1/3rd irrigation water under controlled irrigation schedule compared to assured irrigation schedule with no significant effect on yield of groundnut. Application of hydrogel had not any significant effect ongrowth attributes viz., plant dry weight (60 DAS), root weight (75 DAS), SCMR (75 DAS), plant height; yield attributes viz., number of nodules/plant (75 DAS), pegs/plant (75 DAS) and100-kernel weight, and haulm yield over the control. On the other hand, number and weight of mature pods/plant, pod yieldand harvest index improved significantly with the application of hydrogel up to 2.5 kg/ha. Application of 2.5 kg hydrogel/ha increased pod yield by 18.2% over the control. Significantly higher shelling out-turn was recorded in the control and was at par with application of hydrogel @ 2.5 kg/ha. Jain *et al*. (2014) also obtained significantly higher pod yield of summer groundnut due to application of 2.5 kg hydrogel/ha. Application of nitrogen had not any significant influence on growth attributes viz., plant dry weight (60 DAS), root weight (75 DAS), SCMR (75 DAS) and plant height, relative water content in leaves (75 DAS) and yield attributes viz., number of nodules/plant (75 DAS), number of pegs/plant (75 DAS), number and weight of mature pods/plant and 100-kernel weight;and harvest index significantly. Shelling out-turn improved significantly with the application of 25 kg N/ha over 12.5 kg N/ha. Pod and haulm yieldsalso increased significantly with the application of 25 kg N/ha over 12.5 kg/ha and registered 6.0and 3.6% improvement, respectively. Similar findings were also reported by Hossain *et al*. (2007).Application of higher dose of phosphorus also did not have any significant influence on growth attributes viz., plant dry weight (60 DAS), root weight (75 DAS), SCMR (75 DAS) and plant height, and yield attributes viz., number of nodules/plant (75 DAS), pegs/plant and 100-kernel weight; haulm yield and harvest index significantly. Relative water content in leaves (75 DAS), number and weight of mature pods/plant increased significantly due to application of 22 kg P/haover 11 kg P/ha. Pod and haulm yields improved significantly with the application of 22 kg P/haby 8.5 and 5.6% over 11 kg P/ha. Similar findings were also reported by Hossain*et al*. (2007).

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Growth, yield and solute content of wheat in soils treated with sewage sludge

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In India, estimated 33,212 million litter/day (MLD) of sewage water. This implies that a huge amount of sludge has been generated in our country. These waste waters carry appreciable amount of plant nutrients as well as trace toxic metals. Land application of the sewage sludge is also becoming popular due to possibility of recycling valuable components such as organic matter, N, P and other plant nutrients. However, long-term use of sewage, sludge and industrial effluents in agricultural lands is restricted as these non-conventional sources of plant nutrients often carry trace toxic metals. In view of increasing cost of fertilizers and declining availability of irrigation water, feasibility of recycling these non-conventional sources of plant nutrients on agricultural lands will merit investigation.

METHODOLOGY

A field experiment was initiated in the year 2014 and 15 at IARI, New Delhi with the following treatment combinations:

T1, Control; T2, 100% RDF NPK (150:60:50); T3, 25% N by SS + NPK; T4, 50% N by SS + NPK; T5, 100% N by SS + PK; T6, 200% N by SS; T7, 300 % N by SS and T8, T2 + 2.5 t sludge/ha. The experimental soil had pH 8.2, available N 171, available P 28.1 kg ha^{-1}, available K 265 kg ha^{-1}, DTPA Zn 1.91 mg kg^{-1}, DTPA Mn 3.39 mg kg^{-1}, DTPA Fe 4.22 mg kg^{-1} and DTPA Cu 1.33 mg kg^{-1}. The Sewage sludge was applied 15 days before sowing of wheat as per treatments. Standard agronomic practices were followed for raising wheat (November to April).

RESULTS

Results showed that wheat responded significantly to fertilizer N and P. Combined application of 100% NPK with 2.5 t/ha SS increased significantly in comparison to 100% NPK alone treatment. Highest yield of wheat was obtained with 100% NPK combined with 2.5 t/ha SS which was more or less equal yield of wheat with the application of 25% or 50% N substituted by SS with NPK fertilizers. However, there was no significant difference in the yield of wheat amongst 100% NPK alone and 25% or 50% N substituted by SS with NPK treatments. Increasing the dose of SS from 100% to 300% N substituted by N significantly decreased grain yield of wheat. The results further showed that wheat yields could be maintained even at 50% N substituted by SS when used in conjunction with NPK fertilizers. Incorporation of SS resulted in slightly build-up of soil available N, P, K, Zn, Fe and Cu except Mn content and greater nutrient uptake by the crops. The results suggest that conjunctive use of 50% N substituted by SS with NPK is extremely important for sustaining wheat yield and improving soil health.

CONCLUSION

The maximum wheat yield was obtained with 100% NPK with 2.5 t/ha sewage sludge which was more or less equal yield of wheat with 25% or 50% N substituted by sludge with PK fertilizer application. Application of 100% NPK with 2.5 t/ha sludge increased significantly over that 100% NPK alone. Addition of sewage sludge increased total contents of N, P, K, Zn, Fe and Cu except Mn in comparison to 100% NPK. The heavy metals (Ni and Cd) also increased but under permissible limit

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Enhancing legume productivity under different moisture conservation practices in fruit-based landuse system

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Rainfed agriculture hinges the food and livelihood security of a large number of people worldwide. However, production of rainfed areas is constrained by the extreme variability in rainfall, poor nutrient status of soils, land degradation through erosion etc. Under such situations, agri-horti and other agroforestry land use systems are receiving greater attention to protect the land from various types of degradation, diversifying the farming system and increasing the soil carbon build up and moisture (Masebo *et al.,* 2014; Lenka *et al.,* 2012). Though hardy fruit crops have better choice in these areas, but utilization of inter- space between trees can improve soil nutrient and biological characteristics, physical properties, enhancing total biomass production and further improve farmer's income from a unit land. These benefits of agro-forestry can be improved by incorporating *in-situ* moisture conservation practices and legume crops intercropped with fruit trees may provide important source of cash and income. Bengal quince or *bael* (*Aeglemarmelos* (L.) Corr. Serr.), one of the important fruit tree species is an integral part of arid and semi-arid regions of India. Again India is the largest producer and consumer of pulses in the world, but average yield of pulses in India is low compared to the world average. Therefore, Government of India is also emphasizing for enhancing the pulses production (Gowda *et al*., 2013) and the 68th UN General Assembly declared 2016 as the international year of pulses. Better survival and establishment of fruit trees and enhancing legume yield in rainfed requires proper *in-situ* moisture conservation (Sikka *et al.,* 2014, and Dass *et al.,* 2011). However, less information is available on the effects of legumes in conjunction with trees.

METHODOLOGY

The experiment was carried out on a sandy loam soil under agri-horti system with three legume crops (soybean, cowpea, and mungbean) grown under *Bael* trees with three different moisture conservation practices of trench, micro-catchment (MC), ring basin (RB) and no moisture conservation (NMC) practices under tree and no tree (NT) as control at *Bael* orchard, near Water Technology Centre of ICAR-Indian Agricultural Research Institute, New Delhi 110 012, India during the *kharif* season of 2015. The experiment was laid out in split plot design with four replications under rainfed conditions. Soil moisture content was measured periodically by gravimetric method from 0–15, 15–30, and 30–60 cm soil depth. Infiltration and other soil physical and chemical properties were studied through standard procedures. Values of surface runoff from the rainfall data were estimated on daily basis using SCS curve number technique. The Penman–Monteith equation was used for calculating the reference crop evapotranspiration for all the three crops and tree. Effective rainfall was estimated using FAO equations. Data on bio-physical parameters for crops and trees were recorded using standard procedures. Cowpea pod yield and soybean and mungbean grains yield were recorded after harvesting. Fruit yield of *Bael* were also harvested from each tree and then calculated plot wise.

RESULTS

The results indicated that in soybean, crop yield is having not significantly different within moisture conservation practices, But trench yielded more crop yield (1.21 q/ha) compared to others followed by micro-catchment. The lower crop yield of soybean was due to severe water stress during pod formation stage. In cowpea, green pod yield in micro-catchment moisture conservation practice was better (32.8 q/ha) compared to others, but among trench and ring basin there was no significant difference of green pod yield, also there is no significant difference between ring basin and no moisture conservation practices, but there was significant difference among trench and NMC. In moongbean plots, trench was having significant effect on crop yield (3.97 q/ha) followed by micro-catchment, ring basin and no moisture conservation practices. Similarly Bael fruit yield (19.1–33.1 q/ha) and cow-

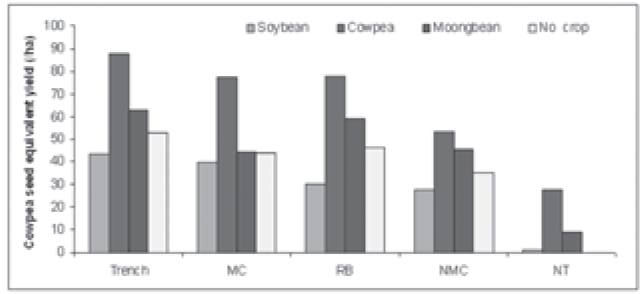

Fig. 1. Cowpea seed equivalent yield of the agri-horti system under moisture conservation practices

pea seed equivalent yield were highest in trench moisture conservation practices in all the three crops (Fig 1). This was due to higher soil moisture availability in these plots

CONCLUSION

Based on the above results, it was found that cowpea is the best legume crop which yielded highest cowpea seed equivalent yield followed by mungbean and soybean under *Bael* based agri-horti land use system with trench *in-situ* moisture conservation practices.

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Yield and economics of bed planted barley cultivars as influenced by crop geometry and moisture regimes

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Barley (*Hordeum vulgare* L.) is the fourth-largest cereal crop in the world, with a share of seven percent of the global cereals production and 15 percent of coarse grains consumption, used in animal feed, malting and food products. The growing demand from the breweries is enforcing the farmers to increase the production of barley from the limited resources of land, as horizontal expansion seems difficult, due to its competition with other cereals like wheat for the land resources. Barley is commonly grown in India under restricted irrigation conditions, following conventional system of flat sowing and flooded irrigation, which is conducive to excessive irrigation water use, downward leaching of native and applied nutrients and periodic aeration stress. The good quality water resources have started depleting, which has been continuing in agriculture for many years, resulting into fall in water table and this is likely to continue in the future. During recent years, furrow irrigated raised bed planting system (FIRBS) has proved to be one of the important components of low cost sustainable production system for crop production in several parts of the world, including India. Sowing of crops under FIRBS is a relatively new technology in India. Soil moisture is also one of the most important factors influencing the availability of water and nutrients to plants (Kumar *et al.* (2005), Mammnouie *et al.* (2006) and Kumar *et al.* (2010)). Interval of irrigation application greatly influences the soil moisture and hence, the grain yield and quality of barley. Since, barley is grown in limited irrigation condition in semi-arid region of Haryana, it is important to quantify the level of moisture regime under FIRBS planting to maximize the yield and economics.

METHODOLOGY

A field experiment was conducted during *rabi* 2011-12 and 2012-13 in a semi-arid climate at Research Farm, CCS Haryana Agricultural University, Hisar, Haryana (India) to study the productivity and economics of barley cultivars planted on raised beds in relation to crop geometry and moisture regimes. The experiment was laid out in split plot design

Table 1. Productivity and economics of barley cultivars planted on raised beds in relation to crop geometry and moisture regimes

Treatment	Grain Yield (kg/ha)		Cost of cultivation(/ha)		Net return(/ha)		B:C	
	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13
Cultivar								
BH 393	4305	4348	28432	30432	23913	34457	1.84	2.1
BH 902	5058	5174	28432	30432	34108	48607	2.20	2.5
BH 885	3338	3634	28432	30432	13319	24685	1.47	1.7
CD (P=0.05)	213	261	-	-	-	-	-	-
Row spacing								
2 rows per bed	4117	4221	28432	30432	22161	33241	1.78	2.0
3 rows per bed	4351	4550	28432	30432	25399	38597	1.89	2.2
CD (P=0.05)	174	213	-	-	-	-	-	-
Moisture regime								
IW/CPE = 0.3	3363	4122	28432	30432	13607	31060	1.48	2.0
IW/CPE = 0.4	4589	4450	29632	31632	26545	36060	1.90	2.1
IW/CPE = 0.5	4750	4585	29632	31632	28788	38240	1.97	2.1
CD (P=0.05)	412	150	-	-	-	-	-	

Irrigation at IW/CPE 0.3, but increase in moisture regime increased gross return, net return and benefit cost ratio of barley cultivation.

with three replications keeping three cultivars viz., BH 393, BH 902 and BH 885 and two rows spacing viz., 2 rows per bed and 3 rows per bed (70 cm wide with 40 cm top and 30 cm furrow) in main plots and three moisture regimes (irrigation at IW/CPE 0.3, 0.4 and 0.5) in sub-plots. The grain and straw yield obtained from net plot area was converted into kg/ha. Economics was calculated separately taking into consideration grain and straw yields and their market prices.

RESULTS

The results revealed that grain and straw yields were recorded significantly higher in cultivars BH 902, followed by BH 393 and lowest in BH 885 (Table 1). Significantly higher grain and straw yield were produced by planting of barley on raised beds with 3 rows per bed than 2 rows per bed. The grain and straw yields increased significantly with increase in moisture regime from irrigation at IW/CPE 0.3 to IW/CPE 0.4 or 0.5, the latter two being at par with each other in both years. The input cost was similar under different barley cultivars, while, the gross return, net return and benefit cost ratio were maximum in BH 902, followed by BH 393 and BH 885. Similarly, the input cost was similar under the row spacings, but planting of barley with 3 rows per bed resulted into higher gross return, net return and benefit cost ratio than 2 rows per bed. Input cost increased with application of irrigation at IW/CPE 0.4 or 0.5, than

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Response of groundnut to supplemental irrigation under dry farming condition of Saurashtra region

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In Gujarat state, nearly 88 per cent of cultivated area falls under arid and semi-arid region. A major area of Saurashtra and Kutch falls under this zone, where the annual rainfall ranges from 250 to 750 mm. The groundnut is the main crop of Saurashtra region. If the critical stages of groundnut is subjected to water stress, then crop yield is very adversely affected. Mostly during the crop growth period, dry spells are observed, if the supplemental irrigation is applied at water stress period, production may considerably be enhanced. Yield reductions are greatest with water stress imposed during the period between pegging and pod development and lowest with stress imposed from pod development to maturation (Patel and Golakiya, 1988). Therefore, the present experiment was conducted to find out the effect of supplemental irrigation at different water stress periods on groundnut yield.

METHODOLODY

A field experiment was conducted on medium black soil during the *kharif* season of 2009-10 to 2014-15 at Main dry farming Research Station, Junagadh Agricultural University, Targhadia. The soil of experimental field was clayey in texture having pH 7.75 and EC 0.28dS/mand organic carbon 0.49 %. The soil was low in available nitrogen(248.00 kg/ha) and phosphorus (24.40 kg/ha) and high in available potash (397.50 kg/ha).The field experiment comprised of six treatments*viz.,* no irrigation (control), irrigation at soil moisture deficit of about 40, 50, 60, 70 and 80 weretried in a randomized block design with fourreplications.Modified Penman method was used to predict referenceevapotranspiration on daily basis. The daily cumulative water balance established

Table 1. Productivity, water use efficiency and economics of groundnut as influenced by supplementary irrigation (pooled data over 4 years)

Treatment	Podyield (kg/ha)	Haulm yield (kg/ha)	WUF (Kg/ha-cm)	Gross returns (Rs/ha)	Net returns (Rs/ha)	B:C ratio
No irrigation (control)	607	2733	15.12	37945	7872	1.26
Irrigation at soil moisture deficit of about 40 %.	1162	3924	29.23	66100	32277	1.95
Irrigation at soil moisture deficit of about 50 %.	1014	3610	25.46	58610	25837	1.79
Irrigation at soil moisture deficit of about 60 %.	885	3324	22.38	52020	19485	1.60
Irrigation at soil moisture deficit of about 70 %.	824	3171	20.77	48815	16280	1.50
Irrigation at soil moisture deficit about 80 %.	781	2986	19.64	46170	13635	1.42
SEm ±	36	80	-	-	-	-
CD (P=0.05)	109	226	-	-	-	-

over the growing seasons of groundnut was calculated using meteorological information collected at Main Dry Farming Research Station, Targhadia. The water retained in the soil is also taken into account in the calculation from sowing to maturity of groundnut crop. The crop was irrigated when the estimated soil moisture levels attain as per treatments. Gross and net plot size was 8.0 m X 4.8 m and 6.0 m X 3.4 m, respectively. Groundnut (GG-20) was sown at onset of monsoon every year with 60 cm distances between row and applied 12.5 kg N + 25.0kg P_2O_5/ha. Agronomic practices and plant protection measures were followed as and when required. The total rainfall received during the crop season (June to November) was 460.9, 1144.5, 1044.3, 404.5, 1101.4 and 483.1 mm in 17,46,33,21,40 and 22 rainy days in the year of 2009, 2010, 2011, 2012, 2013and 2014, respectively. Productivity and water use efficiency of groundnut were pooled over only four years (2009-10, 2011-12, 2013-14 and 2014-15) because of low yield and treatments was not imposed due to unavailability water for irrigation in the year of 2012-13, while in the year of 2010-11, experiment was vitiated due to sufficient and well distribution of rainfall throughout growing season.

RESULTS

Pod and haulm yield of groundnut were significantly affected due to different treatments of supplementary irrigation in pooled results. Application of supplementary irrigation at soil moisture deficit of about 40% recoded significantly highest pod and haulm yield of groundnut with water use efficiency (29.23 kg/ha-cm) over control and rest of treatments. Similarly, application of supplementary irrigation at soil moisture deficit of about 50% also recorded significantly higherpod and haulm yield of groundnutwith water use efficiency (25.46kg/ha-cm) over control and rest of supplementary irrigation treatments (at soil moisture deficit of about 60, 70 and 80%) which was at par with each other and recorded significantly higherpod and haulm yield of groundnutover control. Economics of supplementary irrigation was worked out on the basis of pooled results of productivity of groundnut indicated thatsupplementary irrigation applied at soil moisture deficit of about 40% gave the highest gross (Rs 66100/ha) and net returns (Rs 32277/ha) with the B: C ratio of 1.95.

CONCLUSION

On the basis of the above results, it canbe concluded that farmers of the Saurashtra region are advised to apply supplementary irrigation at soil moisture deficit 40% in the groundnut GG-20 for obtaining higher productivity and net returns and improving crop water use efficiency under dry farming conditions.

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Energy analysis of rice-wheat cropping system in Indo-genetic plains of India

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Rice-wheat cropping system is one of the most important cropping systems of the country contributing about 32% to the national food basket. Therefore, their sustained high productivity is inevitable for national food security. Rice-wheat cropping system requires huge amount of input energy for growing the seedlings, puddling, transplanting, irrigation, fertilizer and weed management, etc. Among different indicators of crop performance, the energy analysis is one of the most important. The net output energy of a cropping system can be assessed for the planning of sustainable cropping systems. (Tuti *et al*., 2012). The consumption of energy is increasing by adoption of improved cultivation practices through fertilizers, chemicals, machineries etc. A study was made to assess the energy use in rice-wheat cropping system for two years.

METHODOLOGY

An energy flux of rice-wheat cropping system was estimated using crop management and biomass production records. To study energy inputs and outputs of cropping system of two years, a complete inventory of all crop inputs and outputs of both main and by-products was prepared. The energy value of cropping system was determined based on energy inputs and energy production for the individual crops in the system. Inputs and outputs were converted from physical to energy unit measures through conversion coefficients.The following equations were used to determine the energy indices. Energy ratio = energy input (MJ/ha)/energy output (MJ/ha), net energy = energy input (MJ/ha)- energy output (MJ/ha), energy profitability = net energy (MJ/ha)/energy input

Table 1. Resource inputs, outputs, energy coefficients and energy indicesof rice-wheat system

Resource inputs/ha		Unit	Rice	Wheat	Energy coefficients (MJ/ha) Rice	Wheat	Indices	Rice	Wheat
A) Direct									
1) Labour	man hr	802.4	414.6	1572.8	812.6	ER	8.9	8.6	
2) Fossil fuel (Diesel)	l	36.47	67.2	1746.0	3218.5	NE	174924.3	116972.0	
3) Electricity	kWh	889.9	222.5	3203.9	801.0	EP	7.9	7.6	
B) Indirect	EPr	0.3	0.3						
1) Seed	kg	24.3	103.3	357.5	1519.1	DE	6522.7	4832.1	
2) Nitrogen (N)	kg	106.4	97.6	6450.5	5914.1	IE	15771.8	10532.8	
3) Phosphorus (P_2O_5)	kg	68.5	96.5	760.5	1070.9	RE	1572.8	812.6	
4) Potassium (K_2O)	kg	60.2	60.2	403.2	403.2	NRE	14601.7	13022.3	
5) Insecticide & Weedicide		kg	12.2	0.00	1459.0	0.00			
6) Fungicide	kg	1.2	0.00	124.4	0.00				
7) Machinery	kg	1.4	1.4	96.7	95.5				
8) Animal Ploughing	hr	-	-	-	-				
9) Irrigation	m^3	6000	1500	6120.0	1530.0				
C) Resource outputs									
Main	kg	7179	4710	105531.3	69237.0				
Byproduct	kg	7335	5048	91687.4	63099.9				

Source: (Mittal *et al*., 1985 and Devsenapati *et al*., 2008)
Note : ER- energy ratio, NE- net energy, EP- energy profitability, EPr- Energy productivity, DE- Direct energy, IE- Indirect energy, RE- Renewable energy, NRE- Non-renewable Energy

(MJ/ha), direct energy = labour + fuel + electricity, indirect energy = seed + feed + fertilizers + chemicals + machineries + irrigation, renewable energy =labour + organic fertilizers, non-renewable energy = fuel + electricity + seed + feed + synthetic fertilizers + chemicals+ machineries,human energy profitability = output energy(MJ/ha)/labour energy(MJ/ha).

RESULTS

The mean data of two years (Table 1) reveals that in rice highest direct energy input was required in electricity due to more number of irrigation followed by fossil fuel and labour. While in wheat the direct energy input of fossil fuel is higher due to zero till planting of wheat. Among different indirect energy inputs of rice and wheat the nitrogenous fertilizer has accounted more because of exhaustive nature of these crops compare to all other inputs followed by irrigation due to higher water requirement of crops. The least indirect energy input was noticed in machinery in both the crops shows lesser mechanization in the system. The energy ratio, net energy return and energy profitability was found higher in rice compare to wheat. However, the human energy profitability was found higher in wheat crop. The energy productivity of both the crops remained same. Direct energy, indirect energy, renewable energy and non-renewable energy consumption was found higher in rice crop compare to wheat crop.

CONCLUSION

Rice crop was found more energy efficient compare to wheat crop. The use of indirect energy and nonrenewable energy was more compare to direct energy and renewable energy in both the crops, shows more energy exhaustive nature of rice and wheat. Rice-wheat cropping system needs diversification with pulses or oilseed crops to make this system more efficient.

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Effect of irrigation schedules of domestic wastewater on fodder sorghum yield and quality

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At present, the country faces a net deficit of 35.60% green fodder, 10.95% dry crop residues and 44% feeds (Anonymous, 2013). It is estimated that 38000 MLD (Million litres per day) of wastewater is generated from urban centers out of which only 35% is treated (CPCB, 2009), at the same time 13,500 MLD of industrial wastewater is also generated with a large gap between sewage generated and treatment capacity at present. In this scenario, reuse of domestic and industrial waste water in agriculture for irrigating crops seems to be a sustainable alternative for productive utilization of this resource. Sorghum (*Sorghum bicolor* L. Moench) is widely used for food and fodder all over the world. So keeping in view the paucity of irrigation water and fodder, the present study was conducted to evaluate the effect of irrigation schedules of domestic wastewater on growth and yield of fodder sorghum.

METHODOLOGY

The study was conducted during *Kharif* season (May to September 2013) in micro-plots (36, 2×2 m^2) at ICAR-Central Soil Salinity Research Institute, Karnal, Haryana. Multicut forage sorghum hybrid Raseela (MFSH-4) of Mahyco

Table 1. Effect of water quality and their irrigation regimes on leaf area index, green fodder yield, dry matter content and crude protein of sorghum

Treatment	LAI	Green fodder yield (t/ha)	Dry matter content (%)	Crude protein content (%)
Irrigation schedules (ID/CPE)				
0.8	3.61	27.24[a]	17.09[a]	9.46[a]
1	3.76	28.90[b]	16.25[b]	9.60[b]
1.2	3.90	31.41[c]	15.00[c]	9.76[c]
CD (P=0.05)	0.058	1.37	0.32	0.022
Water quality				
Tube Well water	3.53	27.37[a]	17.01[a]	9.50[a]
Tube Well water: Sewage water	3.76	28.88[a]	16.19[b]	9.56[b]
Sewage water	3.98	31.31[b]	15.15[c]	9.76[c]
CD (P=0.05)	0.058	1.37	0.32	0.022

Seed Company was used as test crop in the study. The experiment was conducted in factorial randomized block design consisting of nine treatment combinations of three irrigation water quality levels (tube well water (TW), cyclic use of tube well water (TW) : sewage water (SW), sewage water (SW) and three irrigation schedules based on ID (irrigation depth)/ CPE (cumulative pan evaporation) ratios (0.8, 1.0, 1.2) with four replications. The soil of the experimental plots was slightly alkaline in reaction (pH 8.3-9.2), low electrical conductivity (ECe 0.47-1.29), low in available nitrogen (176-230 kg/ha), and high in available phosphorus (30-47 kg/ha) and medium in potassium (234.9-295.3 kg/ha).The seeds of sorghum were sown on 7th May by Pora method with 8 rows in each micro-plot and distance between the rows was 25 cm.

RESULTS

The data on the LAI, green fodder yield, dry matter content and crude protein as affected by irrigation water quality and irrigation regimes scheduled on the basis of ID/CPE on sorghum have been presented in Table 1. The results revealed that the highest leaf area index of 3.98 was observed in sewage water irrigation treatment, while the lowest (3.53) being recorded in tube well water irrigation. The highest LAI under ID/CPE ratio of 1.2 could be due to the adequate availability of water throughout growth period. There was significant increase in green fodder yield obtained in all the water quality treatments as compared to tube well water at Ist cut. Nadia (2005) also recorded that due to higher amount of nitrate in municipal treated wastewater which had led to a significant increase in the yield. The highest green fodder yield observed at ID/CPE ratio 1.2 at 1st cut was 31.31 t/ha. Lowest green fodder yield of 27.24 t/ha at 1st cut, was observed with irrigation schedule of ID/CPE ratio 0.8.Dry matter content decrease under SW irrigation treatment and this reduction was 10.9% at first cut over the control (TW). The dry matter content was highest at ID/CPE ratio of 0.8 and was observed to be 17.09 % at first cut. The highest protein content of 9.76% in first cut was observed with irrigation using sewage water. It was followed by crude protein contents of 9.56 % at first cuts under cyclic use of tube well water and sewage as compared to that of 9.50 obtained using the tube well water treatment. The highest recorded crude protein content was 9.8% in first cut with irrigation being scheduled at ID/CPE ratio of 1.2. A significant difference in crude protein content was obtained in all the ID/CPE levels of irrigation scheduling at first cut.

CONCLUSION

Our experimental findings indicated that sorghum can be profitably grown for quality fodder with use of sewage for irrigationscheduled at ID/CPE ratio up to 1.2

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Influence of moisture regimes and nitrogen levels on productivity and profitability of rice (*Oryza sativa* L.) under aerobic condition.

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Rice is the most important staple food fulfilling 43% of calorie requirement of majority of the Indian population. The traditional rice cultivation is being threatened by increased scarcity of fresh water under wet land ecosystem that warrants new water saving rice cultivation techniques. Cultivation of rice under aerobic condition provides feasible alternative to traditional rice production allowing significant water savings. In aerobic rice system, field remain non-flooded throughout the season like an upland crop. This way of growing rice saves water by eliminating continuous seepage and percolation, land preparation and reducing evaporation (Bouman *et al.,* 2002). Where water is more limiting than land, it has been argued that water productivity becomes more important than yield or 'land productivity' (Tuong and Bouman, 2003). Substantial yield and water productivity gains are possible with the application of appropriate nutrients in combination with optimum water management adapted to the target environments. Keeping this in view an experiment was conducted to study the "Influence of moisture regimes and nitrogen levels on productivity and profitability of rice (*Oryza sativa* L.) under aerobic condition" using the variety MTU-1010.

METHODOLOGY

A field experiment was carried out during *kharif* season of 2012-13 and 2013-14 in split plot design with three replications at Crop Research Centre, Rajendra Agricultural University, Pusa, Bihar with four moisture regimes i.e. M_1– irrigation at 10 % depletion of available soil moisture (DASM), M_2– irrigation at 20 % DASM, M_3– irrigation at 30 % DASM and M_4– irrigation at 40 % DASM and three levels of nitrogen i.e. N_1–100 % of recommended dose of nitrogen (RDN– 120 kg N/ha) through chemical fertilizer, N_2–125 % of RDN through chemical fertilizer and N_3– 100 % RDN through chemical fertilizer + 25 % through organic source (vermicompost). The test variety was MTU– 1010 of medium duration. The soil of the experimental plot was sandy loam in texture and low in available N (252.00 kg/ha) and P_2O_5 (19.83 kg/ha) and medium in K_2O (221.92 kg/ha) with pH 8.7.

RESULTS

Rice grain yield, water productivity, gross return, net return

Table 1. Grain yield, water productivity and economics as influenced by different treatments.

Treatment	Grain yield (t/ha)	Water productivity (Rs./m^3)	Gross return (Rs./ha)	Net return (Rs./ha)	B:C ratio
Moisture regime					
M_1- 10 % DASM	4.25	4.53	61959	32916	1.14
M_2- 20 % DASM	3.68	4.37	54101	26525	0.97
M_3- 30 % DASM	3.26	3.94	48220	21544	0.81
M_4- 40 % DASM	2.90	3.61	43360	17584	0.69
SEm ±	0.094	0.19	1110	1110	0.04
CD (P=0.05)	0.326	0.65	3841	3841	0.14
Nitrogen level					
N_1- 100% RDN through chemical fertilizer	3.01	3.42	45623	20434	0.81
N_2- 125% RDN through chemical fertilizer	3.68	4.77	54122	28504	1.10
N_3- 100% RDN through chemical fertilizer + 25% through vermicompost	3.84	4.15	55985	24989	0.80
SEm±	0.071	0.13	883	883	0.03
CD (P=0.05)	0.213	0.38	2646	2446	0.10

and B: C ratio were influenced significantly due to different moisture regimes. The maximum values of grain yield were recorded with irrigation at 10 % DASM (M_1) which was significantly superior to irrigation at 20 % DASM (M_2), 30 % DASM (M_3) and 40 % DASM (M_4). The respective increase in grain yield at M_1, M_2 and M_3 as compared to M_4 was to the tune of 46.73, 27.20 and 12.63 %, respectively. Water productivity recorded with M_1 moisture regime was significantly superior over M_4 but there was statistical parity between M_3 and M_4 moisture regimes, though, it was decreased with increase in moisture stress from M_1 to M_4. This might be due to lower net return on low availability of soil moisture. The highest values of gross return, net return and B: C ratio was recorded with M_1 moisture regime (10 % DASM) receiving irrigation at all the critical growth stages i.e. tillering, panicle initiation, flowering and grain formation. Gross and net returns were decreased significantly with every increase in moisture stress while B: C ratio was decreased significantly only up to M_3 moisture regime. There was statistical parity between M_3 and M_4 moisture regimes. There was significant variation in rice grain yield, water productivity, gross return, net return and B: C ratio due to different nitrogen levels. The maximum grain yield was recorded with N_3 (100% RDN through chemical fertilizer + 25 % through vermicompost) level of nitrogen which differed significantly from N_1 (100% RDN through chemical fertilizer) but there was statistical parity between N_3 and N_2 (125 % RDN through chemical fertilizer). The respective increase in grain yield due to N_2 and N_3 over N_1 was to the tune of 20.31 and 25.41%, respectively. The maximum water productivity was recorded with N_2 level of nitrogen which was significantly superior over N_1 and N_3 level of nitrogen. Maximum gross return was recorded with N_3 level where nitrogen was applied @ 100 % RDN through chemical fertilizer + 25 % through vermicompost which was significantly superior over N_1 where 100 % RDN was applied through chemical fertilizer but was statistically at par with N_2 where nitrogen was applied @ 125 % RDN through chemical fertilizer, while, significantly higher net return and B: C ratio were fetched with N_2 level of nitrogen as compared to N_3 and N_1. This was due to higher cost of 25 % nitrogen applied through vermicompost.

CONCLUSION

It can be concluded that the maximum rice grain yield, water productivity, gross and net returns and B: C ratio could be achieved with irrigation at 10 % depletion of available soil moisture and with 25% increase in recommended dose of nitrogen either through chemical fertilizer or vermi- compost under aerobic condition.

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Response of sowing dates, irrigation and fertility levels on growth and yield of wheat

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Wheat (*Triticum aestivum* L.) is one of the most important cereal in M.P., India and globally. In India Wheat is grown over an area of about 266.92 lakh ha with a production of 721.40 lakh tones and an average national productivity of 2703 kg/ha. In state of Madhya Pradesh is occupy in total 108.3 thousand ha area with the production of 307.7 thousand tones and average productivity of 2478 kg/ha (Anonymous, 2015). The inadequate management of fertilizer, soil, water, climate and crop are limiting factors of wheat yield. Irrigation plays an important role in wheat development at any critical stage from seed germination to plant maturation. Irrigation applied at a sensitive stage, would be a valuable management practice for improving yield. Thus, there is sufficient scope to find out the minimum amount of water with fertilizers to be

Table 1. Effect of sowing dates, irrigation schedules and fertility levels on Growth and yield of wheat

Treatment	Plant height (cm)	No of effective tillers/m^2	Grain yield (kg/ha)
Date of sowing			
2nd Decemebr	92.72	297.83	2867.32
22nd December	86.21	292.25	2331.03
12th January	78.40	284.13	2067.63
CD (P=0.05)	6.26	9.64	244.08
Irrigation schedule			
3 Irrigationgs - at CRI + flowering stage + milk stage	80.7	277.19	2268.77
4 Irrigations- at CRI + late jointing stage + flowering stage	86.67	305.61	2575.21
CD (P=0.05)	2.41	12.64	210.64
Fertility level			
No dose (Control),	69.55	262.11	1461.69
60 N:30 P_2O_5:20 k_2O (kg/ha)	79.64	279.28	2243.70
120 N:60 P_2O_5:40 k_2O (kg/ha)	87.43	295.28	2745.80
180 N:90 P_2O_5:60 k_2O (kg/ha)	94.61	328.94	3236.77
CD (P=0.05)	9.09	18.19	340.56

applied with appropriate time for realizing higher economic yields as it allows the crop to fully express their yield potential. Seasonal changes in temperature, precipitation and growth periods have potential impacts on the phasic development as well as productivity of crops. (Hussain *et al*., 2014). The effect of planting time on wheat with a general consensus that planting too early or beyond optimum time reduce wheat yield enormously. Therefore present study was under taken with the objective of "to find out optimum dose of fertilizer and irrigation level under different thermal environment for yield maximization under changing climate".

METHODOLOGY

The field research work was carried out at Research Farm of Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh during *Rabi* season 2015-16. The soil of the experimental site was sandy clay loam with pH 7.5, EC 0.48 dS/m and 0.68% OC. The total annual rainfall is 135 mm. The total 24 treatments combinations were evaluated in a split-split plot design under three replications, three sowing dates (2nd December, 22th December and 12th January) as main-plot treatment, two Irrigation schedules-(Three irrigations at CRI + flowering stage + milk stage and Four irrigations at CRI + late jointing stage + flowering stage) were as sub-plot treatment and four Fertilizer levels (No dose (Control), 60 N:30 P_2O_5:20 k_2O (kg/ha), 120 N:60 P_2O_5:40 k_2O (kg/ha) and 180 N:90 P_2O_5:60 k_2O (kg/ha)) were as sub- sub plot treatment. The data collected were statistically analyzed for interpretation of results.

RESULTS

The yield and yield parameters were significantly affected due to application of nitrogen and irrigation water. There were significant yield differences among the sowing dates. The grain yield was maximum (2867.32 kg/ha) on 2nd December sowing. Among irrigation scheduling crop received four irrigation produced significantly higher grain yield (2575.21 kg/ha) than three irrigation. Higher dose of fertility level (180 N: 90 P_2O_5:60 k_2O (kg/ha)) gave significant higher grain yield (3236.77 kg/ha) as compare to other levels. The lowest yield was noted with application of lower dose of fertilizer i.e. 1461.69 kg/ha. Interaction of different treatments indicated that sowing of wheat early with application of four irrigations and higher dose of fertilizer resulted to higher grain yield.

CONCLUSION

On the basis of above study it can be concluded that, sowing of wheat on 2nd December with application of four irrigation and use fertilizer 180 N:90 P_2O_5:60 K_2O kg/ha gave higher grain yield in the Jabalpur condition.

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System of rice intensification for enhancing water productivity and sustainable rice production and mitigating the climate change effects–experiences of India

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Several studies around the world showed changes in global surface temperature, rainfall, evaporation which will have significant impact upon fresh water resources availability. Climate change induced higher temperatures will increase crops water requirements and further every 1° C increase in mean temperature results in corresponding 7% decline in rice yield. Hence, there is a need to identify and popularize water saving technologies especially in rice which consumes more than 50% of the total irrigation water for agriculture in India. The water requirement for rice to produce a kg of grain is around 5000 lt with the present flooded rice cultivation. Experiments were conducted at different irrigated rice sites in India and also at Directorate of Rice Research during 2005-10 to assess the potential of System of Rice Intensification (SRI) in comparison to standard normal transplanting (NTP) under flooded condition. SRI performed well at majority of the locations tested and recorded higher grain yield ranging from 6 to 65% over NTP with reduced in puts especially water to the extent of 31-37%. Long term studies clearly indicated that grain yield was significantly higher in SRI-organic + inorganic (12–23% and 4–35% in *kharif and rabi* seasons, respectively) while in the SRI-organic, the yield was found higher (4–34%) only in the Rabi seasons over NTP where in the water scarcity was significant. About 31% and 37% of irrigation water saved at all stages of crop growth resulted in significant increase in water productivity during *kharif and rabi* seasons, respectively in SRI method of rice cultivation over NTP. SRI performed well and consistently with reduced inputs such as less seed and water in different soil conditions and situations. Research studies in India clearly indicated that with promotion of SRI method, using (80%) less water (35%) for rice production which can free up water (92 miliion M^3) if adopted in 1 m ha. The water saved can efficiently used for other crops, promote crop diversification which can mitigate the water stress and helps for more sustainable rice production systems.

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Water productivity and profitability enhancement of wheat through improved water management practices in south eastern Rajasthan

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Wheat (Triticum *aestivum* L. emend. Fiori & Paol.) is the world’s single most important cereal crop not only in quantitative but in qualitative terms too and considered to be integral component of food security system of several nations.Yield of wheat crop is influenced by improved production technology and water management practices (Sharma *et al.,* 2007).The

Table 1. Effect of improved water management practices on productivity, economics, water expanse efficiency, water productivity and technology index of wheat demonstrations

Year	Grain Yield (t/ha)		Straw Yield (t/ha)		Net return (x 1000)		B:C ratio		WEE (kg/ha/cm)		WP(/M^3)		TI
	IT	FP	IT	FP	IT	FP	IT	FP	IT	FP	IT	FP	
2012-13	5.27	4.90	7.52	7.03	67.0	61.1	3.7	3.4	155	98	19.7	12.2	24.7
2013-14	5.37	4.96	7.69	7.11	73.0	66.0	3.8	3.5	158	99	21.5	13.2	23.3
2014-15	5.11	4.71	7.46	6.70	76.7	68.8	3.8	3.4	150	94	22.6	13.7	26.9
Mean	5.25	4.85	7.56	6.95	72.3	65.3	3.8	3.4	154	97	21.3	13.0	25.0

IT=Improved water management practices, FP=Farmers practices, WEE=Water expanse efficiency, TI= Technology index, WP= Water productivity

low productivity of wheat in south eastern Rajasthan is mainly due to untimely irrigation, fatly method of irrigation, over irrigation at head reach and scarcity of water at tail reach of canal. In command area, method of irrigation and time of application plays an important role in increasing water productivity. Declining availability of irrigation water, needs sustainability in crop production and increasing demand of food can be achieved through adoption of improved water management technology. Keeping this in view, field trials were conducted at farmer's field under operational research programme to improve water productivity and profitability of wheat.

METHODOLOGY

The field demonstrations were conducted during three consecutive years from 2012-13 to 2014-15 at eighteen location of both left main canal and right main canal (three each of head, middle and tail reach of canal) under operational research programme (ORP). The bulk density, pH and cation exchange capacity of these soils varies between 1.30-1.60 Mg/m^3, 7.75-8.50 and 30-40 Cmol/kg, respectively. The soils of the region are poor in organic carbon (0.50±0.08) and available nitrogen (275±5 kg/ha) but are low to medium in available P_2O_5 (24.2± 1.0 kg/ha) and medium to high in available K_2O (290 ± 8 kg/ha). Improved water management technology i.e. four irrigation at CRI, late tillering, flowering and milking stages with 6cm depth by border strip method (6 m x 50 m) at 80% cut off ratio, was compared with farmer's practice (FP) i.e. flooding method of irrigation with no control over the depth of irrigation (usually about 10 cm). Beside this, recommended package of practices were used. Each demonstration was laid out in an area of 0.1 ha. For test plots measurement of water was done by velocity-area method at field level. Wheat were sown using 100 kg/ha seed rate with improved water management technology in second week of November and harvested in third week of April every year. Total five irrigations were applied including pre sowing irrigation during the crop season. In the improved water management practices only 34 cm water was applied in test block which resulted into saving of 16 cm water in comparison to farmer's practices (50 cm). Average cost of cultivation was Rs.20, 000/ha. Data were recorded from demonstration blocks and farmer's practice blocks and analyzed for different parameters.

RESULTS

Mean grain (5.25 t/ha) and straw (7.56 t/ha) yield of wheat under improved water management technology were8.24 and 8.8 per cent higher than yield obtained under farmers practice (Table 1). The higher grain yield under field's trials could be attributed to adoption of improved water management technology. Net return of wheat under improved water management practices was 67032/ha in 2012-13, 73055 /ha in 2013-14 and 76744 /ha in 2014-15 which were 9.6, 10.7 and 11.6% higher having B:C ratio of 3.7, 3.8 and 3.8 than farmers practices, respectively. This fact has been reported by Dhar *et al* (2011). Efficiency indices for water use were estimated in terms of water productivity and water expanse efficiency. Mean data (Table 1) of three years indicated that higher water expanse efficiency (154 kg/ha-cm) and productivity of water (21.3/m^3 water) were observed in improved water management practices as compared to farmers practices. Technology index of three years of study varied from 23.3 to 26.9 per cent with an average of 25.0 per cent. Least technology index was observed during 2013-14.

CONCLUSION

Improved water management practices in wheat cropi.e. four irrigation at CRI, late tillering, flowering and milking stage with 6 cm depth, by border strip method (6 m x 50 m) at 80% cut off ratio, gave higher yields, net return, water expanse efficiency, water productivity and low technology index than farmers practice.

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Fodder yield and quality of different forage crops as influenced by irrigation levels during lean period

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Forages are the backbone of livestock industry. The main stay of animal wealth and their production depends on availability of fodder. Green fodder scarcity is the most common problem from November to June due to non-availability of green fodder in grazing lands. Possibility of extension of perennial fodder cropped area in the country is remote because of preferential food needs for human beings. During *summer* season, where irrigation is not sufficient for commercial crops or major food crops fodder crops of short duration can be grown with limited irrigation. With this background, a field experiment was carried out to study the performance of different forage crops under varied irrigation levels and to identify suitable and most remunerative fodder crop during lean period.

METHODOLOGY

The experiment was conducted during summer seasons of 2011-12 , 2012-13 and 2013-14 at AICRP on forage crops farm, ANGRAU, Hyderabad. Soil of the experimental field was sandy loam, low in available nitrogen, low in available phosphorus and medium in available potassium. The experiment was laid out in split- plot design with three IW/CPE ratios (0.6, 0.8 and 1.0) in main plots and four forage crops (fodder maize var. African tall, fodder sorghum var. CoFS-29, fodder pearl millet var. Giant bajra and baby corn var. DHM.117) in sub plots The four irrigation levels were based on irrigation water (IW) : Cumulative pan evaporation (CPE) ratios of 0.6, 0.8 and 1.0 with at a depth of 5 cm. Crops were sown during the month of February recommended spacing (fodder maize and baby corn 45 x 15 cm, fodder sorghum and fodder pearl millet 30 x 10 cm). Recommended doses fertilizers were applied to all crops. Fifty per cent of the recommended nitrogen and full quantities of phosphorus and potassium were applied as basal at the time of sowing and the remaining 50 % of nitrogen was applied as top dressing at 30 DAS. The quantity of irrigation was calculated per plot and applied accordingly by fixing water meter. All four crops were harvested at 50 % flowering stage for green fodder. Baby cobs were harvested at 2 cm length of silking. Green plant samples were collected at 50 % flowering stage, oven dried at 70^{o}C and crude protein content was worked out on dry weight basis using Kjeldahl's method (Jackson, 1973).

RESULTS

Pooled over data for three years (Table 1) revealed that the forage yield and quality of all the four crops were significantly affected by irrigation levels. Application of irrigation at 1.0 IW/CPE ratio recorded significantly higher green fodder yield (426 q/ha), dry matter yield (96.0 q/ha) than other levels of irrigation. Higher green fodder yield under I_3 could be attributed to cumulative effect of increase in plant height, leaf stem ratio. Among different crops studied fodder maize var. African tall recorded significantly higher plant height followed by fodder bajra during both the years. Higher green fodder yield and dry matter yield were observed with maize var. African tall followed by Giant bajra and both were significantly superior over baby corn. This could be due to the vigorous growth of African tall by genetic nature. However ,even under limited irrigations(IW/CPE-0.6) all the fodder crops recorded significant quantities of green fodder during summer Increase in green forage yield with increase in irrigation frequency was also reported by Subba Reddy *et al.* in fodder maize, Pareek *et al* in Pearlmillet, Jahanzad *et al* and shivkumar *et al* in baby corn. DHM 117, a variety of maize raised for baby corn as well as fodder purpose performed well by giving fodder yield of 308 qha^{-1}, 68.0 q ha^{-1} of dry matter yield and 6.0 qha^{-1} of crude protein yield (average of three years). In addition to these, about five pickings of baby corn were taken , which will be having good market in peri-urban situations.

Gross returns, net returns and benefit cost ratios were significantly influenced by frequency of irrigations. Irrigations scheduled at IW/CPE ratio of 1.0 and 0.8 recorded significantly higher values over 0.6 IW / CPE ratio. Among the four

Table 1. Effect of irrigation levels on green forage yield, quality and economics of different forage crops during lean period (pooled data for 3 years)

Treatments	Plant height (cm)	Green fodder yield (q/ha)	Dry matter yield (q/ha)	Crude protein yield (q/ha)	Net returns (Rs/ha)	B:C Ratio
Main plots						
I1- IW/CPE-0.6	151.32	299	66.0	5.0	22616	2.34
I2- IW/CPE-0.8	163.75	381	83.9	7.5	32539	2.88
I3- IW/CPE-1.0	182.48	426	96.0	8.6	38682	3.17
S Em±	3.00	4.12	1.21	0.12		
CD (0.05)	11.67	12.7	3.74	0.37		
Sub plots						
C1- Fodder maize	194.58	435	90.7	8.20	26955	2.62
C2- Fodder sorghum	151.21	350	84.8	5.7	19636	2.25
C3- Fodder pearl millet	164.90	382	84.3	8.4	23352	2.55
C4- Baby corn	152.72	308	68.0	6.0	55174	3.78
S Em±	2.70	5.55	1.71	0.19		
CD (0.05)	8.00	15.75	4.88	0.54		
I x C S Em±	3.29	9.62	2.97	0.33		
CD (0.05)	NS	27.28	8.42	0.93		
CV %	5.50	7.83	10.89	13.86		

forage crops tested, baby corn recorded higher gross returns, net returns and benefit cost ratio. This is due to the sale of baby corns in addition to the green forage. Baby corns were harvested in five pickings (Table 1) and at final harvest green fodder yield was also recorded. This will be an additional benefit to the farmers in peri-urban areas. This was followed by maize var. African Tall, Giant Bajra and fodder sorghum.

CONCLUSION

This study revealed that in peri-urban situations, under limited irrigation conditions baby corn can be raised profitably both for baby cobs and green fodder. All the four fodder crops viz., Maize, Sorghum, Bajra, and Baby corn Maize have yielded considerable quantities of green fodder even with limited irrigations (IW/CPE= 0.6 or 0.8).Hence all these four crops can be grown under limited irrigation to overcome the fodder scarcity during the lean periods.

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Response of Indian mustard to irrigation, nitrogen and topping

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Brassica group of oil seed crops, commonly referred to as rapeseed-mustard, play an important role in the oilseed economy of the country. Among oilseeds rapeseeds and mustard is the second most important *rabi* oilseeds crop, contributing nearly 25-30% of the total production in the country. The productivity of mustard depends on the prevailing environmental conditions during the crop growth which can be modified to a great extent under field conditions by adopting agronomic practices like nitrogen and irrigation management etc. Irrigation increases the availability of water and nutrients through the establishment of relatively favourable moisture conditions around root zone of crop. Among nutrients nitrogen is an important constituent of protein, enzyme and chlorophyll and is involved in all processes associated with protoplasm, enzymatic reaction and photosynthesis. Topping is a common practice to check excessive vegetative growth in several crops. A field experiment conducted during *Rabi* 2013-14 at the Instructional Farm (Agronomy), Rajasthan College of Agriculture, Udaipur to study effect of irrigation, nitrogen and topping on growth, yield attributes, yield and quality of the mustard crop.

METHODOLOGY

The experiment consisted of 24 treatment combinations comprising irrigation level (control, one irrigation at pre-flowering, one irrigation at pod filling and two irrigations- one each pre-flowering and pod filling), nitrogen level (control, 40 kg/ha and 80 kg/ha) and topping (with topping 30 DAS and without topping). The experiment was laid out in split plot design with irrigation level in main plots and nitrogen level and topping in sub plots. It was replicated three times. Mustard variety Pusa Jai Kisan (Bio- 902) with seed rate of 5 kg/ha was sown at spacing of 30 cm x 10 cm. The soil of experimental field was clay loam in texture and slightly alkaline in reaction (pH 7.8) and calcareous in nature. It was medium in available nitrogen (250.4 kg/ha), phosphorus (22.5 kg /ha) and rich in available potassium (296.8 kg /ha). A common dose of 35 kg P_2O_5 /ha was drilled manually below the seed as basal dos though single super phosphate. The crop was harvested from the individual plot at physiological maturity. The net plot was harvested close to the ground.

RESULTS

The result showed that two irrigations- one each pre-flowering and pod filling gave significantly higher dry matter accumulation and yield attributing characters *viz.,* number of branches/plant, number of siliquae/plant, number of seed/siliquae, 1000-seeds weight, seed yield/ha, N, P and K content and uptake, oil content (39.44%), net returns (57222 /ha) and B:C ratio (2.5) compared to control, one irrigation at pre-flowering and one irrigation at pod filling. The crop grown with two irrigations- one each pre-flowering and pod filling gave highest seed yield (2069 kg/ha), straw yield (4525 kg/ha) and biological yield (6594 kg /ha) which was significantly superior over control, one irrigation at pre-flowering and one irrigation at pod filling but maximum harvest index (32.82%) was obtained under one irrigation at pre-flowering. Supply of water at flowering stage might have resulted in lengthening of the flowering period as well as rate of fertilization, which increases the number of siliquae/plant. Adequate availability of moisture helps in absorption and translocation of food to seeds and improved seed weight of crop. Amongst the nitrogen levels, application of 80 kg N /ha came out as the most promising when judged in terms of growth and yield attributes, yield, oil content, N, P and K content and uptake, net monetary returns (50645 /ha) and BC ratio (2.23). Application of 80 kg N /ha gave significantly higher seed yield (1887 kg /ha) by 8.94 per cent and 25.35 per cent, straw yield (4426 kg /ha) by 8.99 per cent and 37.0 per cent, biological yield (6312 kg /ha) by 8.98 per cent and 33.32 per cent and oil content (39.49%) by 2.36 per cent and 5.36 per cent over application of 40 kg N /ha and control, respectively. Significant increase in seed, stover and biological yields with increasing levels of nitrogen. Topping at 30 DAS was found to increase the seed yield (1816 kg /ha) by 13.52 per cent, straw yield (4101 kg /ha) by 10.55 per cent and biological yield (5917 kg /ha) by 11.44 per cent over without topping. Topping of mustard caused significant increase in yield to the tune of 25 per cent more than no topping.

CONCLUSION

Application of two irrigation- one each at pre flowering and pod filling with 80 kg N /ha and topping at 30 DAS proved the most efficient and economically viable treatment.

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Efficient and economic use of harvested rain water for sustainable crop production under rainfed agriculture

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Castor (*Ricinus communis* L.) is one of the most important oil seed crop of the North Gujarat region. Gujarat produced 14.5 lac tonnes of castor during the year 2015 and total productivity of castor during 2015 was 2036 kg/ha. Gujarat is largest producer of castor in India. Presently in North Gujarat, area under castor crop is irrigated by border irrigation, with very poor water use efficiency because of huge conveyance and distribution losses. North Gujarat water resources are facing extreme stress particularly in the context of agriculture. With changing life styles and rising water consumption in urban areas, water for agriculture is under threat from other users. Harvested rain water for supplemental irrigation with micro irrigation is one of the demand management strategies to control water consumption in Indian agriculture which included mainly drip and sprinkler irrigation method. Drip irrigation is most efficient among all the irrigation methods and reported to help in achieving yield gains upto 100% and water saving upto 40-80%. It is also increase water use efficiency and stress associated fertilizer, pesticide and labour (Burney *et al*., 2009 and Lodhi *et al*., 2014). Drip irrigation can be practiced successfully to irrigate wide range of crop especially in vegetable, orchard crops, flowers and plantation crops but on the other hand limited studies had been conducted under use of harvested rain water as supplement irrigation through drip irrigation in castor crop. Effective utilization of harvested rain water was done and supplemental irrigation to castor crop through drip irrigation system.

METHODOLOGY

A field trial was conducted on loamy sand soil (*Typic usiipsamments)* during *kharif* - 2011 to 2013 at the National Innovation on Climate Resilient Agriculture (NICRA) village-Chandanki, Taluka - Becharaji, Dist - Mahesana, AICRPDA centre, Centre for Natural Resource Management, S. D. Agricultural University, Sardarkrushinagar, North Gujarat having semi-arid and sub-tropical climate situated in 23°31' North latitude 72°01' East longitude and 153.64 meter above the mean sea level and the soil of experimental field was medium black clay having medium infiltration rate, medium water holding capacity and also low in organic carbon (0.19%), available N (128.60 kg/ha), Whereas medium in available P_20_5 (27.20 kg/ha) and K_2O (162.60 kg/ha). The experiment was conducted with two treatments viz., T_1: Control and T_2: Two life saving irrigations at critical growth stages tested under RBD with 13 replications for efficient and economic use of harvested rain water to increase crop production under dryland condition.

Table 1. Effect of different treatments on yield, economics and RWUE* of castor (Pooled of 3 years)

Treatments	Yield (kg/ha) Seed	Yield (kg/ha) Stalk	Cost of cultivation (Rs/ha)	Gross income (Rs/ha)	Net income (Rs/ha)	B:C ratio mm)	RWUE (kg/ha.
T_1 : Supplemental irrigation	1236	2629	14450	43339	28889	2.00	1.95
T_2 : Without irrigation	937	1923	11450	32820	21370	1.87	1.48
SEm ±	29	60					
CD (P=0.05)	83	171					
Year x Treatment							
SEm ±	50	102					
CD (P=0.05)	NS	NS					
Average rainfall (mm)	634.0						

*RWUE: Rain water use efficiency; Selling price (Rs/kg); Seed – 34.0; Stalk – 0.5.

RESULTS

The results revealed that the seed and stalk yields of castor affected significantly due to different treatment during all the years as well as in pooled results. The higher seed yield of castor 1236 kg/ha (Pooled) was recorded under treatment of two life saving irrigation, which is 31.9% higher than control (937 kg/ha). The findings corroborated the results of Xianshi, *et al*. (1998) and Balaswamy *et al.* (1986). The stalk yield of castor was also observed highest under treatment of two life saving irrigation (2629 kg/ha), which is 36.7% higher than control. The maximum net income (Rs. 28889/ha), B-C ratio (2.00) and rain water use efficiency (1.95) was also under treatment of two life saving irrigation.

CONCLUSION

It is concluded from the discussion of the study that, sowing of castor with two life saving irrigations at critical growth stages from the harvested rain water through drip irrigation system is a good practice of efficient water use in dryland agriculture for getting higher yields and net monetary return.

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Precision irrigation scheduling enhances water productivity in wheat

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The intensive agricultural practices have resulted into severe over exploitation of the natural resources especially water, which has caused a severe imbalance in demand and supply (Sidhu, 2002). The agriculture sector makes use of 75 per cent of the water withdrawn from various sources (Wallace, 2000). India's land and water resources are under considerable stress as the race between food production and population growth surges relentlessly. As a result of this demand-supply gap India's groundwater tables are plunging at an alarming rate. Wheat crop is quite sensitive to water stress but too much moisture can also lead to yield losses from disease, lodging, nutrient losses due to leaching, etc. Wheat crop needs frequent irrigation for good growth and yield but precisionis important particularly fordeficit inputs*i.e.* water. Irrigation using modern technology like precision irrigation scheduling is essential for increasing water productivity.

METHODOLOGY

The field experiment was carried out at the experimental farm of ICAR-Indian Institute of Wheat and Barley Research, Karnal (29°43'N, 76°58'E and 245 m above msl) during four consecutive *Rabi* seasons of 2010-11 to 2013-14. The climate is subtropical with mean maximum temperature ranging in between 34 and 39°C in summer and mean minimum temperature ranging in between 6-7°C in winter. The crop season had received 129.7 mm, 36.3 mm, 203 mm and 189.2 mm from 2010-11 to 2013-14, respectively. Soil of experimental field was sandy clay loam in texture with pH of 7.66 (1:2.5 soil:water), EC 0.184 (dS/m) with 0.40 % OC, 166 kg/ha available N, 6.54 kg/ha available P and 276.64 kg/ha available K. The experiment was laid out in split plot design with three replications. The treatments consisted of three crop residue levels (no crop residue, crop residue @ 2.5 t/ha and @ 5.0 t/ha) in main plot and three irrigation levels in sub plots (irrigations at all critical growth stages, irrigations @ 60kPa and irrigations @ 80 kPa).Nutrients were applied as per recommendation (150:60:30, N:P:K).Tensiometers were installed in the centre of each plot at 45 cm depth. During installation care was taken so that ceramic cups of the tensiometers have good contact with the surrounding soil. In general the tensiometers

Table 1. Effect of crop residue and irrigation scheduling on yield and yield attributing characters of wheat (Pooled of four years)

Treatment	Grain Yield (t/ha)	Biological Yield (t/ha)	Tillers/m^2	1000 grain weight, g	GPEH	WUE (kg/m^3)
M1	5.57	12.5	589	36.6	25.6	1.21
M2	5.73	12.9	592	36.8	26.5	1.24
M3	5.58	12.6	595	36.6	25.7	1.21
LSD (0.05)	0.06	0.1	5.7	0.5	0.64	-
S1	5.64	12.7	590	36.5	25.5	1.01
S2	5.66	12.8	601	36.9	26.7	1.43
S3	5.59	12.5	584	36.6	25.6	1.51
LSD (0.05)	0.02	0.1	5.4	0.4	0.24	-
M1S1	5.67	12.7	595	36.5	24.8	1.02
M1S2	5.76	12.4	607	36.6	26.7	1.13
M1S3	5.74	12.5	564	36.8	25.3	1.49
M2S1	5.63	13.1	574	36.8	26.0	1.02
M2S2	5.57	12.9	605	37.2	27.6	1.16
M2S3	5.51	12.6	596	36.5	25.9	1.54
M3S1	5.60	12.6	600	36.4	25.7	1.01
M3S2	5.62	12.8	591	36.8	25.9	1.14
M3S3	5.52	12.3	593	36.5	25.5	1.49
LSD (0.05)	0.07	0.2	8.6	0.6	0.73	-

M1: No crop residue, M2: Crop residue @ 2.5 t/ha, M3: Crop residue @ 5 t/ha
S1: Irrigations at all critical growth stages, S2: Irrigations @ 60 kPa, S3: Irrigations @ 80 kPa

were monitored twice a week but at high soil water tension the tensiometers were monitored daily. First irrigation was applied uniformly to all the treatments at the crown root initiation and subsequent irrigations were applied as per treatments. Number of tillers/m^2 from the centre of the plot was measured in each plot at maturity. A net plot of 9.8 m^2 was harvested manually for biomass and yield data. Grain samples were randomly selected from grain yield of each subplot and 1000-grain weight was recorded. Statistical analysis was done using SAS (Statistical Analysis Software) version 10.3.

RESULTS

The yield of wheat varied significantly due to irrigation scheduling and residue application (Table 1). Rice residue retention @ 2.5 t/ha produced significantly higher grain yield (5.73 t/ha) than other treatments. Similarly irrigations @ 60 kPa gave highest yield (5.64 t/ha) than other irrigation schedule. Interaction between residue retention and irrigation schedule was significant. Maximum grain yield was recorded with no crop residue and irrigations scheduled @ 60 kPa. Increases in grain as well as biological yield were due to higher number of tillers, 1000 grain weight and grains per ear head by retention of crop residue and precise irrigation scheduling. The effect of crop residue on water productivity was found under precision irrigation scheduling. Maximum water productivity was recordedwith irrigation scheduling @ 80 kPa(1.54 kg.m^{-3}) followed by irrigation scheduling @ 60 kPa (1.16 kg.m^{-3}) over irrigations at all critical growth stages (1.02 kg.m^{-3}) under residue retention @ 2.5 t/ha and similar results also recorded for residue retention @ 5 t/ha. The higher water productivity at irrigation scheduling @ 80 kPa was primarily due to decrease in quantity of water applied whereasunder irrigation @ 60 kPa was due to saving of water as well as higher yield as compared to irrigations at all the critical growth stages. The results are in resemblance with the findings of Onyibe (2005) and Shamsi and Kobraee (2013).

CONCLUSION

Preciseirrigation scheduling requires knowledge of soil water initially available to the plant and enables to estimate the earliest date at which the next irrigation should be applied for efficient irrigation with the particular system, before water stress affects crop adversely. Precise irrigation scheduling can reduce irrigation costs and increase water productivity of crop.

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Response of mentha to wastewater irrigation and nitrogen under different land configurations

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Increasing population coupled with rapid industrial growth and urbanization has not only raised the demand for fresh water consumption but also caused manifold increase in generation of wastewater. Both limited number and capacity of sewage treatment plants for recycling of polluted water compared to its generation has created a great challenge of safe disposal of wastewater which could otherwise pose a risk of health hazards if used untreated (Kaur *et. al.* 2012). Under such conditions, there is a need to explore the ways to dispose untreated wastewater safely. In contrary, wastewater also contains good amount of nutrients which can benefit by enhancing the productivity of the crop while saving the nutrient applied through fertilizers. Therefore, the use of wastewater for irrigation purpose by selecting the suitable crop like mentha (*(Mentha arvensis* L.), which is not consumed directly as food offers a good scope. It contains 0.50 to 0.75% oil having 80-85% menthol. Globally there is a great demand of mentha oil as is widely used for several purposes like in the food, perfumery, flavouring and pharmaceutical industry. It has the potential to fetch high market price due to higher demands, convenient storage and easy marketing especially in the urban and peri urban areas.

METHODOLOGY

An experiment was conducted to assess the response of wastewater irrigation and nitrogen under different land configuration in mentha at IARI, New Delhi during 2015. The experiment consists of two sources of irrigation water (Municipal Wastewater and Ground water) and three levels of nitrogen 0, 37.5 and 75 kg/ha) under raised and flat bed condition with three replications in split plot design. The soil of the experimental field was sandy loam in texture with low in available N content, medium in phosphorous and high in potassium. The soil pH and EC was 7.7 and 0.62 respectively. The municipal wastewater and tube well water was used for irrigation as per treatment. The crop was raised through transplanting of 45 days old seedling raised through suckers of mentha variety 'Kosi'. Two rows of mentha were planted on each raised bed spaced at 90 cm whereas under flat bed planting row to row spacing was 45 cm. Plant to plant spacing was 15 cm in both raised and flat bed planting. A uniform dose of 40 kg/ha of P_2O_5 was applied before transplanting whereas nitrogen was applied as per treatments in two equal split half at first week and remaining half at 40 days after transplanting. Only one cutting of the crop was taken in the first week of July and the herb yield was recorded. Oil content in the herb was determined through hydro-distillation using Clevenger's apparatus.

RESULTS

Irrigation with wastewater significantly increased the plant height (5.7 %), Leaf area index (LAI) and herb yield (10.8 %)

Table 1. Response of mentha to waste water irrigation involving land configuration under different levels of nitrogen

Treatment	Plant height (cm)	Stools/ m^2	Leaf area index (LAI)	Herb yield (t/ha)	Oil content (%)
Waste water	48.4	124.2	2.69	1.95	0.67
Ground water	45.8	119.8	2.15	1.76	0.68
CD (P=0.05)	2.4	NS	0.16	0.09	NS
Raised bed	47.6	123.0	2.39	1.87	0.68
Flat bed	46.6	121.0	2.26	1.84	0.67
CD (P=0.05)	NS	NS	NS	NS	NS
Control (0 kgN/ha)	38.9	91.9	1.73	1.44	0.65
50 % Rec. N (37.5kg/ha)	48.2	130.0	2.45	1.90	0.70
100 % rec. N (75kg/ha)	54.1	144.0	3.08	2.22	0.68
CD (P=0.05)	4.1	9.4	0.21	0.12	NS

of mentha than that irrigated with ground water (Table 1). However, the response in terms of stools/m^2 and oil contents was statistically non significant. Raised and flat bed planting proved equally effective as the differences in terms of all the recorded aspects were statistically non significant. Application of 75 kg N/ha of (100 % recommended dose of nitrogen) increased the plant height, LAI, stools/m^2 and herb yield significantly as compared to control and 50 % recommended dose of nitrogen. The interaction effects indicated that application of 100 % recommended dose of nitrogen (75kg /ha) along with ground water irrigation produced herb yield of 21.8 t/ha which was statistically at par with that obtained (20.8 t/ha) by applying 50 % recommended dose of nitrogen under waste water irrigation thereby showing 50 % (37.5 kg /ha) saving of applied nitrogen. This was due to higher nitrogen content in the wastewater than ground water. Different doses of nitrogen application did not show any significant effect on oil content.

CONCLUSION

Irrigation with wastewater significantly increased the growth and herb yield (10.8 %) of mentha than that irrigated with ground water. Wastewater irrigation in mentha resulted in saving of 50 % (37.5kg /ha) of recommended nitrogen without adversely affecting the herb yield.

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Mitigating adverse impact of saline water irrigation on fennel (*Foeniculum vulgare*) seed spice through organic inputs in semi-arid conditions

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India is a leading producer of spices and condiments; and the seed spices have unique position being the commodity of economic importance. In India, seed spice fennel grown during *rabi* season in Gujarat, Rajasthan, Madhya Pradesh, Haryana and Uttar Pradesh covering an area of 100 thousand ha with production of 143 thousand tonnes in the year 2012-13 (Indian Horticulture Database, 2013). Since the crop is widely grown in arid and semi-arid regions where soil and water often contain high concentration of salts, farmers resort to irrigate it with saline groundwater. Though the farmers use saline water for irrigation but no systematic information is available on irrigation water salinity tolerance limits of this crop. In addition to this, the people are becoming more quality conscious; the demand for organically grown spices is increasing in the global market. Information on role of organic fertilizers in mitigating the adverse effects of saline water irrigation in seed spice crops is not available. Therefore, this study was planned with the objectives (i) to assess the effect of saline water irrigations on the yield of fennel and (ii) to investigate the mitigation of adverse impacts of saline water through appropriate combinations of organic inputs under irrigation using low and high saline water for sustainable production of the crop.

METHODOLOGY

A field experiment was conducted during 2008-09 to 2013-14 on "Organic input management options with saline water irrigation for sustaining productivity of high value crops" at Bir Forest Farm, Hisar (29^o 10' N latitude and 75^o 44'E longitude at an altitude of 220 m above mean sea level). The total rainfall received during June to May during six years (2008-09 to 2013-14) varied from 399.2 mm to 918.8 mm with average of 622 mm, of which 75% was received during July to September. The soil of the experimental site is sandy loam and highly calcareous (Ustic Haplocambids) in nature with EC_e 0.80 – 0.86 dS/m, pH_s 8.2 – 8.5 and organic carbon 0.26%. The average EC_{iw} of two tube wells available at the farm was 1.9 dS/m and 8.6 dS/m and designated as low saline and high saline water, respectively. Periodic average EC_{iw}, pH, RSC and SAR of low saline water were 1.9 dS/m, 8.4, 4.8

meq/l and 12.9 m mol/l; and of high saline water were 8.6 dS/m , 7.7, nil and 18.5 mmol/l, respectively. The fennel variety Hisar Swarup (HF-33) was sown during *rabi* season for six years (2008-09 to 2013-14). The treatments comprised of two saline water qualities in main plots and sub plots, comprised of 8 different treatment combinations (in treatment $T_1 – T_5$ 100% N is applied through combination of different fertilizers while in $T_6 – T_8$ 200% N was applied) in combinations of organic inputs, viz., farmyard manure, vermi-compost and non-edible neem manure as shown under:

T_1: 100% inorganic fertilizers (60 kg N/ha and 30 kg P_2O_5/ha;

T_2: 50% N through urea and P through SSP (inorganic) + 50% using organic inputs, for initial three years. This treatment was fully converted to organic in the 4th year applied through FYM+VC+NM @ 8 t, 1.74 t and 1.60 t/ha, respectively;

T_3: 50% of N equivalent each farmyard manure @ 6 t/ha + vermi-compost @ 1.3 t/ha;

T_4: 50% of N equivalent each farmyard manure @ 6 t/ha + non-edible neem manure @ 1.2 t/ha;

T_5: 33.3% of N equivalent each farmyard manure @ 4 t + vermi-compost @ 0.87 t + non-edible neem manure @ 0.8 t/ha;

T_6: 100% N equivalent (200% of T_3) each farmyard manure @ 12 t + vermi-compost @ 2.6 t/ha;

T_7: 100% N equivalent (200% of T_4) each FYM@ 12 t + non-edible neem manure @ 2.4 t/ha;

T_8: 66.6% N equivalent (200% of T_5) each farmyard manure @ 8 t + vermi-compost @ 1.74 t + non-edible neem manure @ 1.60 t/ha.

RESULTS

Seed weight per umbel varied from 1.81-2.66 g and 2.06-2.60 g with low and high saline water, respectively with an average of 2.35 and 2.36 g, respectively (Table 1). Small differences were recorded between two salinities of irrigation water. This might be due to several reasons, possibly adverse effects of higher RSC in low saline water irrigation and mitigation of the adverse effect of high saline water irrigation by application of different organic inputs. Pooled analysis over six years showed that 100 seed weight differ non-significantly with saline water irrigation. Averaged data showed that highest 100 seed weight was recorded under high saline water, may be due to presence of RSC in low saline irrigation water which might have adversely affected the development of seeds as compared to high saline water. Similarly, seed yield of fennel showed decreasing trend initially which got reversed during third and fourth years and it was at par on pooled basis over six years. Pooled seed yield showed that the yield of 1.47 t/ha was obtained under both low and high saline water irrigation (Table 1). Seed weight per umbel and seed yield with different organic input management options varied significantly during first year. Pooled seed weight per umbel ranged from 1.99 g with inorganic treatment to 2.63 g with organic manure treatment T_8. Highest seed weight per umbel was recorded during fourth year which ranged from 3.40 to 4.40 g. Data on 100 seed weight showed that it differed non-significantly during all the years ranged from 0.77 to 0.82 g under different organic input treatments. On pooled basis, the lowest seed yield (1.34 t/ha) of fennel was obtained with the application of inorganic fertilizer application while highest 1.57 t/ha was obtained under treatment T_8 which was at par with the seed yield (1.49 t/ha) obtained in treatment T_3. The results of lower yield in treatment T_2 (50% inorganic+50% organic) might be due to availability of nutrients applied through organic inputs needs time to build-up for its availabil-

Table 1. Growth, seed yield and yield attributes of fennel under saline water and organic input application (Pooled over 6 years)

Treatment	Plant height (cm)	Umbels/ plant (No.)	Umbellets/ umbel (no.)	Seed weight/ umbel (g)	100 seed weight (g)	Seed yield (t/ha)
Salinity of irrigation water						
Low saline	135.0	22.7	21.3	2.35	0.78	1.47
High saline	126.8	22.4	20.2	2.36	0.81	1.47
SEm (±)	0.41	0.38	0.23	0.04	0.02	0.03
CD (P=0.05)	2.7	NS	NS	NS	NS	NS
Organic inputs						
T_1	118.9	23.1	19.2	1.99	0.77	1.34
T_2	123.6	21.3	19.1	2.07	0.79	1.48
T_3	130.5	23.2	20.3	2.32	0.81	1.49
T_4	131.0	22.7	20.5	2.37	0.81	1.46
T_5	132.6	22.1	21.9	2.54	0.82	1.49
T_6	133.8	23.4	22.1	2.52	0.79	1.48
T_7	138.4	22.0	21.1	2.39	0.80	1.44
T_8	138.6	22.6	21.8	2.63	0.80	1.57
SEm (±)	2.02	0.83	0.50	0.09	0.02	0.04
CD (P=0.05)	5.88	NS	1.45	0.27	NS	0.11

ity to the plants. Year to year variations in crop yield varied from 0.88 t/ha to 2.21 t/ha appears to be natural as result of variations in initial soil salinity, irrigation water quality, rainfall and its distribution during crop growth period. Results based on six years data revealed that saline water up to 8.6 dS/m can be used for irrigation of fennel along with application of organic manures particularly in sandy soils with average annual rainfall of 500-750 mm under semi-arid conditions. Later helps in mitigating the adverse effect of saline water application and sustaining the productivity of high value crops as compared to application of inorganic fertilizers alone. On the basis of analysis of soil physical properties it can also be attributed to improved soil physical state especially in low saline RSC water and sustained release of macro and micro nutrients. The results presented in this paper are of great importance in managing saline water supplementing with organic inputs in arid and semi-arid regions for cultivation of seed spices in general and fennel in particular.

CONCLUSION

Considering the cost and quality of organic inputs, a combination of 6 t/ha farmyard manure and 1.3 t/ha vermi-compost seems to be a good combination to achieve the sustainable production of fennel crop in saline environment.

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Evaluation of water saving technologies for enhancing water use efficiency and productivity of *rabi* sorghum

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Rabi sorghum is an important crop of Deccan Plateau region of India. Growingon shallow Entisol and Vertisol soils in an area about 5.6 m ha with productivity of 0.85 t/ha grain and 3.4 t/ha fodder. In this region water availability remains at sub-marginal level due to unfavourable soil physical conditions and erratic rainfall behaviour that leads severe crop failure. In majority of times crop faced terminal droughts that cause 61 to 96 % loss in grain and 46 to 69 % in fodder yield (Kholova *et al*., 2013). Therefore, the present investigation was undertaken to evaluate different water saving technologies for enhancing WUE and productivity of *rabi* sorghum.

METHODOLOGY

A field experiment was conducted at the research farm of the ICAR–National Institute of Abiotic Stress Management, Baramati (18°09' N, 74°30' E and 560 MAMSL), during the *rabi* season of 2014–15. The weather parameters of cropping season are given in Table 1. The experiment comprised eight combinations of irrigation schedules based on cumulative pan evaporation (CPE), irrigation methods and abscisic acid (ABA) spraying [75 mm CPE+every furrow(EF);75 mm CPE+ alternate furrow (AF); 75 mm CPE + fixed furrow (FF);75 mm CPE+EF+ABA; 120 mm CPE+EF; 120 mm CPE+EF+ABA; 200 mm CPE+EF and 200 mm CPE+EF+ABA] were arranged in randomized block design with four replications. The experimental crop sorghum variety ‘DSV-4’ was sown on top of ridges in ridge furrow planting methodon 24thOctober, 2014 at 45 x 15 cm spacing,a common irrigation was given to field just after sowing to ensure proper germination. Irrigation treatments started from 20th November, 2014; details of irrigations are given in Table 2.Foliar sprayof ABA @5μM/l (spray solution 100 l/ha) at heading stage (100 DAS) was given to crop.Soil moisture determination of soil profile 0-15, 15-30 and 30-45cm from sowing to harvesting was done for calculating consumptive useas methods described by Dastane,N. G. (1972). The crop harvested on 22ndMarch, 2015.The experimental data was analysed statistically by applying ‘Analysis of Variance’ technique and results are presented at 5% level of significance.

RESULTS

In*rabi* sorghum flowering stage is highly sensitive to low temperature. If night temperature falls below 10°C at flowering stage, it causes peculiar damage to seed setting (Reddy *et*

Table 1. Mean monthly weather parameters ofseasonand daily T minat flowering stage of *rabi*sorghum

Month	T max(°C)	T min(°C)	R/F(mm)	Evap.(mm)	Dates	T min(°C)
October	32.0	19.5	26.1	5.1	04-Feb-15	13.0
November	30.2	16.3	44.0	4.4	05-Feb-15	11.5
December	28.4	11.8	7.6	3.6	06-Feb-15	11.0
January	28.3	12.0	0.1	3.9	07-Feb-15	10.0
February	32.2	12.9	0.0	6.0	08-Feb-15	10.0
March	34.5	17.5	22.4	6.8	09-Feb-15	10.0
Mean/Total	30.9	15.0	100.2	5.0	10-Feb-15	14.5

Table 2. Execution of irrigation treatment to *rabi*sorghum

Irrigation treatment	Dates and number of irrigations					Total
	I	II	III	IV	V	
75 mm CPE	10.12.2014	03.01.2015	23.01.2015	08.02.2015	20.02.2015	5
120 mm CPE	25.12.2014	27.01.2015	19.02.2015	–	–	3
200 mm CPE	17.01.2015	24.02.2015	–	–	–	2

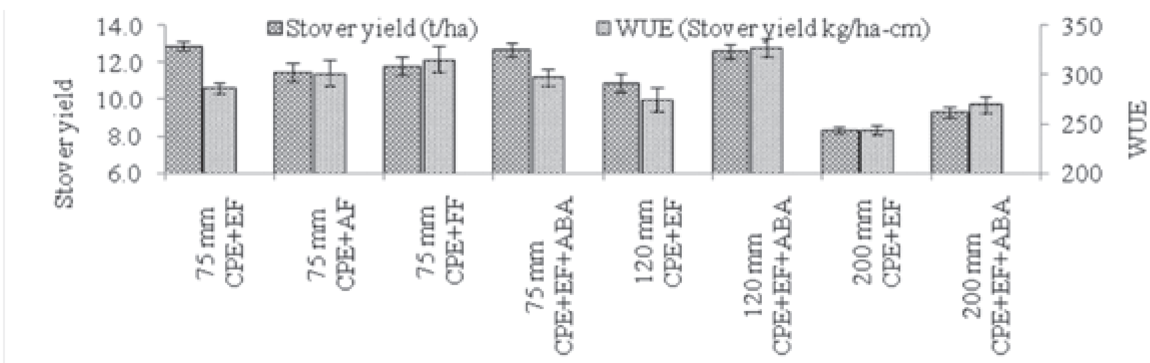

Fig. 1. Stover yield and WUE of *rabi* sorghum as affected by different water saving technologies.

al., 2014). Weather data presented in Table 1 indicate that experimental crop encountered by low night temperature (10-11.5°C) continuously for 5 days at flowering stage that cause partial seed setting. Therefore, tover yield and water use parameters were considered for result interpretation. The experimental results (Fig. 1) revealed that stover yield and WUE of *rabi* sorghum was significantly affected by water saving technologies. Among various water saving technologies, the technology combination, irrigation at120 mm CPE+EF+ABA spraying resulted the highest WUE with maintaining yield level equal to the technology combination, which receiving the highest water, that is irrigation at 75 mm CPE+EF±ABA spraying. It may be due to the exogenous applied ABA increased endogenous concentration ofABA, which optimize plant leaf water status through regulating guard cells and also induced cellular dehydration tolerance in water stressed conditions. The optimized leaf water status of plants increased LAI in water stressed conditions, which resulted higher photosynthesis and ultimately yield.

CONCLUSION

Among various water saving technologies, the technology combination, irrigation at 120 mm CPE+EF+ABA spraying @ 5μM/L (spray solution 100 l/ha) at heading stage can maintainstoveryield level equal to the technology combination, which receiving the highest water.Thus,ABA spraying can help in mitigating water stress and promotethe productivity of *rabi*sorghum under waterscarcity.

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Deficit irrigation can reduce arsenic accumulation in popular rice varieties grown in Gangetic alluvium of southern West Bengal

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Rice is the principal crop in West Bengal and rice requires 1200–1400 mm water to meet the higher (3–5.5 mm/day) evapo-transpiration demand during the growing period of summer rice and more than 60% of this is met through ground water. More than 90% of the tested shallow tube wells exceed the WHO guideline value of arsenic concentration in irrigation water which encompass about one third of cultivable land of the state. Irrigating rice with As contaminate water exposed people to dietary arsenic toxicity not only in the contaminated area but in other areas also, making the source of contamination more diffuse and vulnerable (Kile *et al*., 2007).In view of the above, the present study has been hypothesized with the objective to formulate a mitigation strategy of arsenic in rice grain through deficit irrigation practices and varietal screening.

METHODOLOGY

The present experiment was carried out in farmer's field at the village of Ghetugachi (Chakdah block, Nadia district; N-23ˆ02.138', E-88ˆ34.861'), West Bengal during *rabi* 2014-

Table 1. Growth, Yield and Arsenic accumulation in soil and grain influenced by selected rice cultivars observed under simulated moisture situations

Treatment	Plant height at harvest (cm)	Number of grains/ panicle	Grain yield (t/ha)	As in grain (mg/kg)	Available soil As at harvest (mg/kg)
V_1	91.18	160.22	4.05	0.78	0.58
V_2	91.67	145.00	3.84	0.84	0.71
V_3	115.01	245.33	4.59	0.32	0.63
SEm±	0.70	3.26	0.06	0.02	0.03
CD (P=0.05)	2.10	9.76	0.17	0.06	0.10
I_1	101.70	201.44	4.38	0.75	0.81
I_2	99.33	180.56	4.21	0.65	0.62
I_3	96.82	168.56	3.90	0.54	0.49
SEm±	0.70	3.26	0.06	0.02	0.03
CD (P=0.05)	2.10	9.76	0.17	0.06	0.10
V_1I_1	93.13	176.33	4.11	0.91	0.82
V_1I_2	91.03	155.33	4.08	0.75	0.57
V_1I_3	89.37	149.00	3.96	0.67	0.34
V_2I_1	93.43	163.33	4.08	0.91	0.94
V_2I_2	91.57	148.00	3.80	0.85	0.65
V_2I_3	90.00	123.67	3.64	0.76	0.55
V_3I_1	118.53	264.67	4.94	0.41	0.65
V_3I_2	115.40	238.33	4.75	0.34	0.65
V_3I_3	111.10	233.00	4.09	0.20	0.58
Mean	99.28	183.52	4.16	0.64	0.64
SEm±	3.64	16.90	0.30	0.04	0.06
CD (P=0.05)	91.18	160.22	4.05	0.11	0.18

V_1: IET 4786, V_2: IR 36 and V_3: GontraBidhan 1; I_1: Continuous flooding, I_2: Saturation, I_3: Alternate wetting and drying

15 and 2015-16. Arsenic concentration of the shallow tube well was 0.21ppm. There were three irrigation practices [I_1: Continuous submergence (CS), I_2: Saturation (SAT) & I_3: Alternate wetting and drying (AWD)] along with three popular variety of rice [V1: IET 4786, V2: IR 36 & V3: Gontra Bidhan 1 (GB-1)] designed in factorial experiment and replicated thrice. All other practices were done same in all treatment except irrigation. Continuous submergence was maintained with water @ 4 cm depth where as irrigation was applied when soil metric potential at 20 cm depth reached -0.03 MPa after disappearance of ponding water in case of situation and in alternate wetting and drying situation, irrigation was given on visual appearance of hair crack in experimental field. The soil, plant and water solution were analyzed in a Perkin-Elmer Atomic Absorption Spectrophotometer in the laboratory.

RESULTS

Continuous submergence supported highest grain yield and growth parameters (plant height, grains/panicle) throughout rice growth stages and across cultivars. Gontra Bidhan-1 produced highest yields in both the years followed by IET-4786>IR-36. Deficit irrigation at SAT and AWD moisture regimes reduced grain yields significantly from CS and such reduction in AWD regime rose up to 10-12% from CS. Reddy and Bandyopadhyay (2015) observed that continuous saturation produced 7.82% less grain yield than the continuous submergence. Arsenic accumulation in grains of different rice cultivars varied in ranges of 0.20-0.91 mg/kg under simulated moisture situations at harvest. The recoveries of available arsenic from soils, under same experimental situation were in ranges of 0.54-1.01 mg/kg. Gontra Bidhan was observed to accumulate significantly lesser arsenic in grain as compared to IR-36>IET-4786. Significantly less arsenic is recovered from grain of selected rice cultivars exposed to alternate wetting and drying as compared to saturation < continuous submergence. Similar changes in recoveries of available soil arsenic were observed when exposed to simulated moisture situations. Such variations in arsenic accumulation in different variety may be due to genetic differences while, Wu *et al*. (2011) described such variation among genotypes is influenced by root anatomy. Simulation of moisture regimes through irrigation management always recovered significantly less arsenic in selected rice cultivars under alternate wetting and drying (AWD) and saturation (SAT) as compared to conventional continuous submergence (CS) situation which is due to less use of contaminated irrigation water and less addition of arsenic to the system (soil-plant) in former two situations

CONCLUSION

From the experiment it can be concluded that IET-4786 can be safely cultivated with intermittent irrigation (AWD) to ensure arsenic mitigation where as Gontera Bidhan-1 can be recommended with intermittent irrigation (AWD) in highly contaminated zones for arsenic mitigation with an acceptable compromise in net return.

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Influence of irrigation scheduling on system productivity, profitability and water productivity under rice based cropping systems

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Rice is a staple food of our country. Continuous cultivation of cereal after cereal may affect the soil fertility which ultimately declines the productivity. The basic need of farmers is not fulfilled only by cereals. To fulfill the demand of increasing population inclusion of oilseed, pulses and vegetables in rice based cropping sequence was found more beneficial than cereal alone (Kumar *et al*., 2008). Therefore, challenge to develop novel technologies and production system that allow rice production to be maintained or increased in the face of decreasing water availability. SRI is another emerging water saving technology with many fold increase in crop yield. In view of these facts, the present experiment was conducted with the objective to study the influence of irrigation scheduling on system productivity, profitability and water productivity under rice- based cropping systems.

METHODOLOGY

A field experiment was conducted during *Kharif,* rabi and summer seasons of 2012-13 and 2013-14 at research farm, Rajendra Agricultural University, Bihar, Pusa (Samastipur). The soil of experimental plot was sandy loam in texture with low in available N and P, and medium in K having pH 8.2. The experiment on rice based cropping systems with 3 irrigation levels was laid out in split plot design replicated thrice. Five rice based cropping sequences [rice-potato-groundnut; rice-potato-cowpea (green pod); rice-potato-green gram; rice-maize+potato-sesbania (GM) and rice-maize+garden pea (green pod)] were assigned to main plots and three irrigation levels (IW/CPE-0.8, IW/CPE-1.0 and IW/CPE-1.2) were allocated to sub plots. Rice was grown under system of rice intensification (SRI) in all the cropping sequences. Cultivation practices were followed as per standard recommendation for each crop. The crop residues of rabi/summer season crops were incorporated in to the soil after harvest of the crop. Rice equivalent yield (REY) and economics were calculated considering the prevailing market price of the crop. Water productivity in ₹/m^3 was worked out dividing the net return by water use.

RESULTS

Result reveals that among the different cropping sequences rice-maize+potato-sesbania (GM) sequence produced significantly higher rice equivalent yield and gross returns (Rs. 366915/ha) as compared to rice-potato-cowpea (green pod), rice-potato-greengram and rice-maize+garden pea (green pod) cropping sequences but was statistically at par with rice-potato-groundnut sequence. Rabi and zaid crops mostly influenced the REY of the systems because rice was the base crop. Besides, higher production potential of potato, maize, and better market price of groundnut were instrumental for attaining higher REY, gross returns by this sequence. Inclusion of sesbania as green manure crop increased the yield of succeeding rice crop and ultimately productivity of the system. The maximum net returns (‘230300/ha) was recorded under rice-maize+potato-sesbania (GM) cropping sequence which was significantly superior to rice-potato-cowpea (green pod) and rice-potato greengram cropping sequences but was statistically at par with rice-maize+garden pea (green pod) and rice-potato-groundnut cropping sequences. However, the maximum B:C ratio of 3.05 was recorded under rice-maize+garden pea (green pod) cropping sequence which was significantly superior to all other sequences. This was due to the minimum cost of cultivation of rice-maize+garden pea (green pod) sequence. The maximum water productivity (18.84 ‘/m3) was also recorded under rice-maize+potato-sesbania (GM) cropping sequence which was significantly superior to rice-potato-cowpea (green pod), rice-potato-greengram and rice-potato-groundnut cropping sequences but was statistically at par with rice-maize+garden pea (green pod) cropping sequence. Among the different moisture regimes IW/CPE ratio of 1.2 recorded significantly higher REY, gross returns, net returns and B:C ratio as compared to 0.8 IW/CPE ratio which was statistically at par with 1.0 IW/CPE ratio. Moisture regimes did not cause significant difference in water productivity though maximum water productivity was recorded at 1.2 IW/CPE ratio followed by 1.0 and 0.8 ratios.

Table 1. Rice equivalent yield (REY), economics of the system and water productivity affected by different treatment (pooled data of 2 years)

Treatment	REY (t/ha)	Economics of the system Gross returns (₹/ha)	Net returns (₹/ha)	B : C ratio	Water productivity (₹/m^3)
Cropping sequence					
Rice-potato-groundnut	27.75	362029	221998	1.58	17.59
Rice-potato-cowpea (green pod)	22.53	294867	170400	1.37	13.49
Rice-potato-greengram	23.12	302651	176274	1.39	14.91
Rice-maize+potato-sesbania (GM)	28.11	366915	230300	1.68	18.84
Rice-maize+garden pea (green pod)	22.98	300549	226402	3.05	18.51
SEm±	0.36	4790	4790	0.04	0.40
CD (P=0.05)	1.09	14362	14362	0.12	1.20
Moisture regimes					
IW/CPE = 0.8	23.93	312968	193674	1.74	16.61
IW/CPE = 1.0	25.06	327514	207020	1.83	16.69
IW/CPE = 1.2	25.70	335724	214530	1.87	16.70
SEm±	0.25	3262	3262	0.03	0.27
CD (P=0.05)	0.71	9323	9323	0.08	NS

CONCLUSION

It can be concluded that rice-maize+potato-sesbania (GM) cropping sequence should be adopted in order to get higher system productivity and profitability. Rice-potato-groundnut and rice-maize+garden pea (green pod) could also be a viable alternative cropping sequence. Irrigation scheduling at IW/CPE ratio of 1.2 in rabi and zaid crops generated the highest system productivity and net income however, was at par with 1.0 IW/CPE ratio.

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Response of aerobic rice (*Oryza sativa* L.) to drip fertigation

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Rice, the staple food crop of India is a moisture hungry crop and a prolific user of water which requires 3000-5000 litres of water to produce one kg of grain which is twice or thrice higher than any other cereal crops like wheat and maize (IRRI, 2009). Water resources are diminishing day by day and efficient utilization of available water resources is crucial for sustainable rice production which consumes major share of water available for agriculture. Drip irrigation is a novel technique of supplying water to the crop root zone with right amount at right time matching with crop demand. In the current scenario simultaneous use of drip irrigation and fertigation offers a viable alternate water and nutrient saving system for aerobic rice (Parthasarathi *et al..,* 2015).In view of the above, present study was conducted with the objective to assess the effect of fertigation intervals and combination of fertilizer sources on yield of aerobic rice.

Table 1. Effect of fertigation intervals and fertilizer combinations on leaf area, productive tillers at harvest and yield of aerobic rice.

Treatments	Leaf area (cm^2)	Productive tillers (No. per hill)	Grain yield (kg/ha)
Fertigation once in two days with 100% WSF	2464	35.7	11949
Fertigation once in two days with 50% WSF+ 50% NF	2332	34.2	11331
Fertigation once in two days with 25% WSF+ 75% NF	2033	31.8	9819
Fertigation once in two days with 100% NF	1943	29.8	9192
Fertigation once in four days with 100% WSF	2291	33.6	11185
Fertigation once in four days with 50% WSF+ 50% NF	2174	33.2	10569
Fertigation once in four days with 25% WSF+ 75% NF	1856	27.0	8839
Fertigation once in four days with 100% NF	1710	25.2	8281
Fertigation once in eight days with 100% WSF	1872	27.7	8872
Fertigation once in eight days with 50% WSF+ 50% NF	1757	26.3	8646
Fertigation once in eight days with 25% WSF+ 75% NF	1507	23.2	8012
Fertigation once in eight days with 100% NF	1386	19.7	7591
Aerobic rice with surface irrigation and soil application of fertilizers	1071	16.2	6309
CD (P=0.05)	457.58	5.18	1620.95

METHODOLOGY

The experiment was conducted at ZARS, GKVK, University of Agricultural Sciences, Bengaluru during *Kharif* 2013 and summer 2014. The soil of the experimental site was sandy clay loam with medium OC (0.56 per cent), available N (285.4 kg /ha), available P_2O_5 (38.0 kg /ha) and available K_2O (248.0 kg /ha). The experiment was laid out in RCBD with three replications consists of twelve treatments with a combination of three fertigation intervals once in two days, once in four days and once in eight daysand four fertilizer combinations like 100% water soluble fertilizer (WSF), 50% WSF + 50%normal fertilizer (NF), 25% WSF + 75% NF and 100% NF with aerobic rice with surface irrigation and soil application of fertilizers as control.

RESULTS

Among fertigation intervals and fertilizer combinations, drip fertigation once in two and four days with 50 per cent WSF and 50 per cent NF combination realized higher grain yield (11331 and 10569 kg/ha) in aerobic rice as compared to aerobic rice with surface irrigation (6309 kg/ha). It is because frequent split application of fertilizers in drip irrigation coincided with the actual needs of crop and favored good growth, which resulted in maximum yield. Scheduling fertigation once in eight days might have led to leaching losses and did not match with crop demands for nutrients which in turn resulted in low yields under wider fertigation intervals. Application of straight fertilizers in combination with water soluble fertilizers is best alternative source to water soluble fertilizers alone.

CONCLUSION

Study concluded that drip fertigation once in two days or four days with 50 per cent WSF and 50 per cent NF combination was optimum for realizing higher yield in aerobic rice.

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Performance of *hirsutum* cotton varieties under high density planting system

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The manipulation of row spacing, plant density and the spatial arrangements of cotton plants, for obtaining higher yield have been attempted by agronomists for several decades in many countries (Venugopalan *et al.,* 2013). Higher density planting of cotton compact genotypes with reduced inter and intra row spacing seems to be an alternative strategy to increase the cotton yields under assured rainfed conditions in vertisols. The productivity of rainfed cotton in this region is low with the present production practices adopted for these genotypes. The optimum plant density will depend upon the genotype characteristics, soil and climatic parameters and management practices. Under assured rainfall conditions the high density planting of potential suitable compact/semi compact early cotton genotypes holds promise to enhance the productivity of cotton as against the present production practices. Suitable agronomic requirements like planting geometries are to be standardized through research for further adoption on the farmer's fields. The pros and cons of the high density planting system (HDPS) need to be assessed before the technology is commercially recommended on large scale. Hence, the studies were initiated under Technology Mission on Cotton to optimize the production strategies for compact/semi compact cotton genotypes under HDPS.

METHODOLOGY

AField experiment was conducted at Agricultural Research

Station, Dharwad, Karnataka, India during *kharif* season of 2015-16. The soil was medium deep black clay having pH 7.01 and electrical conductivity (EC) of 0.20 dS/m. The soil had medium organic carbon (0.51%), low available nitrogen (215.0 kg/ha), high available phosphorus (31.0 kg/ha) and high available potassium (550.0 kg/ha). The experiment was laid out in Factorial Randomized blockdesign with three checks and treatments were replicated thrice. Five compact varieties were assigned as Factor-1 to main plots i.e., V_1: Suraj, V_2: DSC-99, V_3: ARBC-64, V_4: DSC-1351 and V_5: ARBC-19 and four planting geometries i.e., S_1: 45 cm×10 cm, S_2: 60 cm×10 cm, S_3: 75 cm×10 cm and S_4: 90 cm ×10 cmwere assigned as factor-ii sub plots. Check plots included normal planting of compact variety (C_1: 60×30 cm), planting of potential Bt cotton hybrids under high density planting system (C_2: 60×10 cm) and normal planting of Bt cotton (C_3: 90 cm ×60 cm). Farm yard manure of 5 t/ha was applied commonly for all the treatments. All treatment plots of compact varieties received the recommended inorganic fertilizer dose of 60:40:40 NPK/ ha, where as the Bt cotton hybrid received 100:50:50 kg NPK/ha. Fifty per cent of nitrogen and full dose of phosphorus and potassium were applied at the time of sowing as basal and the remaining 50 per cent N was applied into two splits at 30 and 45 days after sowing.

RESULTS

The data on seed cotton yield (SCY) per hectare and yield components and economics of *hirsutum* varieties as influenced by different plant geometry are presented in Table 1.Results indicated that, among the different cotton genotypes, DSC-1351 genotype recorded significantly higher SCY(2296 kg/ha) which was closely followed by the SCY obtained with DSC-99 (2215 kg/ha) under high density planting. Suraj and ARBC-19 were recorded lower SCY of 1959 kg/ha and 1952 kg/ha respectively. Significantly higher number of bolls/plant, mean boll weight and yield per plant was recorded with genotype DSC-1351 (7.41, 4.17 g and 22.3 g/plant respectively) as compared to other genotypes. Planting geometry of 90 cm× 10 cm resulted in significantly higher SCY, (2393 kg/ha) as compared with the SCY obtained with planting geometry of 75 cm x10 cm (2145 kg/ha) and planting geometry of 60 cm x10 cm (2031 kg/ha) and 45 cm ×10cm(1930 kg/ha). Planting geometry of 90 cm ×10 cm recorded significantly higher SCY per plant (25.8 g/plant), boll weight (4.15 g) and number of bolls per plant (7.98) as compared to other planting geometies. All interactions were non-significant. DSC-99 with a planting geometry of 60 cm ×30 cm recorded higher SCY (2600 kg/ha). Bt cotton at high density planting of 60 cm ×10 cm recorded the lower SCY (2347 kg/ha) as compared to the normal planting of 90cm× 60 cm (2410 kg/ha).Significantly higher net returns and B:C ratio were possible with DSC-1351(Rs.34113/ha and 1.59 respectively) under HDPS closely followed by the net returns realized with DSC-99 (Rs.31268/ha and 1.54) and both were higher than the net re-

Table 1. Effect of planting geometry on seed cotton yield and economics of *hirsutum*varieties under high density planting system during 2015-16.

Treatment	SCY (kg/ha)	Bolls perplant	Mean boll weight (g)	SCY/plant (g)	Net Returns (Rs./ha)	B:C ratio
Varietiy (V)						
V_1: Suraj	1959	6.57	3.82	21.3	22308	1.40
V_2: DSC-99	2215	7.33	4.06	20.8	31268	1.54
V_3: ARBC-64	2202	6.95	3.88	21.5	30808	1.54
V_4: DSC-1351	2296	7.41	4.17	22.3	34113	1.59
V_5: ARBC-19	1952	5.53	3.91	17.1	22080	1.39
CD (P=0.05)	140	0.71	0.25	2.7	5583	0.10
Spacing (S)						
S_1: 45 cm × 10 cm	1930	5.63	3.81	16.5	20611	1.36
S_2: 60 cm × 10 cm	2031	6.28	3.94	18.1	24746	1.44
S_3: 75 cm × 10 cm	2145	7.13	3.98	22	29089	1.51
S_4: 90 cm × 10 cm	2393	7.98	4.15	25.8	38015	1.66
CD (P=0.05)	125	0.64	0.23	2.4	4994	0.09
Interaction (Vx S)						
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Check plots (C)						
C_1: DSC-99 (60 cm x 30 cm)	2600	16.67	4.12	53.5	45851	1.79
C_2: Bt cotton(60 cm x 10 cm)	2347	7.10	4.85	44.2	11435	1.14
C_3: Bt cotton(90 cm x 60 cm)	2410	34.60	4.92	129.7	36902	1.62
CD (P=0.05)	274	1.69	0.52	8.9	10951	0.19

Note: NS: Non Significant; SCY: Seed cotton yield turns and B:C ratio obtained with Suraj (Rs. 22308/ha and 1.40) and ARBC-19 (Rs.22080 & 1.39). While DSC-99 under normal planting of 60x30 cm resulted in significantly higher net returns and B:C ratio (Rs.45,851/ha and 1.79, respectively). Planting geometry of 90 cm ×10 cm resulted in significantly higher net returns and B:C ratio (Rs.38015/ha and 1.66, respectively) as against the planting of 75 cm ×10 cm (Rs.29089/ha and 1.51 respectively).

CONCLUSION

Based on the seed cotton yield of different *hirsutum* genotypes and economics under HDPS, it was concluded that DSC-1351 and DSC-99 are found to be promising genotypes with a planting geometry of 90cm × 10 cm (1,11,111) plants/ha respectively under high density planting system in assured rainfed conditions in medium deep black soils.

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Water and nitrogen stress on radiation interception, extinction coefficient and use efficiency of wheat in a semi-arid environment

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Water (irrigation) and fertilizer (nitrogen) are the two most important inputs which must be optimized to achieve sustainable wheat productivity. There are very few studies evaluating the integrated effect of irrigation and nitrogen supply on the ecophysiological determinants of above ground biomass (AGB) production and radiation interception by wheat. Successful modeling of plant growth and remote sensing estimation of biomass relies on accurate description of light extinction coefficient (κ) for intercepted photosynthetically active radiation (IPAR) and radiation use efficiency (RUE). Keeping these in view, the objectives of this study was to determine the interactive effect of irrigation and nitrogen on total IPAR (TIPAR), AGB, κ and RUE of wheat in a semi-arid location of India.

METHODOLOGY

Field experiments were conducted during winter season of 2013-2014 at the experimental farm of the Indian Agricultural Research Institute (IARI), New Delhi, (77°89' E Longitude, 28°37' N Latitude and 228.7 m above mean sea level), Delhi, India with wheat (*Triticum aestivum* L.) as test crop. The area comes under semi-arid subtropical climatic belt. The soil is sandy loam (Typic Haplustept) low in organic carbon and available nitrogen and medium in available P and K content. The experiment was laid out in a split-plot design with irrigation levels as main plot treatments and nitrogen levels as subplot treatments, replicated three times. The irrigation levels were I2: two irrigations (CRI and flowering stages), I3: three irrigations (CRI, flowering and grain filling stages) and I5: five irrigations (CRI, tillering, Jointing, flowering and grain filling stages). The nitrogen levels were N40: 40 kg N/ha and N160: 160 kg N/ha as urea. The source of nitrogen fertilizer was urea. All the plots received recommended basal dose of phosphorous and potassium (60 kg P_2O_5/ha as single super phosphate and 60 kg K_2O/ha as muriate of potash). Leaf area index was measured at regular intervals using a plant canopy analyzer. Both incoming and outgoing photosynthetically active radiation (PAR) values were measured periodically at the top and bottom of the wheat canopy throughout the season using line quantum sensor LI-191SA. The fraction intercepted PAR (fIPAR), total intercepted photosynthetically active radiation (TIPAR), radiation use efficiency (RUE) and κ value were computed as per Pradhan *et al*. (2014). The net plot (5 m × 5 m) was harvested manually by cutting the plants close to ground after leaving the border rows and the dry weight of above ground biomass (AGB) was recorded.

RESULTS

The above ground biomass (AGB) was not affected significantly ($P<0.05$) by irrigation levels (Table 1). However, the AGB of wheat was significantly affected by nitrogen levels (Table 1). N160 treatment registered 25 % higher AGB compared to N40 treatment. The interaction effect of irrigation and nitrogen treatments on AGB was significant. The highest AGB was observed in I5N160 and lowest in I2N40 treatments. Similar to AGB, the TIPAR was not significantly affected by irrigation levels (Table 1). However, the nitrogen levels significantly ($p<0.05$) affected TIPAR. N160 registered 20 % higher TIPAR than the N40 treatments It was found that 86 % variation in AGB yield of wheat could be explained by TIPAR. Similar to AGB, the interaction effect of irrigation and nitrogen on TIPAR was significant and the highest TIPAR was observed in I5N160 and lowest in I2N40 treatments. Contradictory to AGB and TIPAR, RUE was significantly affected by irrigation levels (Table 1). I3 (2.70 g/MJ) treatment registered significantly highest ($P<0.05$) RUE followed by I5 (2.55 g/MJ) and I2 (2.29 g/MJ). However, RUE of wheat was not significantly affected by nitrogen levels (Table 1) though it showed a decreasing trend (5% in 2013-2014 and 13 % in 2014-2015) with decrease in N levels. The interaction effect of irrigation and nitrogen levels on RUE was not significant. The extinction coefficient (κ) was not significantly affected by irrigation levels. However, κ was significantly ($P<0.05$) lower (16 %) in N40 compared to N160. It indicated that under nitrogen stress condition, the leaf becomes more erect resulting in better penetration of PAR into the canopy and hence lower fIPAR and RUE (Bassu *et al.,* 2011). Similar to RUE, the interaction effect of irrigation and nitrogen levels on K was not significant.

CONCLUSION

It can be concluded that under nitrogen stress condition the light extinction coefficient decreases resulting significant reduction in above ground biomass, total intercepted radiation and RUE. Application of 5 irrigations at critical growth stages and 160 kg N/ha registered highest above ground biomass and TIPAR whereas 3 irrigations at critical growth stages registered highest RUE. So, the optimum level of irrigation and nitrogen should be applied to wheat in order to achieve better crop growth, productivity and radiation use efficiency in semi-arid location of India.

Table 1. Above ground biomass (kg/ha), TIPAR (MJ/m^2), RUE (g/MJ) and light extinction coefficient (κ) of wheat for different irrigation and nitrogen levels in 2013-2014

Treatment	AGB (t/ha)	TIPAR (MJ/m^2)	RUE (g/MJ)	K
Effect of irrigation				
I2	9.7	422	2.29c	0.57
I3	12.7	469	2.70a	0.59
I5	13.0	509	2.55b	0.58
SEm ±	-	-	0.05	-
CD P=0.05)	-	-	0.21	-
Effect of nitrogen				
N40	10.5	424	2.29	0.53
N160	13.2	509	2.70	0.63
SEm ±	0.5	12	-	0.01
CD P=0.05)	1.7	41	-	0.04

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Evaluation of SRI and its contribution towards enhancement of grain yield

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System of Rice Intensification (SRI) with weed management is an imperative to convince the today's crop production in a sustainable way. Due to scarcity of water and energy, the weed competition is going to be the major constraint in achieving higher production in transplanted rice. SRI is a six components like young seedlings transplanted at wider spacing using ,use of organics, conoweeding and saturation moisture package aimed at realizing higher rice production using

Table 1. Evaluation of SRI and added components towards enhancement of rice grain yield (t/ha)

Treatment		*Kharif*	*Rabi*
T1	SRI (use of 8-12 days old seedlings, raised bed nursery, careful transplanting at spacing of 25 cm × 25 cm. weed management with conoweeder (4 times). saturation of water management, and use of (75%) inorganic along with (25%) organic.	8.35	7.85
T2	T1 with 3-4 seedlings per hill (instead of 1 seedling per hill)	8.50	8.08
T3	T1 with 30 to 35 days old seedlings (instead of 8-12 day old seedlings)	7.14	6.77
T4	T1 with 20 x10 cm spacing (instead of 25 x25 cm spacing)	7.39	6.85
T5	T1 with only inorganic (RDF) instead of organic + inorganic)	8.42	7.89
T6	T1 with herbicide + manual weeding (instead of Cono-weeding)	8.22	7.47
T7	T1 with 2+5 standing water during crop growth (instead of Saturation / alternate wetting and drying of water management)	8.00	7.13
T8	Conventional transplanting(Location specific best management practices with 30 day old nursery, planted at a spacing of 20 x 15 cm spacing, 3-4 seedlings per hill and 2+5 standing water during crop growth)	6.67	6.21
	CD (P=0.05)	0.86	0.68

less inputs especially, seed ,water and fertilizers (Uphoff, 2002). Since entire package may not possible to adopt in all cases, in order toEvaluation of principles of SRI and their contribution towards enhancement of grain yield with following objectives to study the effect of principles and interactions effect on grain yield.

METHODOLOGY

Two field experiments were conducted during *rabi* 2012-13 and *kharif* 2014at Perunthalaivar Kamaraj Krishi Vigyen Kendra (PKKVK), Puducherry State experimental farm in a randomized block design with three replication. The treatments were T_1-SRI (use of 8-12 day old seedlings, raised bed nursery, careful transplanting at a spacing of 25 cm x 25 cm, weed management with cono weeder (4 times), Saturation of water management, and use of (75%) inorganic along with (25%) Organic, T_2- T1 with 3-4 seedlings/hill (instead of 1 seedling/hill), T_3- T_1 with 30 to 35 day old seedlings (instead of 8-12 day old seedlings), T_4- T_1 with 20 x 10 cm spacing (instead of 25 x 25 cm spacing), T_5- T_1 with only inorganic (RDF) (instead of organic + inorganic),T_6- T_1 with herbicide + manual weeding (instead of cono-weeding),T_7- T_1 with alternate wetting and drying (instead of situation of water management) and T_8-Conventional transplanting management practices that were tested on SRI crop.

RESULTS

The findings of two seasons, use of 8-12 days young seedlings with four times conoweeding at 10, 20, 30 and 40 DAT at spacing of 25cm x 25cm, saturation of water management and use of (75%) inorganic along with (25%) Organic with 3-4 seedlings/hill (T_2) was performed excellent by registering higher yield attributes and grain yield of 8500 and 8080 kg/ha (Table 1) during *kharif 2012* and *rabi* 2012-13 respectively, besides it also gave higher net return by reducing the cost production.

CONCLUSION

It may be concluded that in SRI, with young seedlingscoupled with conoweeding four times at 10, 20, 30 and 40 DAT favorably increased the growth parameter which ultimately reflected in higher yield.

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Impact of irrigation schedules on corm yield and water productivity of elephant foot yam (*Amorphophallus paeoniifolius* (Dennst.) Nicolson)

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Among the tropical tuber crops, Elephant foot yam (*Amorphophallus paeoniifolius* (Dennst.) Nicolson) is gaining popularity not only as a food security crop, but also as a cash crop due to its production potential and popularity as a starchy vegetable having high nutritive and medicinal values. Till recent times, the crop was cultivated under rainfed conditions, like other tuber crops. Presently its cultivation is attempted in non traditional areas also due to its perennial demand as well as the attractive prices, which quite often necessitates assured irrigation. In states like Andhra Pradesh, Odisha, Bihar and West Bengal, farmers resort to flood irrigation once in 7-15 days interval. Recently, commercial farmers started using micro irrigation also, but without any rationale. They even keep the drippers open for 8 or more hours to completely wet the field; thereby a major portion of irrigation water is lost by evaporation and deep percolation resulting in lower efficiencies. So an attempt was made at ICAR- CTCRI to arrive at an optimum irrigation schedule for elephant foot yam for attaining maximum corm yield, water use efficiency and water productivity.

METHODOLOGY

Field experiments were conducted at ICAR - Central Tuber Crops Research Institute, Kerala, India during 2013-2014 and 2014-2015 in split plot design with two methods of irrigation as main plots (Drip irrigation and Flood irrigation) and two levels of irrigation at 4 different stages of growth as sub plots (S1: Irrigation at 75% of pan evaporation (PE) during 1-12 weeks after planting (WAP), S2: Irrigation at 75% PE during 13-24 WAP, S3: Irrigation at 75% PE during 1-24 WAP, S4: Irrigation at 100% PE during 1-12 WAP, S5: Irrigation at 100% PE during 13-24 WAP, S6: Irrigation at 100% PE during 1-24 WAP, S7: Irrigation at 75% PE during 1-12 and 100 % during 13-24 WAP and S8: Irrigation at 100% PE during 1-12 and 75 % during 13-24 WAP. The leading variety in India, 'Gajendra' was used for the study by planting 500 g each of the seed corms at a spacing of 90 x 90 cm. Planting was taken up during Feb-March, in both the years. Quantity of irrigation was fixed based on the daily open pan evaporation and pan factor, in mm. Crop factor was taken into account at different stages of growth as suggested by Allen and Pruitt (1991). Drip irrigation was given once in two days and flood irrigation, once in a week. The crop was harvested after 10 months and corm yield recorded. The data pertaining to two years were pooled and analysed using Indian NARS Statistical Computing Portal.

RESULTS

Pooled analysis of the data showed superiority of drip irrigation over flood irrigation. During both the years, drip irrigation resulted in significantly higher corm yield than flood irrigation. Among the sub plot treatments, 100 % irrigation given during 13-24 WAP was on par with all other treatments except 75% irrigation given either during the first 12 weeks or next 12 weeks thereafter. Among the treatment combinations, drip irrigation at 100% PE during 13-24 WAP resulted in maximum corm yield (44.56 t/ha), however, this was on par with drip or flood irrigation given during the entire period of 1-24 weeks at 75% and 100% levels (Table 1). Fertigation experiment conducted at CTCRI, RC, Bhubaneswar indicated that drip irrigation at 100% PE on alternate days along with fertigation recorded highest corm yield (Annual Report, 2011). Based on fertigation trials conducted under AICRP on tuber crops, James George *et al.* (2013) concluded that corm yield was significantly reduced when irrigation was less

Table 1. Corm yield of elephant foot yam (t/ha) under different treatments (Pooled mean of 2 years)

Treatment	Drip method	Flood method
Irrigation @ 75% PE 1-12 wks	20.12	27.01
Irrigation @ 75% PE 13-24 wks	24.58	29.19
Irrigation @ 75% PE 1-24 wks	34.71	32.61
Irrigation @ 100 % PE 1-12 wks	28.95	31.28
Irrigation @ 100 % PE 13-24 wks	44.56	26.86
Irrigation @ 100 % PE 1-24 wks	39.19	30.17
Irrigation @ 75 % PE 1-12 & 100% PE 13-24 wks	36.36	32.03
Irrigation @ 100 % PE 1-12 & 75 % PE 13-24 wks	37.31	27.99
CD (P=0.05)	12.26	

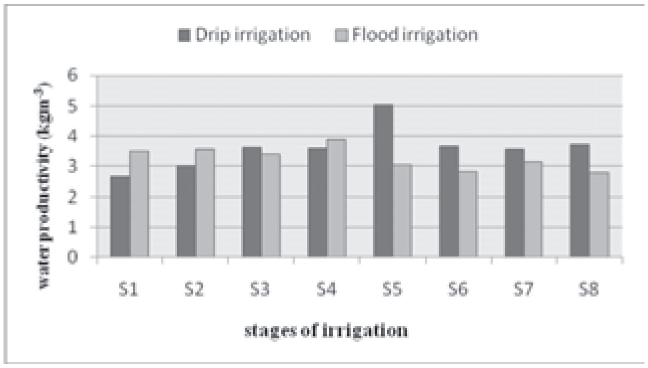

Fig. 1. Water productivity of elephant foot yam under different irrigation treatments

than100% PE. The results of the present study clearly indicated that water requirement of elephant foot yam is critical during 13-24 weeks after planting, which coincides with tuber development phase and drip irrigation at 100 % PE during this phase is as good as irrigation given throughout the growth cycle. Water use efficiency and water productivity were also worked out for different treatment combinations. Drip irrigation at 100 % PE during 13-24 weeks resulted in highest water use efficiency (WUE) and water productivity (5.02 kg/m^3) (Fig.1). Under flood irrigation, maximum water productivity recorded was 3.87 kg/m^3.

CONCLUSION

The study revealed that drip irrigation at 100% pan evaporation during 13-24 weeks after planting is most ideal for attaining maximum corm yield and water use efficiency in elephant foot yam.

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Carbon sequestration potential of sugarcane based cropping system for sustaining soil health and crop productivity

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The outstanding contribution of agricultural research towards improving the livelihoods of poor farmers on the Indo-Gangetic Plain (IGP) through the Green Revolution technologies is well documented. Now, in the face of, increasing global warming, diminishing ground water supplies and degrading soils, the challenge is to sustain crop productivity gains for supporting the millions of farmers on the IGP. Increase in soil organic matter pool by 1 t C/ha can increase additional annual 30-40 mt of food production in developing countries (Lal, 2006). In the proposed study we intend to workout the carbon input output balance in sugarcane-wheat cropping system, which is practiced in about 1 million ha area in Indo Gangetic Plains of Uttar Pradesh. It is worth to mention here that rice-wheat cropping system where reports of depleting soil organic carbon are emerging also practiced in Indo Gangetic Plain Region of Uttar Pradesh. This study may provide some clues to improve organic carbon status under rice-wheat system to provide its long term sustainability.

METHODOLOGY

In field experiment at IISR farm, in two cropping systems (i.e, rice-wheat and sugarcane –ratoon –wheat), the following treatments were superimposed T_1: Complete residue recycling (CRR) T_2: CRR with *Trichoderma* T_3: CRR with 25% higher RFD T_4: Partial residue recycling (PRR) T_5: PRR with *Trichoderma viride* T_6: PRR with 25% RFD and *Trichoderma viride* T_7: No residue application T_8: Residue burning. Thus sixteen treatments were applied in RBD with three replications.

RESULTS

Non availability of bulky organic manures and abolition of green manuring practice, micronutrients Zn, Fe, Mn, and Cu were found deficient in more than 60% fields in rice-wheat system. Trash mulching and inoculation of *Trichoderma viride* are key components for enhancing soil organic carbon, nutrient status. Thus modified rhizospheric environment in sugarcane based system as compared to rice-wheat system is responsible for improvement of C stock and sustaining crop yields as well. Significant improvement was recorded in population of soil micro flora, soil microbial biomass carbon, soil microbial biomass nitrogen and respiration in sugarcane based cropping system as compared to rice-wheat system. Analysis of data of past 30 years at IISR farm showed that, sugarcane cultivation did not adversely affect soil health. Total nutrient removal from rice and wheat was higher than sugarcane alone in one year cycle. Thus sugarcane crop acts as soil fertility restorer because of higher biomass production and recycling. Soil organic carbon and availability of nutrient increased after incorporation of crop residues with application of *Trichoderma viride*. Carbon built-up increased with higher amount of crop residue recycling and it could be increased by 28-36% in sugarcane based cropping system. It is clear from Table 1 that residue management practices increased mean soil organic carbon and total soil carbon in both the cropping systems. The higher level of SOC and total soil carbon in 0-15 and 15-30 cm depths were analyzed in sugarcane based system as compared to rice-wheat system. Residue removal from fields in both the systems decreased soil organic carbon and total carbon contents. The highest soil organic carbon (20.26 Mg/ha) in 0-15 cm depth was analyzed with adoption of crop residues recycling + 25% extra N application. However, in total carbon increase, partial residue incorporation ranked first in 0-15 cm. However, it was at par with complete residue recycling along with *Trichoderma*. Complete residues recycling, complete crop residues recycling with *Trichoderma* and partial residue recycling with *Trichoderma* were found at par in increasing total soil carbon content (Table 1). Thus, it was clearly observed that crop residues recycling brought forth significant effect on increasing soil organic carbon and total carbon contents. Increase in total carbon will improve the C sequestration ability of the crop. Further, inoculation of *Trichoderma* also played major role in improving the availability of nutrients as well as boosting C sequestration. SOC has a profound effect on soil quality where it improved soil aggregation, increased water retention, nutrient supply, and soil organism activities, soil fertility and productivity (Karlen *et al.,* 1997). Thus it ensures the long-term sustainability of an agro-ecosystem. Soil can also be a sink for atmospheric carbon dioxide (CO_2) and increased sequestration of carbon in agricultural soils has the potential to mitigate the global increase in atmospheric greenhouse gases.

CONCLUSION

Soil organic carbon, availability of nutrients and crop yields increased after complete residue recycling with application of *Trichoderma viride*. Sugarcane is efficient carbon capturer and can reduce the effect of global warming efficiently than other field crops. Carbon built-up increased with higher amount of crop residue recycling and it could be increased by 36.5% in sugarcane based cropping system. Results have vast potential in scenario of decreasing factor productivity, increasing cost of production and decreasing water availability for agriculture. Application of crop residues with *Trichoderma* is beneficial for rice, wheat or sugarcane. It can

Table 1. Soil organic carbon and total carbon contents as influenced by different treatments after completion of two crop cycles

Treatment	SOC (Mg/ha)		Total soil carbon (Mg/ha)	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm
Cropping system				
CS1 (Rice-wheat) two years	16.31	13.29	20.72	16.44
CS2 (Sugarcane-Ratoon-wheat)	19.51	15.95	23.15	17.88
SEm±	0.07	0.51	0.81	1.02
CD (P=0.05)	0.31	2.21	NS	NS
Residue management				
T1, Residue Removal	12.56	10.74	15.96	12.34
T2, Residue burning	14.82	12.32	18.20	13.95
T3, Residue Incorporation	18.21	15.34	23.91	20.59
T4, Residue incorporation + *Trichoderma*	19.09	14.85	25.18	16.11
T5, Residue-incorporation + 25% extra Nitrogen	20.26	13.32	23.03	18.17
T6, Partial Residue Incorporation	19.20	16.39	25.20	20.06
T7, Partial Residue Incorporation + *Trichoderma*	19.99	17.16	23.20	17.90
T8, Partial Residue Incorporation + 25% extra N	19.13	16.84	20.82	18.19
SEm±	0.58	0.73	1.05	0.71
CD (P=0.05)	1.19	1.49	2.15	1.45

increase crop yield besides sustaining soil fertility for longer period.

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Maximizing the productivity of rainfed groundnut under different sowing dates through protective irrigation in scarce rainfall zone of Andhra Pradesh

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Groundnut (*Arachis hypogaea* L.) is one of the important legume crops of tropical and semiarid tropical countries, where it provides a major source of edible oil and vegetable protein. India stands first in area and second in production of groundnut but the productivity is less than the other countries. In India Andhra Pradesh, Gujarat, Karnataka, Tamil Nadu are the major producers of kharif groundnut. Ananthapuramu and Kurnool districts of scarce rainfall zone is the important groundnut areas of Andhra Pradesh.Ananthapuramu district alone contributed for about 68% of the total area and 48% production of kharif groundnut in Andhra Pradesh during the last three years. (DAC, 2014). Due to high variability of monsoon rainfall, narrow sowing window and dry spells during the crop growth period, groundnut productivity is low in the zone. A total moisture use of 350–380 mm was found to be optimum for obtaining a maximum yield; moisture use of either less than this amount or more reduced pod yield (AICRPAM, 2003). Hence, maximizing the productivity of rainfed groundnut through protective irrigation is one of the options to enhance the production. With this objective the present study was under taken to study the response of groundnut varieties with early, normal and late sown conditions under rainfed and protective irrigation.

METHODOLOGY

A field experiment was conducted during kharif season 2012, 2013 and 2014 at AICRP on Agrometeorology, Agricultural Research Station, Ananthapuramu, Andhra Pradesh, India. The soil was red sandy loam with pH 6.4, organic carbon 0.48%, available nitrogen, phosphorous and potassium, 112, 52 and 135 kg /ha, respectively. Three varieties of groundnut viz., Vemana, Kadiri 6 and Anantha were sown during 1st FN of July, 2nd FN of July and 1st FN of August under rainfed and protective irrigation. The treatments were arranged in split split plot design with rainfed and protective irrigation as main plots, dates of sowing as sub plots and varieties in sub sub-plots and replicated thrice. The rainfall received during the crop growing period was 278 mm, 278.7mm and 245.4 mm during 2012, 2013 and 2014 respectively. Rain water harvested in the farm pond was utilized for providing protective irrigation @ 10mm per irrigation when there is a continuous dry spell for 15 days. Fertilizers (20-40-50 kg/ha of N, P_2O_5 and K_2O) were applied as per the recommendation for groundnut crop in scare rainfall zone of Andhra Pradesh.

RESULTS

Pooled analysis of the three years experimental results revealed that mean groundnut pod yield under protective irrigation (1233 kg/ha) was significantly higher than the rainfed condition (1049 kg/ha) in all the three dates of sowing and varieties. Yellamanda Reddy and Sulochanaama (2008) also reported that 10 mm of supplemental irrigation during pod filling phase of groundnut has increased the pod yield. The crop sown during 2nd FN of July has recorded significantly higher pod yield than 1st FN of July (1145 kg/ha) and 2nd FN of August (1012 kg/ha), whereas there is no significant difference in pod yield of Vemana (1138 kg/ha), Kadiri 6 (1150 kg/ha) and Anantha (1135 kg/ha) varieties. There a significant

Table 1. Economics of groundnut varieties as influenced by date of sowing under rainfed and protective irrigation (Pooled data of 2012 to 2014)

Variety/Date of Sowing	Rainfed			Irrigated		
	Gross returns (Rs./ha)	Net returns (Rs./ha)	B: C Ratio	Gross returns (Rs./ha)	Net returns (Rs./ha)	B: C Ratio
Vemana						
1st FN of July	46547	30339	2.9	55499	37624	3.1
2nd FN of July	49484	33276	3.1	58937	41062	3.3
1st FN of August	39022	22814	2.4	44050	26175	2.5
Kadiri 6						
1st FN of July	45801	29593	2.8	53332	35457	3.0
2nd FN of July	47027	30819	2.9	58794	40919	3.3
1st FN of August	43183	26975	2.7	49325	31450	2.8
Anantha						
1st FN of July	42929	26721	2.6	50113	32238	2.8
2nd FN of July	51802	35594	3.2	60524	42649	3.4
1st FN of August	40019	23811	2.5	48033	30158	2.7

interaction between dates of sowing and varieties. Pod yield of all the three varieties was significantly higher under 2nd FN of July sowing compared to 1st FN of July and 2nd FN of August sowing. Highest pod yield was recorded with Anantha varieity sown under protective irrigation (1406 kg/ha). The percentage yield increase was higher in 2nd FN of July sown Kadiri 6 variety (24.1%) followed by Anantha sown during 1st FN of August (19.5%) and Vemana sown during 2nd FN of July (18.6%). Groundnut crop experienced two dry spells of 21-23 days during pod development stage during 2012, one dry spell of 27-34 days during 2013 and two dry spells of 19-38 days during the year 2014. The late sown crop during 2nd forthnight of August experienced dry spell for more number of days compared to early sown crop. During the period of dry spell, two protective irrigations of 10 mm each were given during 2012, three during 2013 and two during 2014. The water productivity in terms of yield per ha mm of water was higher under protective irrigation than rainfed conditions. All the varieties sown during 2nd fortnight of July (Anantha - 4.33, Vemana - 4.29 and Kadiri 6.4 kg/ha mm) under protective irrigation recorded higher water productivity. All the three varieties sown during the 2nd FN of July under protective irrigation has given significantly higher gross returns, net returns and B:C ratio (Vemana - 3.3, Kadiri 6 - 3.3, Anantha - 3.4) compared to rainfed (Vemana - 3.1, Kadiri 6 -2.9, Anantha - 2.5) crop (Table 1). The pooled analysis of the experimental results revealed that two or three protective irrigations @ 10mm each during the continuous dry spell of 15 days at pod development stage will maximize the groundnut productivity in scarce rainfall zone of Andhra Pradesh. Farmers can attain higher pod yield and economic benefit if the crop was sown during 1st and 2nd forthnight of July and by providing 10mm protective irrigation during prolonged dry spell, utilizing the rain water harvested in the farm ponds.

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Crop contingent planning in scarcity zone of Maharashtra

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Occurrence of normal rain during south west monsoon season (June- September) is very crucial for agricultural production as nearly 65% of Indian agriculture is rainfed. Even during the normal rainfall year some region within the states may get less or scanty rainfall. Timely formultion and implementation of contingent agriculture plan helps to neglate the ill effects of low rainfall on production and productivity of crops in such regions. Such adverse effects on crops can be combated by contingent measures (Joel *et al*., 1996).

METHODOLOGY

Field experiments were conducted during rainy seasons of 2009-2012 at National Agricultural Research Project, Scarcity Zone, Agriculture College, Dhule on medium deep black soil. The experiment was carried out in split plot design with three treatments of sowing dates in main plots and fifteen *kharif* crops in sub plots were tested. The gross and net plot size were 4.50 m x 3.60 m. The crops were sown by dibbling

Table 1. Mean crops yield, pooled cotton equivalent yield, gross, net monetary returns and B:C ratio

Treatment	Crops yieldt/ha	Cotton equivalent yield t/ha	Gross monetary returns (Rs./ha)	Cost of cultivation	Net monetary returns (Rs./ha)	B:C ratio
Sowing date						
S_1-Ist Fortnight of July	13.60	1.064	45313	21676	23637	2.09
S_2-IInd Fortnight of July	10.83	0.798	33669	21393	12276	1.57
S_3-IstFortnight of August	4.84	0.396	16383	20906	-4523	0.79
SEm±	-	0.051	1494	-	2070	-
CD (P= 0.05)	-	0.177	5170	-	7163	-
Kharif crop						
C_1-Pigeon pea	1.42	1.280	53484	21885	31599	2.44
C_2-Sorghum (fodder)	36.33	0.782	34009	16781	17228	2.03
C_3-Cowpea	0.65	0.617	26485	21916	4569	1.21
C_4-Cowpea (fodder)	19.92	0.571	24055	15449	8657	1.56
C_5-Sunflower	0.71	0.581	22941	21810	1131	1.05
C_6-Pearlmillet	1.94	0.576	25064	18877	6327	1.33
C_7-Soybean	1.39	0.824	35672	23434	12238	1.52
C_8-Horsegram	0.59	0.448	18465	18899	-441	0.98
C_9-Maize (fodder)	39.12	1.159	50223	17761	32462	2.83
C_{10}-Clusterbean	1.73	0.722	29479	25356	4123	1.16
C_{11}-Castor	1.95	0.951	40142	26374	13768	1.52
C_{12}-Giant Bajra (fodder)	38.36	0.592	24721	15956	8793	1.55
C_{13}-Cotton	0.88	0.882	38782	31353	7429	1.24
C_{14}-Groundnut	1.03	0.882	36320	26988	9332	1.34
C_{15}-Sesamum	0.32	0.415	16977	17240	-267	0.98
SEm ±	-	0.067	2730	-	2713	-
CD (P= 0.05)	-	0.188	7640	-	7594	-
SEm± AxB	-	0.116	4728	-	4699	
CD (P=0.05) AxB	-	0.326	13233	-	13153	-
SEm ± BxA	-	0.123	4806	-	4990	-
CD (P= 0.05) BxA	-	0.360	13758	-	14534	-

method at spacing *viz*., Pigeon pea (45 cm x 22.5cm), Sorghum fodder (30 cm), Cowpea (30 cm x 10 cm), Cowpea fodder (30 cm), Sunflower (45 cm x 30 cm), Pearlmillet (45 cm x 10 cm), Soybean (45 cm x 10 cm), Horsegram (45 cm x 15 cm), Maize fodder (30 cm), Clusterbean (45 cm x 15 cm), Castor (60 cm x 25 cm), Giant bajra fodder (30 cm), Cotton (45 cm x 22.5cm) Groundnut (30 cm x 10 cm), Sesamum (30 cm x 10 cm). The recommended dose of fertilizer was applied to each crops. The crops were sown at three sowing dates *viz*., S_1-Ist Fortnight of July, S_2-IInd Fortnight of July, S_3-Ist Fortnight of August. The crops were harvested as per maturity. The data on yield, cotton equivalent yield and economics were worked out on per hectare basis. The calculation of growing degree days and helio thermal units required by different sowing dates were worked out for different crops.

RESULTS

The first sowing date (Ist forthnight of July) has recorded significantly maximum yield of all crops. Significantly highest cotton equivalent yield, gross and net monetary returns was recorded with the first sowing date amongst the three sowing dates over the season (Table 1). Similarly higher B;C ratio was recorded by the same sowing date over the rest of the sowing dates. Among the crops fodder maize has recorded higher crop yields over the period of season. Whereas the pigeonpea recorded significantly highest cotton equivalent yield among the all the 15 crops under study over the season and it was at par with maize fodder. The interaction effects revealed that, the maize fodder crop gave significantly highest cotton equivalent yield followed by pigeon pea over the season, which is at par in first sowing. The same trend observed in second sowing over the season. In third sowing the pigeon pea gave significantly highest cotton equivalent yield. In case of the grossmonetary returns and B:C ratio the same trend observed over the season. However the maize fodder crop recorded highest net monetary returns in first and second sowing. In third sowing the pigeon pea registered highest net monetary returns than all the crops under study. The four year means growing degree days (GDD) and helio thermal units (HTU) influenced by different sowing dates. It is observed that the highest mean value of GDD was recorded with first sowing date followed by second and third sowing date. The mean maximum GDD required by Caster & lowest by sorghum fodder crop. The same trend was observed in case of HTU. In case of HTU, the higher values were required by third sowing, followed by second and first, respectively. Among the crops the HTU recorded by castor followed by pigeonpea crop and minimum HTU required by sorghum crop.

CONCLUSION

In contingent crop planning first sowing date were recorded significantly higher yield of different crops, cotton equivalent yield, gross, net monetary returns and higher B;C ratio. Among the crops pigeon pea followed by fodder maize shown good performance in case of yield and economics in three sowing dates.

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Relative efficiency of various moisture regimes and weed control practices in FIRBS planted maize (*Zea mays* L.) under semi-arid conditions

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Maize is a versatile crop and can be grown under diverse agro climatological regions ranging from tropical to temperate conditions. In Haryana, maize is usually grown during *kharif* season and yields tended to be low due to high as well as low moisture stresses and severe weed competition being the most important factors. Maize could be an alternative to water guzzling rice provided its productivity is enhanced to the level of economic competitiveness. The present yield levels of maize in India (2.48 t/ha) and Haryana (2.67 t/ha) are very low i.e., < 50% of the world average (5.18 t/ha) (Anonymous, 2013). In *kharif* (rainy season) maize water management is essential for achieving potential yields with high water productivity. It also suffers heavily from weeds and yield losses can vary from 28-100% (Patel *et al.,* 2006). Furrow irrigated raised bed system (FIRBS) of planting crops enhance yields, improves water productivity and facilitates better weed management (Kumar *et al*., 2014). Therefore, refinement of water and weed management practices and their integration under FIRBS plantation need to be evaluated for achieving higher and stable yields.

METHODOLOGY

The field experiment was conducted at Research Farm of Department of Agronomy, Chaudhary Charan Singh Haryana Agricultural University, Hisar during *kharif* 2013 to study irrigation scheduling and weed management strategies on furrow irrigated raised bed (FIRB) planted maize. The soil was slightly alkaline (pH=8.2), sandy loam in texture with low available N, medium P and K. It contained 17.7% moisture at -0.03 MPa (FC) and 5.2% at -1.5 MPa (PWP). Four irrigation schedules viz., irrigation at 80, 120, 160 and 200 mm cumulative pan evaporation (CPE) in main plots and five weed treatments *viz.,* weed free, weedy check, pendimethalin (1000 g/ha) (pre emergence), atrazine (750 g/ha) (pre emergence) and tembotrione (120 g/ha) (15-20 DAS) in sub plots were studied. Maize hybrid HQPM-1 was dibbled on the top of bed keeping 75 cm row and 20 cm plant spacing. During the *kharif* season of maize crop a total of 564.3 mm well distributed rainfall was received and therefore one irrigation was applied at 80 mm CPE only.

RESULTS

Different moisture regimes viz. irrigation at 80, 120, 160 and 200 mm CPE interval had no significant influence on total weed density and weed dry weight at harvest in maize crop. Maximum weed control efficiency (WCE) of 61.5% was recorded under irrigation applied at an interval of 80 mm CPE which was significantly higher as compared to other moisture regimes *viz.,* 120 mm, 160 mm and 200 mm CPE which remained at par with each other. Pre-emergence application of atrazine at 750 g/ha and post-emergence application of tembotrione at 120 g/ha being at par with each other, resulted in significantly lower weed density as compared to pre emergence application of pendimethalin at 1000 g/ ha and weedy check. Among the herbicidal application, weed density was significantly higher under pre emergence pendimethalin at 1000 g/ha as compared to pre emergence application of atrazine at 750 g/ha and post-emergence application of tembotrione at 120 g/ha but it was substantially lower than weedy check. Similar trend was observed in weed dry matter at harvest. Herbicides *viz.,* pre emergence application of atrazine at 750 g/ha and post emergence application of tembotrione at 120 g/ha being statistically similar with each other resulted in substantially higher WCE of 63.5 & 61.4 % over pre emergence application of pendimethalin at 1000 g/ha and weedy check.

Irrigation applied at 80 mm CPE interval resulted in significantly higher grain yield of maize (5210 kg/ha) as compared to 120 mm, 160 mm and 200 mm CPE. The difference among the latter three irrigation regimes was found to be non-significant. Grain yield of maize was found to be statistically similar among weed free, pre emergence application of atrazine at 750 g/ha and post-emergence application of tembotrione at 120 g/ha treatments but was significantly higher over weedy check and pre emergence application of pendimethalin at 1000 g/ha.

Table 1. Weed growth and yield of maize under different irrigation and weed control treatments

Treatment	Weed density at harvest (No./m^2)	Weed dry matter at harvest (g/m^2)	Weed control efficiency (%)	Maize grain yield (kg/ha)
Irrigation scheduling				
80 mm CPE	6.21(47.5)	6.47(53.7)	61.5	5210
120 mm CPE	6.10(46.1)	6.66(53.5)	52.4	5008
160 mm CPE	6.01(44.5)	6.63(52.8)	47.9	4938
200 mm CPE	5.97(43.0)	6.62(52.7)	49.3	4913
SEm±	0.08	0.06	2.0	43
CD at 5%	NS	NS	6.8	150
Weed control practices				
Weed free	1(0)	1 (0)	100.0	5648
Weedy check	10.30(105.2)	10.72(114.5)	0.0	3634
Pendimethalin (PRE), 1000 g/ha	7.66(57.7)	8.30(68.1)	39.1	4794
Atrazine (PRE), 750 g/ha	5.61(30.7)	6.37(40.4)	63.5	5542
Tembotrione (POST), 120 g/ha	5.80(32.8)	6.59(42.8)	61.4	5468
SEm±	0.08	0.09	1.4	68
CD (P=0.05)	0.23	0.27	3.9	195

Data on weed density and weed dry matter is square root transformed. Values in parentheses are original.

CONCLUSION

Pre emergence application of atrazine at 750 g/ha or post emergence application of tembotrione at 120 g/ha coupled with irrigation at 80 mm CPE was found to be most effective in controlling weeds and improving grain yield of maize during the *kharif* 2013 season.

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Effect of irrigation scheduling and nitrogen levels on yield and water use efficiency of direct seeded rice

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Rice (*Oryza sativa* L.) is the most important food crop of India and provides food security to billions of people in India (Ladha *et al*., 2003). Here, rice is generally grown as irrigated puddle transplanted conditions which consume a lot of water. Further, with looming water threat under changing climatic conditions an additional 500 litres of water will be required to have 1 kg of rice in 2025 (Kukal *et al*., 2010). Direct–seeded rice (DSR) is one of alternative of puddled transplanted rice which requires less water, labour and tends to mature faster (Chauhan *et al*., 2012). Here, sowing of rice is done under aerobic environment which avoids the puddling and maintains continuous moist soil conditions and thus reduces the overall water demand for rice culture. The infestation of weeds, nitrogen and iron deficiency are the major limiting factor in enhancing the DSR yield. The most of the nitrogen applied through fertilizer is lost from the soil in various ways. There is hardly 30% recovery of applied nitrogen and most of the nitrogen lost through leaching, volatilization, denitrification and runoff kind of processes. One of the major factors contributing to low N use efficiency is the uniform application rates of N fertilizer to spatially variable landscapes (Choudhury *et al*., 2005; Sahrawat, 2000). The adoption of alternative method of rice establishment with better nitrogen management practices to enhance the water and nitrogen use efficiency under increasing water shortage and changing climate is the need of hour. Therefore, an experiment was carried out to study the effect of irrigation and nitrogen on yield and yield attributes, and to optimise the nitrogen and water use efficiency in DSR.

METHODOLOGY

The field experiment was carried out to study effect of irrigation scheduling and split application of nitrogen in direct–seeded rice (DSR) during the *kharif* season of 2015 at the research farm of ICAR-Indian Agricultural Research Institute, New Delhi, India. The experiment was laid out in split plot design with 12 treatments combination of irrigation scheduling (0 kPa; 10 kPa, 20 kPa and 40 kPa irrigation scheduling threshold was maintained between tillering to flowering stages) in main plot and N application of 150 kg/ha as (control (N_0), ½ RDN basal + ¼ at 2 week + ¼ at 5 week and ¼ RDN basal + ¼ at 2 week + ¼ at 5 week + ¼ at 9 week after sowing) in sub plot with 3 replications.

RESULTS

The findings indicated that all yield attributes and yield was observed with irrigation scheduling at 0 kPa i.e. in saturated condition which was found at par with maintaining water threshold in soil through irrigation at 10 kPa. Thereafter irrigation scheduling at higher threshold i.e. 20 kPa and 10 kPa

Table 1. Effect of irrigation scheduling and N application on yield attributes and yield, agronomic and water use efficiency of direct–seeded rice.

Treatment	Effective Tillers/m^2	1,000-grain weight(g)	Grain yield (t/ha)	Net returns (Rs×10^3 ha)	Agronomic efficiency (kg grain increased/ kg N applied)	Water use efficiency (kg/ha-mm)
Irrigation scheduling						
0 kPa	370	23.0	4.83	45.0	2.94	4.26
10 kPa	364	22.8	4.68	45.1	3.55	4.63
20 kPa	353	22.3	4.24	39.2	8.59	4.56
40 kPa*	341	21.6	3.96	37.4	7.10	4.75
SEm±	5.5	0.19	0.13	1.59	0.93	0.140
LSD (P=0.05)	18.9	0.68	0.46	5.51	3.23	NS
Nitrogen application						
Control (N_0)	205	20.5	3.60	28.1	-	3.66
N_1**	279	22.9	4.62	44.8	6.92	4.76
N_2***	286	23.7	5.06	52.1	9.71	5.24
SEm±	2.65	0.09	0.06	0.83	0.47	0.064
LSD (P=0.05)	7.93	0.28	0.18	2.49	1.41	0.19

*10 kPa throughout the growing season except 40 kPa during tillering to flowering; **½ basal + ¼ at 2 week + ¼ at 5 week; ***¼ basal + ¼ at 2 week + ¼ at 5 week + ¼ at 9 week

throughout the growing season except 40 kPa during tillering to flowering recorded a decline in grain yield of DSR during the growing season. This might be due to the positive role of water on plant cell turgidity and adequate availability of nutrients during the plant growing activity (Yadav *et al*., 2011). Likewise, the split application of N significantly influenced the yield attributes and yield of DSR. The highest values of all these parameters were recorded with ¼ RDN basal + ¼ at 2 week + ¼ at 5 week + ¼ at 9 week followed by ½ RDN basal + ¼ at 2 week + ¼ at 5 week. The maximum gross return (‘84.7 × 10³ Rs/ha) and net return (Rs 45.1 × 10³ Rs/ha) were recorded with irrigation scheduling at 0 kPa and 10 kPa, respectively. The split application of N as ¼ basal+ ¼ at 2 week+ ¼ at 5 week + ¼ at 9 week recorded maximum gross return (‘88.7 × 10³ Rs/ha) and net return (‘52.2 × 10³ Rs/ha) followed by ½ basal + ¼ at 2 week + ¼ at 5 week N application. The different threshold of irrigation influenced the concentration and uptake of N in grain and straw of DSR. Likewise, the split application of N as ¼ basal + ¼ at 2 week + ¼ at 5 week + ¼ at 9 week gave the highest values of N uptake and N use efficiency compared to no application of N This could be ascribed as affirmative influence of N on all the growth parameters due to higher N availability to plants in N applied plots compared to control (Kadiyala *et al*., 2012 and Singh *et al*., 2013). Based on the findings, it was concluded that alternative of 0 kPa (complete saturation) could be 10 kPa without any reduction in grain yield of DSR. Likewise, split application of recommended dose of 150 kg N ha-1as ¼ basal + ¼ at 2 week + ¼ at 5 week + ¼ at 9 week gave the highest grain yield and economics in DSR.

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Response of fenugreek (*Trigonella foenum-graecum*) to irrigation schedule at vegetative and reproductive phases and organic manuring under middle Gujarat conditions

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India is the largest producer and consumer of seed spices in the world. Rajasthan and Gujarat has been emerged as "seed spice bowl" and together contribute more than 80 per cent of total seed spices produced in the country but presently, due to low productivity of seed spices, our country is able to meet only 51 per cent of the total global demand.Fenugreek commonly known as *methi,* is one of the important seed spices of India. The productivity of a crop is controlled by many factors, of which mineral nutrition and irrigation are, by and large, the most important factors. Therefore, to sustain the productivity of land and sustainability in the productivity of crop, integration of organic manures with chemical fertilizers and timing the length of irrigation interval with the stages of crop growth might bring about a reduction in the number of irrigations and results in an economic crop yield.

METHODOLOGY

The presentexperiment was conducted during *rabi* seasons of 2010-11 and 2011-12 at College Agronomy Farm, B. A. College of Agriculture, Anand Agricultural University, Anand, Gujarat .The soil of the experimental plot was loamy sand in texture. There were twelve treatment combinations comprising of four irrigation schedules and three levels of organic manures which were tested in a split plot design with four replications. Irrigation schedule treatments were relegated into the main plots and organic manures in sub plots as sub plot treatments. The treatments consisted of four irrigation schedules *viz.*, I_1: (0.6 + 0.8 IW: CPE ratio); I_2: (0.6 + 1.0 IW: CPE ratio); I_3: (0.8 + 1.0 IW: CPE ratio) and I_4 (At critical growth stages) and three levels of organic manures *viz.*, M_0 (No FYM), M_1 (FYM 10 t/ha) and M_2 (FYM 5t/ha + CC 1 t/ha.

RESULTS

Results revealed that grain yield of fenugreek was recorded significantly higher (1827 kg/ha) with the irrigation applied at 0.6 IW: CPE + 1.0 IW: CPE (I_2) over all other treatments except the treatment I_3 (0.8 IW : CPE + 1.0 IW : CPE) which was also found equally effective in respect of grain yield. Irrigation schedules were also found to cause significant variation in moisture content of soil before irrigation, CU, WUE and FWUE wherein, the treatment I_3 (0.8 IW: CPE + 1.0 IW: CPE) recorded the maximum values for moisture content before irrigation (9.64%) and CU (300.28 mm) over all other treatments. With respect to organic manure treatments, the significantly higher grain (1831 kg/ha) and straw yield (2712 kg/ha) and highest moisture content before irrigation (9.08 %), consumptive use (279.48 mm) by crop, WUE (6.58 kg/ha mm) and FWUE (5.59 kg ha^{-1}mm) was recorded under treatment M_2 (FYM 5 t/ha + CC 1 t/ha). From the above findings, it is concluded that potential yield and profit from fenugreek variety GF-2 grown on loamy sand soil under middle Gujarat conditions could be obtained by irrigating the crop at 0.6 IW: CPE ratio (21-27 days interval) during vegetative phase and 1.0 IW: CPE ratio (10-12 days interval) during reproductive phase with one common irrigation immediately after sowing along with organic manures (FYM or castor cake).

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Dry-seeded rice response to planting time, irrigation and cultivar regimes in a sub-tropical environment

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Increasing water scarcity and rapid fall in groundwater table warrant the judicious use of irrigation water and to adopt management strategies that increase water productivity and reduce labour requirement while maintaining or increasing land productivity. Dry-seeded rice (DSR) has been observed to serve as an alternative with reduced water demand by reducing losses due to evaporation, percolation and amount of water needed for land preparation (Bouman and Tuong, 2001). Moreover, it is conducive to mechanization, less labour-intensive and consumes less irrigation water than PTR when using the same irrigation scheduling criteria (Sudhir-Yadav *et al.*, 2011).

METHODOLOGY

The experiment on DSR was conducted at Punjab Agricultural University, Ludhiana, Punjab, India on a sandy loam soil, slightly alkaline with pH of 7.9 and organic carbon content of 0.38 %, during 2014 growing season. The soil contained 73% sand, 15% silt and 12% clay. The experiment was laid out in a split plot design with two planting dates, May 31 (D_1) and June 20 (D_2) as main plots and combination with two irrigation regimes viz., irrigation water to pan evaporation (IW/CPE) ratios of 2.4 and 1.2 with cultivars PR115 (V_1, 125 d) and PR121 (V_2, 140 d) as sub-plots.

RESULTS

Interaction effects of planting dates, irrigation and cultivar regimes on biomass and grain yield showed that early planting date (D_1) recorded higher total biomass in PR115 and PR121 cultivars in $I_{2.4}$ regime than $I_{1.2}$ regime. This could be contributed by higher dry matter accumulation under more frequent than less frequent irrigation regimes. However, biomass and grain yield of PR121 (V_2) under late planting (D_2) was very low under both the irrigation regimes, more so in $I_{1.2}$ regime, due to reduction in air temperature during grain fill stage. Irrespective of planting dates and cultivar duration, yield attributes like effective tillers per square meter and 1000 grain weight were recorded higher in $I_{2.4}$ regime than $I_{1.2}$ regime. The short duration cultivar produced highest effective tillers, biomass and grain weight under late planting while as the long duration cultivar showed highest effective tillers, biomass and grain yield under early planting date.

CONCLUSION

The experiment has shown that under dry seeded PR115 performed well in $I_{2.4}$ irrigation regime under both the planting dates. However PR121 performance was very poor under late planting in both the irrigation regimes.

Table 1. Effect of planting date, irrigation and cultivar regimes on biomass and grain yield, effective tillers/m^2 and grain weight

Treatment	Effective tillers/m^2	1000 grain weight (g)	Grain yield (t/ha)	Biomass (t/ha)
D_1, Planting date May 31 V_1, Cultivar PR115 $I_{2.4}$, IW/CPE ratio 2.4	435	9.6	5.1	11.7
D_1, Planting date May 31 V_1, Cultivar PR115 $I_{1.2}$, IW/CPE ratio 1.2	401	9.3	4.1	10.3
D_2, Planting date June 20 V_1, Cultivar PR115 $I_{2.4}$, IW/CPE ratio 2.4	475	12.6	6.2	12.0
D_2, Planting date June 20 V_1, Cultivar PR115 $I_{1.2}$, IW/CPE ratio 1.2	460	10.8	4.3	10.9
D_1, Planting date May 31 V_2, Cultivar PR121 $I_{2.4}$, IW/CPE ratio 2.4	460	11.5	6.3	12.8
D_1, Planting date May 31 V_2, Cultivar PR121 $I_{1.2}$, IW/CPE ratio 1.2	420	11.4	4.7	10.3
D_2, Planting date June 20 V_2, Cultivar PR121 $I_{2.4}$, IW/CPE ratio 2.4	430	10.5	1.9	8.0
D_2, Planting date June 20 V_2, Cultivar PR121 $I_{1.2}$, IW/CPE ratio 1.2	370	9.8	0.6	6.1

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Determination of water requirement and response of wheat varieties to different numbers of irrigations

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India is an agriculture country and wheat is the second most important cereal crop after rice. Due to climate change water shortage in the country demands to develop new technologies and methods of irrigation that can be helpful to utilize this precious input in an effective way. Knowledge of precise amount of water required by different crops in a given climatic condition of a region will be helpful in planning of irrigation scheme, irrigation scheduling and management of irrigation system. Therefore, there is need to save irrigation water by providing minimum no. of irrigations without affecting the yield by carrying out practices of irrigation water management to achieve higher water use efficiency (WUE). Thus, keeping these facts in view, the study was carried out to determine the water requirements of wheat varieties.

METHODOLOGY

A field experiment was conducted to determining the water requirement of two wheat varieties *viz.* HD-2967 and HD-2894 during *Rabi* seasons of the year 2012-13 and 2013-14 in a sandy loam soil at Research Farm of Water Technology Centre, IARI, New Delhi. Irrigation treatment consisted of I1-one irrigation, I2-two irrigations, I3-three irrigations, I4-four irrigations and I5-five irrigations based on 50% Soil Moisture Depletion (SMD) which were arranged in split plot design with four replications. Moisture contents for irrigation were recorded from a root zone of 90 cm (from five depths viz., 0–15, 15–30, 30–45, 45-60 and 60–90 cm). Data on meteorological parameters like temperature and rainfall were also recorded during the period. The amount of water applied to each treatment was calculated on the basis of the soil moisture contents at the time of irrigation.

RESULTS

The results showed that yield was significantly affected by numer of irrigations as well as varieties. The interactive effect of variety and number of irrigation was also found significant. Both the varieties gave significant response up to three irrigations (I3) only. The water use efficiency for varieties HD-2967 and HD-2894 was 198 kg/ha.cm and 190 kg/ha.cm, respectively during the year 2012-13 and 190 kg/ha.cm & 167 kg/ha.cm, respectively, during the year 2013-14. Naeem and Rai (2005) determined water requirement and response of some wheat cultivars to irrigation at 50% and 70% SMD levels and it was found that grain yield, harvest index and water use efficiency were greater when irrigation was applied at 50% SMD and was reduced at 70% SMD. The total amount of water applied to wheat varieties HD-2967 and HD-2894 was 25.5 cm including pre-sowing irrigation and rainfall during the growing period and the corresponding yield was 5.04 t/ha and 4.86 t/ha, respectively in the year 2012-13 and during the year 2013-14, the total amount of water applied is 27.5 cm and the corresponding yield was 5.23 t/ha and 4.59 t/ha, respectively. The optimum water requirement for both of the varieties was only three irrigations including rainfall in which highest yield was obtained during both years.

CONCLUSION

In the present study, water requirement of two wheat varieties was estimated and it was observed that yield was significantly affected by number of irrigations as well as varieties. The interactive effect of variety and number of irrigation was also significant. Both the varieties gave significant response up to three irrigations (I3) only. Therefore, it can be concluded that, this type of study would be useful for precise irrigation in wheat crop where farmers will supply the required amount of water and reduce wastage of water.

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Technologies for improving water use efficiency in agriculture – success stories from rainfed Shivalik

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The water level in India has declined drastically (10-20 cm per year) depending upon the local hydrological conditions. Since, there is little scope for further exploitation of water resources, the alternative is to increase the water use efficiency of crops to obtain higher yield per unit of water applied. Shivaliks in Himachal Pradesh, Punjab, Jammu and Kashmir, Uttaranchal, Haryana and union territory of Chandigarh occupy about 3.1 m ha and represent most fragile ecosystem of Himalayas and characterized by barren hill slopes, undulating agricultural fields, too high or too low rainfall and lack of resource to invest on other inputs..Increasing water use efficiency (WUE) implies lowering the water needs to achieve higher yield. Two or three supplemental irrigationshas the potential to improve total water use, grain yield and water use efficiency of crops in Shivaliks.

METHODOLOGY

The most widely applicable expression of water use efficiency is agronomic or crop water use efficiency, which is defined as the amount of dry matter produced per unit amount of water consumed by the crop. Water use efficiency (WUE) of the crop was computedusing the formula:Water use efficiency (kg/ ha.mm) = Seed yield (kg/ha)/ Water use (mm)

RESULTS

Water harvesting for enhancing water productivity- a case

Table 1. Total water use, grain yield and water use efficiency of wheat

Wheat growing season	Seasonal rainfall (mm)	Total water use (mm)			Wheat grain yield (t/ha)			Water use efficiency (kg/ha.mm)		
		I_2	I_1	I_0	I_2	I_1	I_0	I_2	I_1	I_0
1977-78	193 (Normal)	511	421	299	4.26	3.08	1.63	8.4	7.3	5.5
1978-79	298 (High)	517	453	394	4.64	3.36	1.90	8.9	7.4	4.8
1979-80	79 (Low)	374	206	85	3.35	1.32	0.38	9.0	6.4	4.5

I_0 = No irrigation; I_1 = One irrigation at pre-sowing; I_2 = Two irrigations at pre-sowing + crown root initiation stage

Table 2. Effect of mulches on grain yield and water use efficiency of *Rabi* crops

Treatment	Grain yield (kg/ha)			Water use efficiency (kg/ha.mm)		
	Mustard	Gram	Taramira	Mustard	Gram	Taramira
Control	783	988	574	3.30	3.98	2.47
Grass mulch (2t/ha)	949 (21)	1175 (19)	688 (20)	4.09	4.86	3.03
Grass mulch (2t/ha)	1100 (40)	1309 (32)	776 (35)	4.87	5.54	3.49
Grass mulch (2t/ha)	1185 (51)	1412 (43)	865 (51)	5.36	6.14	4.00

Figures in parenthesis are percent increase over control study in Sukhomajri watershed: Supplemental irrigation from harvested rain water was found to improve total water use, grain yield and water use efficiency of wheat in Sukhomajri watershed (Table 1). Mulching for increasing water use efficiency: Studies conducted at research centre, Chandigarh, have indicated the possibility of increasing wheat yield by 58% by providing grass much during Rabi season. The yield of rainfed mustard, chick pea and taramira increased substantially with grass mulch application (Table 2).

CONCLUSION

Supplemental irrigation along with proper fertilization and soil moisture conservation technologies have significant potential to improve crop yield and water use efficiency in rainfed Shivalik. Rainwater harvesting techniques with a hydraulically efficient water conveyance, application and distribution system coupled with geometrically efficient irrigation layout will complement to the premise of more crop and income per drop of water.

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Effect of moisture conservation practices and grasses on productivity of *Hardwickia binata* based silvopasture systems

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Development of silvopasture systems by introducing trees into natural pasture lands and waste lands provides nutritious green forage and foliage to small ruminants for getting higher production from unit of land in rainfed areas (Rao, 2010). Under rainfed conditions, productivity of silvopasture system is often poor because of dominance of low yielding annual grasses and lack of moisture. In this context, introduction of suitable grasses in association with tree and construction of moisture conservation practices can play a vital role in improving the productivity of natural pasture lands and wastelands. *Hardwickia binata* belongs to the family Leguminocae sub-family Caesalpinioideae and considered to be an important multipurpose tree species in semi-arid conditions of India. It provides extremely hard, heavy and durable timber in addition to high quality forage and fire wood (Roy, 1996). In view of this the present study was carried out to study the effect of moisture conservation practices and grasses on productivity of *Hardwickia binata* based silvopasture systems in semiarid rainfed conditions.

METHODOLOGY

A field experiment was conducted on sandy loam soil during 2013-2016 at Central Research Farm (25^0 27' N latitude, 78^0 37' E longitude and 275 m above mean sea level) of Indian Grassland and Fodder Research Institute, Jhansi to study the effect of moisture conservation practices and grasses on productivity of *Hardwickia binata* based silvipasture systems in semiarid rainfed conditions. There were 9 treatment combinations replicated thrice in randomized block design. The treatment consisted of establishment of three grasses viz. *Cenchrus ciliaris, Chrysopogon fulvus* and *Panicum maximum* and construction of three moisture conservation practices viz. staggered trenches (2 m x 0.5 m x 0.5 m), bunding and control (without bund and staggered trenches). *Hardwickia binata* was uniformely planted at a distance of 6 x 6 m in all the experimental plots and grasses were transplanted at 100 x 50 cm spacing and *Stylosanthes hamata* seed @ 4 kg/ha were sown in line between two rows of grasses in association with *Hardwickia binata*. Harvesting of pasture was done at 50 % flowering stage in second fortnight of September in each year. The trees were pruned once every year during November- December for proper growth, form and yield. Dry matter content was estimated by drying 500 g plant sample of each treatment and replication in hot-air oven at 70^0C, which led to computation of dry matter yield.

RESULTS

Pooled data of three years showed that construction of bund resulted in significantly higher total dry forage yield from pasture (6.90 t/ha) than control treatment (5.83 t/ha) and found at par with staggered trenches (6.51 t/ha) in *Hardwickia binata* based silvopasture systems. Through *in-situ* moisture

Table 1. Effect of moisture conservation practices and grasses on dry forage yield of pasture, growth parameters and pruned dry yield of *Hardwickia binata*

Treatment	Dry forage yield (t/ha)	*Hardwickia binata*				
		Height (m)	Diameter at breast height (cm)	Canopy spread (m)	Pruned dry yield (t /ha)	
					Leaves	Fire wood
Grasses						
C. ciliaris	6.45	6.17	10.81	2.70	0.83	0.74
C. fulvus	6.27	6.12	10.75	2.68	0.80	0.72
P. maximum	6.53	6.00	10.65	2.61	0.76	0.69
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Moisture conservation practices						
Control	5.83	5.91	10.51	2.60	0.74	0.67
Trenches	6.51	6.28	10.93	2.73	0.86	0.76
Bund	6.90	6.09	10.78	2.66	0.80	0.72
CD (P=0.05)	0.47	0.18	0.32	0.09	0.08	0.07

conservation, there was higher moisture regime in the root zone of pasture which enhanced forage yield. Kumar *et al*. (2010) have also reported significantly higher pasture yield by construction of bund than without bund in ber based hortipasture system. In pasture species, establishment of different grasses in association with *Hardwickia binata* did not influenced significantly the dry forage yield of pasture (Table 1). However, *Panicum maximum* recorded maximum dry forage yield (6.53 t/ha) followed by *Cenchrus ciliaris* (6.45 t/ha) and *Chrysopogon fulvus* (6.27 t/ha). In *Hardwickia binata* growth parameters and pruned yield did not affected significantly by establishment of different grasses (Table 1). However, construction of staggered trenches recorded significantly higher height (6.28 m), diameter at breast height (10.93 cm), canopy spread (2.73 m), dry leafy forage yield (0.86 t /ha) and fire wood (0.76 t /ha) of *H. binata* as compared to control treatment (without trenches- height 5.91 m, diameter at breast height 10.51 cm, canopy spread 2.60 m, leafy forage yield 0.74 and fire wood 0.67 t /ha) in 8th year of establishment. The higher growth parameters and pruned yield of *H. binata* in staggered trenches may be attributed to sufficient moisture regime in the root zone of tree in these plots. Kumar *et al.* (2012) also reported higher growth and production of Guava by construction of staggered trenches.

CONCLUSION

It can be concluded that intercropping of Guinea grass with *S. hamata* in association with *Hardwickia binata* recorded maximum dry forage yield followed by *Cenchrus ciliaris* and *Chrysopogon fulvus* in sandy loam soil. In moisture conservation practices, construction of bund produced maximum dry forage yield from pasture followed by staggered trenches. In *H. binata* construction of staggered trenches resulted in highest growth parameters and pruned dry leafy forage yield and fire wood in 8th year of establishment.

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Effect of moisture conservation practices and seed hardening on pearlmillet [*Pennisetum glaucum* (L.) R.Br.] under rainfed conditions

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India is the largest producer of pearlmillet with an annual production of 10.05 million tonnes from an area of 8.69 millionha (AICMIP, 2014). Rajasthan constitutes about 50% area and 42% of production of pearlmillet in the country. Soil moisture conservation practices such as modification in surface configuration by making ridge and furrow after sowing and use of mulches may help to conserve soil moisture and enhances availability of soil moisture for a longer duration for better crop production. Chemicals like KNO_3 at variable concentrations promote germination of seeds, improve seedling growth, activity of various hydrolyses, solubilization and mobilization of nitrogen from cotyledons to growing embryo, rate of water uptake, resulting in improvement of nitrate content and enhanced yield in crops. Salicylic acid is a phenolic plant growth regulator having a role in regeneration of physiological processes in plants (Sakhabutinova, *et al*., 2003). Thus, seed hardening is a practice adopted to make crop plants resistant to soil moisture stress.

METHODOLOGY

An experiment was conducted at Agronomy Farm, Swami Keshwanand Rajasthan Agriculture University, Bikaner in *kharif* season of 2013. The area has arid ecosystem (hot arid eco-region with desert and saline soil), which is characterized by deep, sandy and coarse loamy, desert soils with low water holding capacity, hot and arid climate. The total rainfall received during the crop growth period was 151.5 mm in 13 rainy days with weekly mean evaporation ranged from 6.1 to 10.4 mm per day. The eighteen treatment combinations comprising of modification in surface configuration as ridge and furrow at 20 DAS and flat sowing and dust, straw and plastic mulch as main plot treatments. Sub plot treatment comprised of seed hardening with KNO_3 0.02%, salicylic acid 100 ppm and without seed hardening. The treatments were laid out in split plot design with four replications. The test pearlmillet variety 'RHB-177' was sown at 45cm x10 cm spacing using seed rate of 4 kg/ ha. The recommendeddose of fertilizers (40kg N/ha, 20 kg P_2O_5/ ha and 30 kg K_2O/ ha) wasapplied at the sowing as basal. N, $P_2O_5$and K_2O were applied through urea, single superphosphate and murate of potash, respectively. Waste straw mulch of pearl millet @ 2.5 t/ hawas spread over the soil surface between the rows of crop.

RESULTS

The results indicated that modification in surface configuration as ridge and furrow significantly increased dry matter accumulation, total number of tillers/plant, CGRand RGR over flat sowing method Similarly, the effective tillers/plant, ear head length, ear head diameter, test weight, grain yield, stover yield and biological yield was alsosignificantly increased with the modification in surface configuration as ridge and furrow method over flat sowing. Modification in surface configuration as ridge and furrow enhanced grain yield to the tune of 22.2 per cent over flat sowing. Ridge and furrow method alsoincreased nitrogen, phosphorus and potassium content and uptake in grain and stover, and total uptake of N, P, and K over flat sowing. Ridge and furrow practice of sowing a way of modification in surface configuration proved more effective and gave significantly higher water use, water use efficiency, net return (23985/-ha) and B: C ratio (2.92). Results further showed that application of plastic mulch significantly improved dry matter accumulation, total number of tillers/ plant, CGR and RGR and yield attributing characters viz. effective tillers/plant, ear head length, ear head diameter, test weight, grain yield, stover yield and biological yield. Nitrogen, phosphorus and potassium content and uptake by grain and stover and total uptake of N, P, and K over rest of the treatments. Application of plastic mulch enhanced the grain yield to the tune of 14.4 and 48.8 per cent over straw and dust mulch, respectively. It also fetched the maximum net return (28189/ ha) and B: C ratio (3.29) as against 14184/ haand 2.31recorded under dust mulch, respectively.Results further revealed that pre sowing seed hardening treatment with KNO_3 significantly improved plant height (60 DAS and at harvest), dry matter accumulation, total number of tillers/plant, CGR and RGR and yield attributing characters viz. effective tillers/ plant, ear head length, ear head diameter, grain yield, stover yield and biological yield. Content and Uptake of nitrogen, phosphorus content in stover, and potassium by grain and stover and total uptake by pearl millet and water use and water use efficiency were also higher in KNO_3 treatment over without seed hardening. Seed hardening with KNO_3 enhanced the grain yield to the tune of 10.5 per cent over without seed hardening. It also fetched the maximum net return (22765/ ha) and B: C ratio (2.86) as against 19482/ haand 2.64 recorded under without seed hardening, respectively.

CONCLUSION

It is concluded that application of moisture conservation through modification in surface configuration as ridge and furrow, plastic mulch and seed hardening with 0.02% KNO_3 significantly enhanced grain yield of pearl millet by 22.2, 48.8 and 10.5 per cent, respectively and gave net return 23985, 28189 and 22765/ ha, with B: C ratio of 2.92, 3.29 and 2.86, respectively.

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Effect of pyrolysis temperature and feedstock on characteristics and stability of biochar in three different soils

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Biochar, a solid elemental C obtained by the process of thermo chemical conversion of biomass in oxygen-limited environment is a much more durable C than parent plant biomass or most forms of C in soil organic matter (Lehmann *et al.*, 2009). Although the understanding of the stability of biochar C in soil has improved in recent years (Ameloot *et al.*, 2013) but very little information is available on the interaction of biochar with soil organic matter (SOM). Biochar is reported to increase (positive priming), decrease (negative priming) or no effect on the mineralisation of native SOM (Purakayastha *et al.*, 2016). The magnitude and direction of "priming effect" is largely controlled by pyrolysis temperature, biochemical composition of feedstock and production conditions. Recently, Purakayastha *et al.* (2016), however, reported that the interaction of biochar with SOM varies with soil type. The objective of the present investigation was to study the effect of pyrolysis temperature on chemical, physic-chemical and spectral characteristics of biochar and their stability in Alfisol, Inceptisol and Mollisol.

METHODOLOGY

The biochar was prepared from rice husk (RHBC), sugarcane bagasse (SBBC) and mustard stalk (MSBC) in a biochar maker at 400°C, 500°C and 600°C in nitrogen atmosphere. Biochar was characterised for pH, EC, CEC, total C, N, H, O, Ca, Mg, P, K, WHC, BD. The spectral analysis of biochar was done by XRD and FTIR (Bera, 2011). The stability of biochar is being carried out in three soils belonging to Alfisol, Inceptisol and Mollisol by long-term C mineralization study.

RESULTS

Increase in pyrolysis temperature increases pH, EC, total carbon (TC), total nitrogen (TN), total phosphorus (TP), total potassium (TK), total calcium (Tca), total magnesium (TMg) and ash contents but decreases cation exchange capacity (CEC) of biochar. Among the biochar, SBBC exhibited highest pH (8.98–11.4) followed by MSBC (8.50-11.0) and rice RHBC (6.22-9.72) (Table 1). The EC and CEC was observed highest in MSBC and it was lowest in RHBC.

The stability of biochar prepared from rice husk, sugarcane bagasse and mustard stalk at three pyrolysis temperature, 400 °C, 500 °C and 600 °C was studied in Inceptisol, Alfisol and Mollisol under long-term C mineralization study continued for 137 days. The stability of biochar was greatly influenced by type of feedstock, pyrolysis temperature and soil type. In Alfisol, increase in pyrolysis temperature significantly decreased C mineralization from all the three biochar indicating their greater stability at 600°C than 400°C (Fig. 1). Among the biochar, RHBC was most stable followed by SGBC and MSBC in Alfisol. The RHBC showed significantly lower C

Table 1. Effect of pyrolysis temperature on physico-chemical properties of biochar prepared from rice husk (RHBC), sugarcane bagasse (SBBC), mustard stalk biochar (MSBC)

Biochar	pH			EC(ds/m)			CEC (cmol (p+)/kg)		
	400 °C	500 °C	600°C	400 °C	500 °C	600 °C	400 °C	500 °C	600 °C
RHBC	6.22	9.77	9.72	0.22	0.19	0.21	24.1	13.4	9.96
SBBC	8.98	11.3	11.4	0.20	0.45	0.58	29.7	22.9	17.2
MSBC	8.47	10.1	11.0	2.41	3.25	4.76	42.0	32.9	25.3
CD (P=0.05)	0.14			0.21			1.41		

minearalization than the treatment with soil without biochar (control) indicating strong negative priming of native soil organic carbon in Alfisol. In Inceptisol, increase in pyrolysis temperature significantly decreased C minelization from SGBC and MSBC, while an opposite trend was observed in the case of RHBC which showed higher C mineralization at 600°C than 400°C.In Inceptisol, a strong negative priming effect was observed in the case of SGBC at 400°C and 600°C and RHBC at 400°C. In Mollisol increase in pyrolysis temperature significantly decreased the C mineralization from SGBC while a reverse trend was evident in the case of RHBC and no effect was observed in the case of MSBC. The negative priming effect was strongest in SGBC at 600 °C followed by RHBC at 400 °C, SGBC at 400 °C and RHBC at 600 °C.

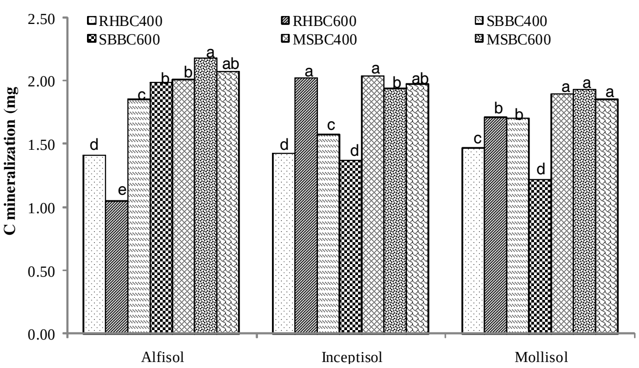

Fig. 1. Effect of pyrolysis temperature in C mineralization from rice husk biochar (RHBC), sugarcane bagasse biochar (SBBC), mustard stalk biochar (MSBC) applied in Alfisol, Inceptisol and Mollisol over 137 day of incubation, bars with different lowercase letters are significant according to Duncan's Multiple Range Test at 5% level of significance

CONCLUSION

The study clearly demonstrated that biochar prepared at 600°C had higher stability than that prepared at 400°C. The stability of biochar was strongly influenced by soil type, in Alfisol the RHBC at 600°C showed greater stability while in Inceptisol and Mollisol the stability was greater in case of SBBC. The biochar which showed greater stability could be advocated for long-term C sequestration in soil. However, the biochar which has higher pH and EC should be used with a caution.

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Energetic of rice as influenced by irrigation regimes and nitrogen management practices under MSRI and SRI

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Traditional planting has been the most important and common method of crop establishment practice under irrigated lowland rice ecosystems in India. In irrigated lowland rice which not only consumes more water but also causes wastage of water resulting in degradation of land. In India, the area under rice crop is decreasing year by year due to various factors such as urbanization, migration of labour from agriculture to non agriculture sector, increased input and labour costs are seriously threatening the cultivation of rice (Yadav *et al.*, 2013). In recent years to tackle this problem, many methods of cultivation have been developed and one among them is System of Rice Intensification (SRI).The mechanical transplanting of rice has been considered the most promising option, as it saves labour energy, ensures timely transplanting and attains optimum plant density that contributes to high productivity. Therefore, in this contest a field experiment was conducted to evaluate the energy productivity of rice under mechanized system of rice intensification and system of rice intensification.

METHODOLOGY

A field experiment was conducted on a clay loam soil at Indian Institute of Rice Research (IIRR) formerly Directorate of Rice Research (DRR), Rajendranagar, Hyderabad, Telangana during the *kharif*seasons of2013 and 2014 to evaluate the **"**Energetic and economics of Rice under Mechanized SRI and SRI**"**. The variety was used Varadhan (DRR Dhan 36). The treatments consisted of two planting methods (Mechanized system of rice intensification (MSRI) and system of rice intensification (SRI)) as main plot treatments, three irrigation regimes (saturation, 5 cm irrigation at three and five days after disappearance of ponded water) as sub plot treatments and four nitrogen management practices (RDN - 100 % through inorganic, RDN - 75 % inorganic and 25 % organic, Leaf Colour Chart (LCC) based nitrogen application and Soil Test Crop Response (STCR) based nitrogen application with target yield of 6.5 t/ha) as sub-sub plot treatments summing up to 24 treatment combinations laid out in split-split plot design with three replications. Yangio - China paddy transplanter [Self-propelled rice transplanter] was used in the preset field experiment. The transplanter is fitted with diesel engine and transplants seedlings from mat type nursery in eight rows (spacing 23.8 cm) in a single pass. The total amount of nitrogen fertilizers were applied for rice during both the crop seasons have been given in Table 1.

RESULTS

The input energy required was 4.50 % higher in MSRI as compared to SRI. This was mainly because of machine transplanter consuming higher input energy in MSRI whereas; labour energy used was minimum in SRI. The SRI had 4.82 % higher gross output energy and 6.02 % higher net energy over MSRI. Owing to higher grain and straw yield in SRI led to higher gross output energy and net energy. System of rice intensification recorded significantly higher energy use efficiency (9.45 %) over MSRI. Saturation treatment (19.67 GJ/

Table 1. Nitrogen applied (kg/ha) in nitrogen management practices treatments at MSRI and SRI during *Kharif* 2013 and 2014

Nitrogen management practice treatments	2013			2014		
	Inorganic	Organic*	Total	Inorganic	Organic*	Total
RDN (100 % inorganic)	120	-	120	120	-	120
RDN (75 % inorganic and 25 % organic)	90	30	120	90	30	120
LCC based N application	130	-	130	130	-	130
STCR based N application (Target yield - 6.5 t/ha)	145	-	145	150	-	150

*Organic source: Vermicompost (1.5 % N) 2 t/ha

Table 2. Energetics of rice as influenced by planting methods, irrigation regimes and nitrogen management practices during *kharif*(2013 & 2014) pooled means

Treatments	Energy input (GJ/ ha)	Gross energy output (GJ/ha)	Net energy (GJ/ ha)	Energy use efficiency (%)	Energy productivity (kg MJ)	Energy intensity in economic terms (MJ/)
Planting methods (M)						
MSRI	19.72	171.00	151.28	8.68	0.642	4.26
SRI	18.87	179.25	160.38	9.50	0.704	4.31
CD (P=0.05)	-	1.63	1.63	0.08	0.005	0.03
Irrigation regimes (I)						
Saturation	19.67	181.94	162.27	9.27	0.686	4.32
3 DADPW	19.32	180.33	161.01	9.35	0.692	4.37
5 DADPW	18.90	163.11	144.21	8.65	0.641	4.16
CD (P=0.05)	-	3.66	3.66	0.18	0.013	0.09
Nitrogen management practices (N)						
100 % RDN (inorganic)	18.07	167.76	149.69	9.29	0.688	4.31
75% inorganic + 25% organic	20.24	174.61	154.37	8.63	0.639	3.70
LCC based nitrogen	19.29	179.74	160.44	9.32	0.690	4.58
STCR targeted yield 6.5 t/ha	19.58	178.40	158.82	9.11	0.675	4.54
CD (P=0.05)	-	3.60	3.60	0.19	0.014	0.09
Interactions	-	NS	NS	NS	NS	NS

SRI - System of Rice Intensification; MSRI - Mechanized System of Rice Intensification
DADPW - Days after disappearance of ponded water; LCC- Leaf Colour Chart; STCR – Soil Test Crop Response, NS – Non significant

ha) recorded significantly higher input energy followed by irrigation at 3 DADPW (19.32 GJ/ha). Among irrigation regimes, saturation treatment registered significantly higher gross output energy (181.94 GJ/ha) and net energy (162.27 GJ/ha) which were at par with irrigation at 3 DADPW 180.33 and 161.01 GJ/ha, respectively but both these treatments were significantly superior over irrigation at 5 DADPW (163.11 and 144.21 GJ/ha), respectively (Table 2). The highest input energy was recorded in RDN (75 % inorganic and 25 % organic) 20.24 GJ/ha as compared to other nitrogen management practices. This was due to organic source (vermicompost) had higher input energy than inorganic fertilizer sources. Application of nitrogen based on LCC and STCR recorded significantly higher gross output energy and net energy (179.74 and 178.40 GJ/ha, respectively) as compared to other nitrogen management practices. The lowest energy use efficiency was 8.63 % in RDN (75 % inorganic and 25 % organic) management practice.

CONCLUSION

It may be concluded that, the gross energy output, net energy, energy use efficiency, energy productivity and energy intensity in economic terms recorded were significantly higher with SRI over MSRI. MSRI required higher input energy as compared to SRI. Irrigation at 3 DADPW recorded significantly higher energy use efficiency, energy productivity and energy intensity in economic terms which were at par with saturation treatment. Nitrogen application based on LCC recorded significantly higher gross energy output, net energy, energy use efficiency, energy productivity and energy intensity in economic terms as compared to other nitrogen management practices.

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Effect of alternate wetting and drying irrigation regimes using practical indicator tool field tube in rice

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Rice, the staple food of 2.7 billion people as well as prolific user of water, are at risk of severe water shortage and hence food insecurity. To cope with looming water crisis, we must sought water saving technologies to maintain and to increase rice production for meeting world's food needs with less water. Water is the single most important component of sustainable rice production, especially in the traditional rice growing area. More than 75 percent of the world's rice is produced under these conventional irrigation practices. It is shown that traditional method with continues flooding need tremendous amount of water for rice cultivation and gives low water productivity. Already different techniques in rice are there to reduce the water requirement including other production factors. However, the monitoring and regulations are very difficult to control timing and the quantity of water. It is also not really match with the actual time of water requirement according to the local soil condition. In the case of alternate wetting and drying system, irrigation under various establishment methods and even under SRI system the irrigation adopted only provisionally and not suits with actual time of crop requirement or not a demand based approach. Its efficiency and suitability have to be assessed for effective irrigation and an easy tool to the farmers to regulate the irrigation as per demand driven approach. Hence the experiment was carried out to evaluate the field under alternate wetting and drying with water tube in rice.

METHODOLOGY

Field experiment was conducted at Agricultural College and Research Institute, Killikulam during *Rabi* season of 2012 with the variety of ADT (R) 47. Irrigation management practices were assigned to the main plots in split plot design *viz.,* Conventional practice of Irrigation (CI) (5 cm depth of irrigation one day after the disappearance of previously ponded water), AWDI at 10, 15 and 20 cm drop of below surface water using monitoring device field tube and SRI irrigation practice (2.5 cm depth of irrigation and reirrigation given after the formation of hair line cracks). The plastic pipe of 40-cm length and 100cm diameter was used for preparing the field water tube. The tube was perforated with 2 mm holes on all sides leaving 15cm without perforation at one end. It was fitted to the treatment plots closure to the bund, which required the field water tube for regulating the irrigation schedule. The perforated portion of the tube 25 cm was inserted into soils leaving non-perforated 15cm length to projected above the soil surface. The soil inside the tube was removed and provided with float device calibrated to measure the drop in the water directly by the mark of the float stem. As per the treatment schedule of drop in water level is monitored and irrigation schedule was adopted in each treatments. The quantum of water applied was measured with parasol flume fitted in the feeding channels.

RESULTS

Analysis of crop performance as related to water supply and use will enable to gauge the benefits or otherwise of the treatments. Studies on total consumptive water use and its final use efficiency will help to rationalize the water application and its use. The higher consumptive water use (1083 mm) was obtained under conventional irrigation practice. AWDI at 20 cm drop of water table (845 mm) and 15 cm drop of water table (882 mm) using field water tube recorded reduced water use. Increased number of irrigations under conventional irrigation practice *i.e.* 5 cm depth of irrigation, one day after the disappearance of previously ponded water, which in turn increased the daily rate of water use. Lack of substantial increase in grain yield in proportion to the water units used re-

Table 1. Effect of Irrigation regimes on water use, water use efficiency and grain yield

Irrigation regime	Consumptive water use (mm)	Water use efficiency (kg/ha-mm)	Grain yield (kg/ha)
I_1 CI practice	1083	5.46	5909
I_2 AWDI at 10 cm	986	5.85	5769
I_3 AWDI at 15 cm	882	6.29	5549
I_4 AWDI at 20 cm	845	5.84	4942
I_5 SRI irrigation	1009	6.01	6060
CD (P=0.05)		0.48	451

sulted in reduction of water use efficiency under conventional irrigation practice. The AWDI at 10 and 15 cm drop of water table and SRI method of irrigation practice treatments reduced the water use and which led to increased WUE considerably. The WUE was higher in the treatment with AWDI at 15 cm drop of water table (I_3), which registered 6.29 kg ha .mm and was on par with the treatments *i.e.* SRI method of irrigation practice (I_5), AWDI at 10 cm drop of water table (I_2) and AWDI at 20 cm drop of water table (I_4) which recorded 6.01, 5.85 and 5.84 kg ha .mm respectively. The poorest WUE was accounted with conventional practice of irrigation (I_1), which recorded 5.46 kg ha .mm. The reduction in consumptive water use under AWDI at 15 cm drop of water table coupled with the maintenance of yield at an optimum level increased the WUE. In this study the higher grain yield (6060 kg /ha) was obtained with SRI method of irrigation practice comparable with Conventional irrigation (5909 kg /ha) followed by AWDI at 10 cm drop of water table (5769 kg /ha). The SRI method of irrigation practice (I_5), recorded higher grain yield of 6060 kg /ha and was comparable with conventional practice of irrigation (I_1) and AWDI at 10 cm drop of water table (I_2), which recorded the grain yield of 5909, 5769 kg /ha respectively. These were followed by AWDI at 15 cm drop of water table (I_3) registering 5549 kg /ha. The lowest grain yield was recorded under AWDI at 20 cm water table (I_4) with 4942 kg /ha. The increased yields under SRI method of irrigation might be due to favourable growing and nutrition supply environment and with increased uptake of nutrients under SRI method of irrigation which lead the plants with superior growth and the favourable growth traits enhanced the yield attributing characters with higher source to sink conversion, which resulted in higher grain yields.

CONCLUSION

In the view of reduced consumptive water use with higher grain yield, when irrigation given to AWDI at 10 cm drop of water table using monitoring device *i.e.* Field water tube opted as a best need based irrigation monitoring device and valued as a better tool for need based irrigation. Adoption of SRI method of irrigation practice resulted in higher grain yield and in which all the favourable plant growth and yield characters were noticed. The AWDI at 20 cm drop of water table reduced the grain yield.

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Productivity of sugarcane as influenced by surface and sub surface drip fertigation in N.C Zone of A.P, India

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Irrigation is necessary in order to produce sugarcane but water supplies are becoming increasing limited. Drip irrigation systems offer more precise water control than conventional furrow irrigation. Fertigation with conjunctive use of fertilizer nutrients and irrigation water offers the possibility to optimize the water and nutrient distribution over time and space (Nanda 2010). The present study was therefore, conducted to determine the yield response of sugarcane to various methods of irrigation at different nutrient levels under drip fertigation.

METHODOLOGY

A field experiment was conducted at Regional Agricultural Research Station, Anakapalle, Andhra Pradesh, India for three consecutive years from 2012-13 to 2014-15. Soil of the experimental site is sandy loam. The experiment was designed in split plot design with three methods of irrigation (surface drip, sub surface drip and furrow irrigation) and four levels of nitrogen (100, 150, 200 and 250 Kg/ha), thus constituting of twelve treatments randomized in three replications. Fertigation schedule was started at 30 days after planting (DAP) with an weekly interval and continued up to 180 days after planting. Thus the N fertilizers in different doses were applied through drip in 21 equal splits. All other agronomic practices like hand weeding, earthing up, trash twist propping etc., were carried out according to recommendations

Table 1. Yield attributes, yield and quality of sugarcane as influenced by methods of irrigation and nitrogen levels under drip fertigation (pooled mean data of three years)

Treatment	NMC/ha	Cane Yield (t/ha)	Juice Sucrose (%)
Methods of Irrigation			
Sub surface drip irrigation	91,189	104.5	17.1
Surface drip Irrigation	87,512	100.5	17.0
Furrow irrigation	81,944	87.6	16.8
SEm±	516	1.5	0.07
CD (P=0.05)	1542	4.54	NS
Nitrogen levels			
N1:100 Kg/ha	80,953	86.9	17.1
N2: 150 kg/ha	85,072	96.0	17.2
N3: 200 kg/ha	90,432	101.2	16.8
N4: 250 kg/ha	91,119	103.9	16.6
SEm±	454	1.60	0.09
CD (P=0.05)	1340	4.78	NS
Interaction	NS	NS	NS

Table 2. WUE as effected by different methods of irrigation

Treatment	Quantity of irrigation water applied (ha-cm)	Water saving (%)	Cane Yield (t/ha)	Increase in cane yield (%)	Water Use Efficiency (t/ha-cm)
Sub surface drip irrigation	86.5	32.5	104.5	19.3	1.21
Surface drip Irrigation	86.5	32.5	100.5	14.7	1.17
Furrow irrigation	128	-	87.6	-	0.68

RESULTS

Pooled data pertaining to number of millable canes, Juice sucrose per cent and cane yield are presented in table 1&2 and discussed below. Sub surface drip irrigation method registered ignificantly higher number of millable canes (91,189/ha) and cane yield (104.5 t/ha) followed by surface drip irrigation method (87,512/ha and 100.5 t/ha respectively).

Among different nitrogen levels, application of 200 Kg N/ha recorded significantly higher number of millable canes and cane yield as compared to lower levels of nitrogen. Variation in number of millable canes with increase in dose of N fertilizer from 75 to 125 % recommended doses in the form of solid and water soluble forms under drip fertigation was also reported by Raskar and Bhoi (2001). Further increase in level of nitrogen does to 250 Kg/ha not resulted in significant increase in either number of millable canes or cane yield (Table 1). Higher sugarcane yield with increase in fertilizer levels was also reported by Rajanna and Patil (2003).

Significant differences were not observed in respect of per cent juice sucrose due to different treatments. However, highest mean per cent juice sucrose was recorded in drip irrigation treatments as compared to furrow irrigation. Among different nitrogen levels, application of 150 Kg N/ha recorded higher mean sucrose per cent of 17.2. There is saving of water to the extent of 32.5% in drip irrigation as compared to furrow irrigation (Table-2). Among different methods of irrigation, sub surface (1.21) and surface(1.17) methods of drip irrigations registered higher Water Use Efficiency as compared to conventional furrow method of irrigation (0.68).

CONCLUSION

Adopting of drip irrigation both sub surface and surface registered significantly higher cane yield when compared to conventional furrow irrigation. There is saving of water to the extent of 32.5% under drip irrigation as compared to furrow irrigation. Application of 200 Kg N/ha through drip recorded significantly higher cane yield as compared to other nitrogen levels.

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Effect of soil and climate based drip irrigation schedules on yield and water productivity of *rabi* maize

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In India, maize is grown in an area of 8.67 m ha with a production of 22.26 m t and productivity of 2.56 t/ha (DES, 2014). Cultivation of *rabi* maize is a common practice in Peninsular India as well as in North Eastern plains. Any irrigation system, applying excess water to the soil will result in run-off, percolation losses and also damage the crops. For efficient irrigation management, soil moisture levels can be monitored and used as the primary guide for scheduling irrigation. Continuous soil moisture monitoring enables the irrigator to tailored the irrigation to the requirement of individual crops taking into consideration the climate and soil of the location. The present study was undertaken with an objective to study the effect of soil and climate based drip irrigation schedules on yield and water productivity of *rabi* maize *(Zea mays* L.).

METHODOLOGY

The field experiment was conducted at Water Technology Centre, College of Agriculture, Hyderabad for 2 years during *rabi* 2013–14 and 2014–15. The experiment was conducted in a randomized block design in three replications with eight treatments comprises of soil and climate based irrigation schedules (detailed description given in table -1). The experimental soil was sandy loam in texture and low in available nitrogen, medium in available phosphorus and high in available potassium with moderate in infiltration rate (3.2 cm/h). The field capacity and permanent wilting point moisture ranges between 16.89 to 19.26% and 9.40 to 10.84%, respectively with plant available moisture of 70.6 mm in 0–60 cm soil depth. The irrigation scheduling was done based on pan evaporation replenishment at 125 %, 100 % and 75 % and IW/CPE ratio of 1.0 in treatments I_5, I_6 and I_7 and I_8, respectively. Whereas, in treatments I_1, I_2, I_3 and I_4 the drip irrigation was scheduled by monitoring soil moisture potential in the watermark sensors installed at 20 cm soil depth to a pre-determined potential i.e. 20, 30, 40 and 50 cbars critical soil moisture potential, respectively.

RESULTS

The maize grain yield (9.06 and 8.05 t/ha) realized in 2013–14 and 2014–15, respectively with irrigation scheduled at 20 cbars soil moisture potential (I_1) was significantly higher than rest of the irrigation scheduling except with irrigation scheduled at 125% Epan (I_5) and 100% Epan (I_6). Vishwanatha *et al*. (2002) ascribed the high yields in corn were mainly due to maintenance of continuous optimum soil moisture status in the upper 30 cm soil layer. While the lowest grain yield was observed in irrigation scheduled at 50 cbars soil moisture potential (Table 1) which might be due to moisture stress. Edmeades *et al.* (2001) stated that water stress is the most pervasive limitation of yield potential in

Table 1. Grain and straw yield of *rabi* maize as influenced by soil and climate based drip irrigation schedules

Treatment (drip irrigation schedules)	Grain yield (t/ha)		Straw yield (t/ha)	
	2013–14	2014–15	2013–14	2014–15
I_1, Drip Irrigation at 20 cbars threshold soil moisture potential	9.06	8.05	18.73	15.60
I_2, Drip Irrigation at 30 cbars threshold soil moisture potential	7.18	8.03	15.53	13.60
I_3, Drip Irrigation at 40 cbars threshold soil moisture potential	6.29	7.06	13.88	14.13
I_4, Drip Irrigation at 50 cbars threshold soil moisture potential	5.73	6.03	11.28	11.73
I_5, Drip Irrigation equivalent to 125% pan evaporation replenishment	8.98	7.74	19.05	15.86
I_6, Drip Irrigation equivalent to 100% pan evaporation replenishment	8.12	7.50	17.60	14.50
I_7, Drip Irrigation equivalent to 75% pan evaporation replenishment	6.17	6.25	16.65	12.13
I_8, Surface Furrow Irrigation at 1.0 IW/CPE with 5 cm irrigation depth	6.28	6.27	15.01	12.00
SEm±	0.54	0.29	0.58	0.59
CD (P=0.05)	1.66	0.88	1.79	1.78

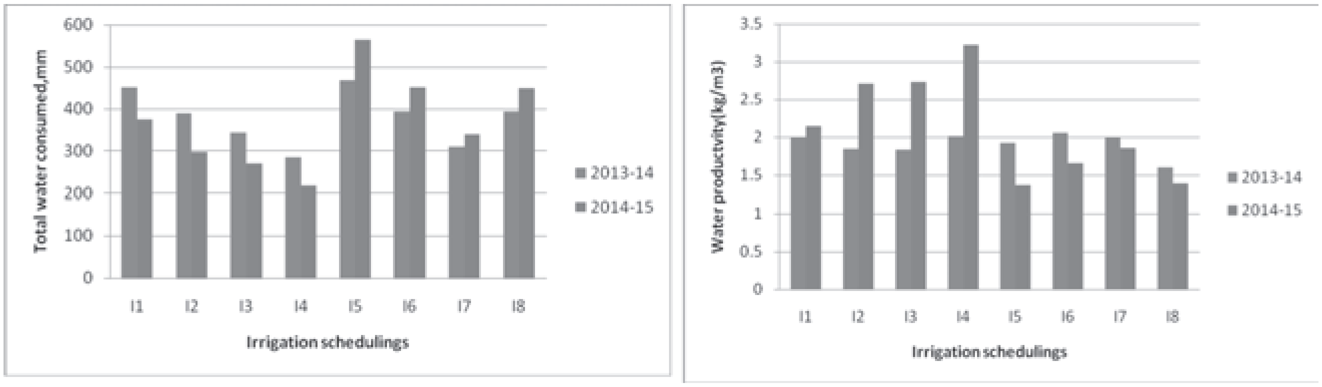

Fig. 1. Total water consumed and water productivity of *rabi* maize as influenced by soil and climate based drip irrigation scheduling

maize. The straw yield of maize was significantly higher (19.05 and 15.86 t/ha in 2013–14 and 2014–15 respectively) with drip irrigation scheduling at 125% Epan and differed with rest of the irrigation scheduling except with drip irrigation scheduled at 20 cbars soil moisture potential threshold and at 100% Epan. The water productivity of maize was relatively higher with drip irrigation scheduled at 100% Epan, 75% Epan and 20 cbars soil moisture potential in 2013-14 (Fig.1) while it was maximum in drip irrigation scheduled at 50, 40 and 30 cbars potential threshold level during 2014-15 with the total water consumption ranging from 2,850 to 4,680 m^3 and 2180 to 5650 m^3 in irrigation scheduled at 50 cbars soil moisture threshold to 125% Epan in 2013–14 and 2014–15 , respectively.

CONCLUSION

The results of the present study clearly indicates that for achieving maximum grain yield and optimum water productivity, the *rabi* grown maize crop can be drip irrigated at 20 cbars soil moisture potential threshold level or at 100 % Epan replenishment.

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Efficient irrigation scheduling for enhancing the productivity and profitability of wheat (*Triticuma estivum*) under semi-arid Inceptisol

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Wheat (*Triticumaestivum* L.) is an important food crop for irrigated perimeters of the arid and semi-arid region of India. The crop productivity in medium-textured shallow soils of this region is low owing to low water retention, poor inherent fertility, low soil organic carbon and rapid development of mechanical impedance with drying caused by high soil crust strength. High soil temperature during early and later parts in a growing season in general is a major production limitation in the North West Plain Zone (NWPZ) of India. Adoption of suitable irrigation water management practice is necessary to overcome expensive irrigation and eliminate many associated problems. This concept is critically important in the areas of central Gujarat, where deep percolation associated with excess irrigation combined with a saline geographical formation would further contribute to the salinity problem. Therefore, irrigation management would become a crucial element in reducing the deep percolation and improving the water quality downstream. In central Gujarat, rice-wheat cropping system is a predominant cropping system, in which wheat is grown after harvesting of rice crop. Wheat requires longer days of cold during its tillering period. However, in Gujarat, short winter does not coincide with the tillering stage and the crop is sown late rather than normal sowing particularly in paddy land (land suitable for transplanting of paddy). In the cultivation of high yielding wheat varieties, irrigation assumes greater importance because during growing season of the crop (October to April) weather remains relatively dry.The judicious application of water signals for immediate attention. This is possible only by following some scientific basis for water application to the crop i.e. critical growth stage approach for scheduling of irrigation. Suitable sowing method and seed rate are the basic inputs for proper stand and use of available resources for production of wheat. The method of sowing and seed rate would play an important role for efficient utilization of air, water, solar energy, space and nutrient and improving the crop yield and quality to a great extent. Keeping in view of irrigated environments and number of plants per acre, the present study was conducted to determine the effect of irrigation schedules in combination with planting methods and seed rates on wheat yield and yield contributing parameters under semi-arid Inceptisols in Gujarat.

METHODOLOGY

A field experiment on wheat (GW-496 variety) was conducted during *rabi* 2010-11 and 2011-12 at Regional Research Station, Anand Agricultural University, Anand in central Gujarat. The experimental site had an even topography with moderate slope and good drainage. Anand is about 70 km away from Arabian Sea coast and hencethe climate of this region is semi-arid and sub-tropical with dry and hot summer. Anand is situated at 22º35' N latitude and 72º55' E longitude with altitude of 45.1 m above mean sea level. The soil is alluvial in origin and is a representative of the soils of the region. The soil texture was sandy clay, having 0.38% organic carbon and pH of 7.6. It was low in soil N (232.4 kg/ha), medium in P_2O_5 (48.2 kg/ha) and high in K_2O (342.2 kg/ha). The field experiment was conducted with 3 factors of irrigation schedules, sowing methods and seed rates in a Randomized Block Design. Four irrigation schedules were tested at critical growth stages and IW: CPE ratio viz., I_1: Irrigations at crown root initiation (CRI) + tillering + jointing + flowering; I_2: Irrigations at CRI + tillering + jointing + flowering + milk-

Table 1. Effect of irrigation, sowing method and seed rate on pooled total and effective tillers, grain and straw yield and field water use efficiency in wheat

Treatment	Total tillers/m^2	Effective tillers/m^2	Grain yield (t/ha)	Straw yield (t/ha)	FWUE (kg/ha-cm)
Irrigation (I)					
I_1: Irrigations at CRI + T+ J + F	463^c	394^c	4.79^c	5.61^c	136^a
I_2: Irrigations at CRI + T + J + F + M	494^b	425^b	5.49^b	5.88^b	117^b
I_3: Irrigations at CRI + T + J + F + M + D	520^a	441^{ab}	5.34^b	6.01^b	108^c
I_4: Irrigations at 0.8 IW:CPE ratio	541^a	453^a	5.86^a	6.53^a	106^c
CD (P=0.05)	21	18	0.27	0.25	8
Sowing method (SM)					
Line sowing	520^a	446^a	5.61^a	6.12^a	119
Broadcast	489^b	410^b	5.13^b	5.89^b	114
CD (P=0.05)	15	13	0.19	0.18	NS
Seed rate (SR)					
125 kg/ha	465^b	385^b	5.07^b	5.81^b	104^b
150 kg/ha	544^a	472^a	5.67^a	6.21^a	129^a
CD (P=0.05)	15	13	0.19	0.18	6
CD (P=0.05) *(I X SM)*	NS	26	0.38	0.36	NS
CD (P=0.05) *(I X SR)*	NS	NS	0.38	0.36	11
CD (P=0.05) *(SM X SR)*	NS	NS	0.27	NS	NS
CD (P=0.05) *(I X SM X SR)*	NS	NS	NS	NS	NS

T: Tillering; J: Jointing; F: Flowing; M: Milking; D: Dough; NS: Non-significant; FWUE: Field water use efficiency;LSD: Least significant difference at $p < 0.05$; Treatments with same letter (a, b, c, d....) indicate that they are at par with each other.

ing; I_3: Irrigations at CRI + tillering + jointing + flowering + milking + dough; and I_4: Irrigations at 0.8 IW: CPE ratio. Similarly, two levels of seed rate viz., 125 and 150 kg/ha and two sowing methods viz., line sowing at 22.5 cm and broadcasting were adopted in the study. Thus there were 16 treatment combinations in the study which were tested in 4 replications.

RESULTS

Application of irrigation at 0.8 IW:CPE ratio resulted in significantly higher pooled grain and straw yields (5.86 and 6.53 t/ha, respectively) as compared to other irrigation schedules. Similarly, higher number of total (541/m^2) and effective tillers (453/m^2) were perceived with same irrigation schedule. Higher grain yield which evidently was due to the cumulative effect of improvement in growth such as plant height and yield attributes such as number of total and effective tillers/m^2 (Brahma *et al.* 2007). However, maximum FWUE (136 kg/ha-cm) was recorded with four irrigations at CRI + Tillering + Jointing + Flowering compared to other irrigation schedules over pooled.FWUE increased with decreasing frequency of irrigation mainly due to higher grain yield in proportional to the quantity of water used (Shivani *et al.* 2001). Line sowing was superior to broadcasting for attaining significantly highest grain and straw yield (5.61 and 6.12 t/ha, respectively). Similarly, higher FWUE (119 kg/ha-cm) was recorded with line sowing over broadcasting. Seed rate @ 150 kg/ha produced higher number of total (544/m^2) and effective tillers (472/m^2) than lower seed rateover pooled. Higher number of total and effective tillers/m^2 under higher seed rate could be ascribed to maximum plant population directly led to increase in overall total tillers/m^2 as compared to lower seed rate (Kabir *et al*. 2009). Seed rate @ 150 kg/ha gave maximum FWUE (129 kg/ha-cm) over lower seed rate over pooled.

CONCLUSION

From the present investigation, it may be concluded that for attaining significantly higher yield of wheat, we should irrigate the crop on the basis of 0.8 IW:CPE ratio (8 irrigations with one common irrigation of 50 mm immediately after dry sowing) in conjunction with 150 kg/haseed rate following the line sowing at 22.5 cm in paddy land under central Gujarat conditions.

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Assessment of municipal solid waste in conjunction with chemical aendment for harnessing productivity potential of salt affected soils

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Salt induced soil degradation is a major concern throughout the world because it often results in the dramatic decline of agricultural production. In addition, the affected areas are expected to increase with the use of poor quality water, increasing canal network, secondary salinization and the intensive use of chemical fertilizers. Salt excess adversely affects the soil physico-chemical properties, especially the structural stability and bulk density. Furthermore, high exchangeable sodium present in sodic soils enhances the dispersion of clay, thus decreasing soil permeability. Ultimately, salt excess may strongly compromise the plant yield. Various organic amendments, such as FYM and pressmud alone and in combination with chemical amendments, have been investigated for their effectiveness in soils reclamation. Application of organic matter on sodic soils could accelerate Nacl/salt leaching; decrease both the exchangeable sodium percentage and electrical conductivity, and increase water infiltration, water holding capacity and aggregate stability. Furthermore, Municipal Solid Waste (MSW) compost represents a source of nutrients that can improve soil fertility and, thereby contribute to restoring the productivity of salt affected soils. The disposal of ever increasing amounts of urban wastes is becoming a serious problem in India. Due to energy crisis, forbidden cost of fertilizers and chemical amendments used for reclamation of sodic soils like gypsum and phosphogypsum and poor purchasing power of marginal and resource poor farmers, we hypothesized that municipal solid waste compost may act as a non-conventional carbon and nutrient source to reduce the adverse effects of sodicity on soil properties. In view of the above background a field study was conducted at Central Soil salinity Research Institute, regional Research station, Lucknow with the objectives to Standardize the methods of on-farm composting of municipal solid waste, To evaluate the effectiveness of organic (MSWC) and inorganic amendments on amelioration of sodic soils, monitor the combined effect of organic (MSWC) and inorganic amendments on soil quality and biochemical changes and to find out the efficacy of inorganic amendments used in conjunction with municipal solid waste compost on soil productivity and sustaining crop yield in sodic soils. From the study it was revealed that the maximum grain yield was recorded with application of gypsum @ 25% GR + 10 t/ha decomposed municipal solid waste which was significantly higher over control (gypsum @ 50% GR) and Phosphogypsum @ 50% GR.

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