Fourth International Agronomy Congress

Agronomy for Sustainable Management of Natural Resources, Environment, Energy and Livelihood Security to Achieve Zero Hunger Challenge

22–26 November 2016, New Delhi, India

Extended Summaries
Vol. 3

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
Precision Nutrient Management
Conservation Agriculture and Smart Mechanization
Innovation Systems and Last Mile Delivery
Livelihood Security and Farmers Prosperity
Emerging Challenges for Agronomic Education
New Paradigms in Agronomic Research

Organized by
Indian Society of Agronomy
Indian Council of Agricultural Research
New Delhi, India

Published in November 2016

Dr Y.S. Shivay
Organizing Secretary
Fourth International Agronomy Congress
Indian Society of Agronomy
Division of Agronomy
ICAR-Indian Agricultural Research Institute
New Delhi 110 012, India

The views expressed in this publication by the authors are their own and these do not necessarily reflect those of the organizers.

Printed at the Cambridge Printing Works, B-85, Naraina Industrial Area, Phase-II, New Delhi 110 028, India

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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 multi-dimensional 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 (120 N : 60 P_2O_5 : 40 K_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

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	

deviation was calculated using the formula (variety yield – mean yield)/mean yield, where mean yield is 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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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 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 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.

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)

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
SEM1	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
SEM1	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

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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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

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

Real time contingency plan

1. High yielding finger millet varieties: 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 (1,720 kg/ha, ₹ 21,161/ha and 2.30, respectively). Similar trends were noticed under ORP also.

2. Method of establishment in finger millet: 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.

3. Modified bullock drawn Seed drill for finger millet: 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.

4. *In situ* moisture conservation practices through conservation furrow in finger millet and groundnut based cropping system: 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.

5. Pulse based cropping system: Pigeonpea intercropping with field bean and cowpea in 1:1 performed better in terms of yield and economics.

6. Integrated nutrient management: Application of organic and inorganic fertilisers along with micronutrients gave maximum net returns of ₹ 36,504/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 ₹ 9,460/ha and B : C ratio of 1.60.

7. Weed management in groundnut + Pigeonpea cropping system: Pre-emergent application of alachlor at 2.5 litres/ha along with one hand weeding recorded lower weed menace and higher groundnut pod yield (499 kg/ha) and B : C ratio (1.96) were recorded compared to farmers' practice 210 kg/ha and 0.97 respectively in groundnut + Pigeonpea (8 : 2) intercropping system.

8. Agromet-advisories: Agromet-advisories and crop-weather bulletins were issued twice a week (Tuesday and Friday) 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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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

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 and 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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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

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). $GDD = \Sigma [(Tx + Tn) / 2 - \text{Base temperature}]$ 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 Krishnakumar *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 per cent 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.

Table 2. Effect of date of planting on GDD (°C) 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 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 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

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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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

ICTs and Digital Services for Scaling Climate Smart Agriculture

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The Agriculture in India recorded impressive achievements in agriculture during three decades since the onset of green revolution in late sixties. This enabled the country to overcome widespread hunger and starvation; achieve self-sufficiency in food; reduce poverty and bring economic transformation in millions of rural families. However the situation started turning adverse trend around mid-nineties, with slowdown in growth rate of output, which then resulted in stagnation or even decline in farmers income leading to agrarian distress, which is spreading and turning more and more serious.

Climate change is considered to be one of the important factor impacting our agriculture. In India policy makers and experts released a National Action Plan on Climate Change (NAPCC) during year 2008, where some of the guiding principles included “Protecting the poor and vulnerable through an inclusive and sustainable development strategy sensitive to climate change”. A total of eight National Missions have been identified under the NAPCC, including National Mission for Sustainable Agriculture and National Mission on Strategic Knowledge for Climate Change. One of the key thrust area identified under these missions are focusing on strategies to make Indian agriculture climate smart with special emphasis on improving productivity of rained areas.

Climate change has already significantly impacted agriculture in India and around the world. The frequency of extreme weather events, such as droughts and floods, are predicted to increase on regular basis. Climate change is affecting production systems, and increasing the pressure on ecosystem services. Greater frequency of erratic weather pattern will directly increase the risk in agriculture food production. Increased frequency of drought, hailstorm, unusual rains and cyclone leads to major agricultural and economic losses and resource poor farmer cannot cope up with these changes due to poor adaptive capacity.

In this context, ICT and DS can play a significant role in minimizing the risk associated with climate change, therefore farmers are in greater need of digital services that provides them information and suggestion well in advance on how to respond risks and opportunities. The crop advisories linked with weather scenario helps farmers on improving farm productivity and maintaining ecosystem health. ICT based solutions are very effective platform for reaching large number of farmers in short time in order to reduce climate risks. Disseminating scientific knowledge on climate smart agriculture practices though different ICT channels helps farmers undertake adaptive measures to reduce risks and losses. In India, where rainfall patterns vary within one kilometre during monsoon period, entire income is always driven by local weather conditions especially for dry land farmers.

In order to scaling the use of ICT and DS tools, there is a need to spread awareness about the various issues around impact of climatic factors on agriculture and agronomy practices to be followed to make our climate smart. We must educate farmers about how climate smart agriculture addresses agronomic issues. Farmers should be able to understand practical issues and repercussions related to non-adoption of these practices. Some of the factors such as lack of trust or poor risk taking appetite of farmers, lack of resources required for paradigm shift, including who can guide on need basis, lack of marketing solutions, in case of crop diversification etc are critical factors while we plan for scaling the information to large number of farmers. ICT and DS can help issues pertaining to climate change in following ways,

1. Service providers can, work with Government agencies & recommend alternate crops/varieties based on availability of long range forecasts and monsoon predictions (including dry spells), available at block level.
2. Digital services can help in estimating the soil health parameters in order to grow effective crops in particular field.
3. Prepare a solid action plan and convey why the change is being recommended, and how the change will benefit them instead of just mere recommendations.
4. Convey the recommendations well in advance for effective decisions to be taken by farmers & also support them with expert advice if required.
5. Ensure that the recommendations linked to markets for uptake of entire production to ensure their profitability.
6. Loop in Agri input providers to make available the seeds and other inputs and operate programs to encourage the crop shift in the region.
7. Digitally connect farmers with dealers and distributors for proper selling of their produce at appropriate profitable price and ensure end to end solution.

The objective of climate smart agriculture can be achieved using interfaces such as mobile application, Kiosks at Panchayats, Agriculture Produce Marketing Cooperation (APMCs), Krishi Vigyan Kendras (KVKs) etc, TV, local radio), which are easy to use by farmers. Some of the following important factors need consideration for effective scaling.

a. High usage of audio-visuals, and info graphics.
b. Readily available and easy to consume information is critical.
c. Information should be delivered preferably in regional language.
d. Contextual and timely interventions, based on farmer profile, Alerts, notification and Calls
e. TV as a medium to spread awareness on the concepts of Climate Smart Agriculture
f. Identifying early adopters using field/extension teams, and using them as brand ambassadors

In order to bring the concept of ICT & DS in reality, RML Ag Tech Pvt Ltd (RML) starts offering critical information and digital services to Indian farmers addressing their agricultural issues at local level by proving highly quality information on weather forecast, scientific crop advisories, market price and agriculture news. Presently RML is proudly serves about 3 million farmers in 50,000 villages across 19 states with coverage of over 550 crop varieties and 700 markets. RML disseminate information through mobile app-RML Farmer and text message for retail customers. On Google play store, RML Farmer app. has 4.3 rating by 5,000+ users. We have designed various products providing customized Agronomic solution & decision support services for our beloved farmers by providing weather forecast and alerts, improved crop advisories and best available market price. The RML information helps farmers in taking precise decision making and our some of the unique offerings are as under.

i. CropPick: Select and identify best suitable crop based on growing degree days, soil types etc and market price situations to make them most productive & profitable crop.
ii. SoDoc: Soil testing through RML verified labs for selected pick up points. Provide handhold solutions for farms to improve soil health by suggesting macro and micro nutrient needs.
iii. CropDoc: Symptom based diagnostic tool and solutions for Integrated pest and weed management keeping pest below Economic Threshold Level (ETL)
iv. Digi Mandi: Helps decide when to sell, choose mandi based on maximum profitability and connect with relevant traders in any mandi across the country.

Climate Change Adaptation Plan of some Indian states has recommended promotion of crop diversification to enhance resilience of local farming system. A resource based farming practices always maintain health of ecosystem and support concept of sustainable agriculture practices. Looking at the demand of such kind of services, RML has started working on addressing the issues of farming community and currently providing weather and resource based agronomic services through different kind of products to serve the farmers in better way through ICT mode

RML approach of ICT based digital services offers greater promises for ensuring precise decision making and wonderful support system for farmers. Impact assessment of RML services carried out by third parties shows that transforming and sharing highly scientific Agriculture knowledge well in advance reduced the adverse impact on crop yield and productivity occurred due to unexpected weather events resulting in economic benefits. Farmers are also benefitted to take appropriate decision for marketing their produce at best available price in nearby local market. We are committed to contribute significantly for improving farm productivity and profitability by our ICT based digital services.

Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Prioritizing CSA land use options at a regional scale

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South Asia is home to more than one-fourth of the world's hungry and 40 percent of the world's malnourished children and women. Though it has witnessed robust economic growth over the past 20 years, the persistent climatic variability resulting in frequent climatic shocks such as droughts and floods are now endangering this growth. Climate change, manifested by depleting glaciers, increasing coastal erosion, frequent heat waves, rising sea level, frequent floods and droughts and varying rainfall patterns, is projected to exacerbate the existing pressures on land and water resources. Several studies have indicated that the productivity of food crops, livestock and fish may decline even in the short-term with significant effects later in the century, if corrective measures are not taken now to improve our adaptive capacity (Aggarwal, 2008; Naresh Kumar *et al.,* 2013; Rosenzweig *et al*., 2014). There is, therefore, an urgent need to develop strategies that can incentivise land use that would meet future food demand, increase farmers' income, build resilience, and wherever possible reduce emissions (FAO, 2010; Lipper *et al*., 2014). A range of technological, institutional and policy options has been proposed to help agriculture become climate-smart like changes in agronomic practices, adoption of the new technologies and the use of relevant information (e.g. climate services, weather index based insurance etc.) which at the farm level are the key components in improving the adaptation of agriculture to climate change (Byjesh *et al*., 2010, Naresh Kumar *et al.,* 2014; Naresh Kumar and Aggarwal, 2013). These options can significantly improve crop yields, increase input-use efficiencies and net farm incomes, and reduce greenhouse gas emissions (Smith *et al*., 2007). These interventions have varying costs and economic impacts. Their implementation requires appropriate investment decisions in both on-farm capital and wider agricultural outreach programmes. Furthermore, climate-smart investment can have a wide range of scales ranging from the single field up the national level. It is unlikely that investment in any single intervention will provide optimal benefits, but rather an integrated portfolio of interventions is required to best support adaptation to climate change in agriculture across a range of scales. Hence, the promotion of such portfolios of the climate-smart interventions in the different parts of the world requires a clear understanding of its relative suitability, costs and benefits, and the environmental implications of various technological interventions in a local context under current and future climates. Such data are generally difficult to obtain from the literature, field surveys and focused group discussions, or from biophysical experiments. This study describes a methodology that generates this information based on a region specific production functions in the current and future climate scenarios. The application of this approach is illustrated for prioritizing agronomic interventions that can enhance productivity and incomes, help farmers adapt to current risk, and decrease greenhouse gas emissions in current and future climates for the flood- and drought-prone state of Bihar in north-eastern India.

METHODOLOGY

The methodology described here builds from quantitative resource assessment for developing input-output relationships to identify climate smart agricultural landuse options. In this study, we demarcated 34 homogenous spatial units for quantitatively describing the input-output relations of the various crops by overlaying biophysical layers of soil texture class, drainage, flooding, rainfall and temperature. Since most of the socio-economic baseline data is available at political boundary scale, we superimposed district boundaries on these 34 zones, which resulted in 194 land units; the smallest units of assessment in this study. Each land unit within an administrative block (here district boundary) differs from another by at least one biophysical attribute. This helps to characterise biophysical responses in the production process. Eight major crops, covering 90 per cent of the gross sown area, dominate Bihar's agriculture land use. These crops are rice in rainy season (*kharif*), Mung bean (Green gram) in summer, wheat, chickpea, mustard, lentil, and *khesari* (*Lathyrus sativus*) in winter (*rabi*) season, and maize in all three seasons. Crop yields in a land unit depend on its soil, climate, technology and related agronomic and monetary inputs. In this study, we have considered 10 production technologies for all eight crops listed above.

INPUT-OUTPUT CALCULATIONS

Inputs required to realize target crop yields under different technological interventions and all other ancillary outputs are calculated under all climate change scenarios at different time slices for each land unit. Key inputs assessed are irrigation requirements by source, labour requirement by type, and costs of inputs (fertilizer, labour, water). Key outputs are yields, by-products, and emissions. A technical coefficient generator (TCG) developed earlier by Aggarwal *et al*. (2001) based on current knowledge of production ecology was used to generate biophysical input/output data for each technology and land unit. The method integrates biophysical, agronomic, and socio-economic data to establish input-output relationships related to water, fertilizer, labour and GHG emissions. In this TCG, the technical coefficients were specifically developed to quantify differences in resource use of current and future-oriented land-use options aimed at increasing production and income. Key in calculating the technical coefficients was the target-yield oriented approach, which acted as the independent variable that dictated the inputs, i.e., nutrients, water, labour, pesticides and machinery, required to attain this yield. GHG emissions are calculated based on the amount of inputs used and related processes in the soil-plant-atmosphere continuum. The emissions were calculated using 'The Cool Farm Tool', an open source spreadsheet based software (Hillier *et al*., 2011).

CLIMATE-SMARTNESS

The climate smartness of current land use was assessed using three benchmark indicators of CSA: productivity, incomes, and emissions. Any crop, technology or land unit is termed as climate smart whenever it has higher yield and income over the baseline and lower emission intensities. We used these indicators as binary at the district level to measure relative changes over the baseline. The binary framework and district scale goes well with planning perspective although the results can be traced to land unit level. For policy planners this approach can help in prioritizing the resources to bring out the desired land use changes in region.

CONCLUSION

The dataset generation methodology presented here combines biophysical datasets with a detailed technology coefficient generator. An illustration of the use of the database developed for Bihar indicated highlighted key inputs and outputs in the agricultural production process under current and future climates. The database outlined here can be used to derive meaningful inferences for prioritizing climate smart interventions, by exploring adaptation strategies for climate change though bio-economic land unit level analysis. Simple agro-ecological-based analysis indicates that current technologies will not remain climate smart under future climate. In general, climate smartness increases with increasingly advanced levels of technologies. Yields are least limiting while emissions are the most limiting factor across the entire crop-technology portfolio. The database developed here can facilitate a wide range of analyses, with the ultimate aim of providing actionable information to policy makers in the pursuit of their development objectives.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Climate resilient agronomic innovations for rainfed farming in sub–tropics

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Rainfed agriculture accounts to 58 per cent (83 m ha) of the net cultivated area in India, contributing about 40% of the food grain production and supporting livelihoods of 80% of small and marginal farmers and two thirds of livestock population. Even iffull irrigation potentialis created, still 40% of net cultivated area will remain as rainfed. In view of this, rainfed farming is crucial to country's food security and economy.

Climate change impacts are evident on Indian agriculture.The high inter- and intra-seasonal variability in rainfall distribution, rainfall events and extreme temperatures are causing crop damages and losses to farmers (Sikka *et al*., 2016).The country experienced 15 deficit and 6 excess monsoon years in post-1960 period in comparison to only 27 deficit and 20 excess monsoon years during 1871–2014. The recent ensemble models project that the frequency of extreme precipitation days is likely to increase. The substantial increase of 6–14% in extreme precipitation by 2080s is projected for large areas of India, particularly over the west coast and west central India (Rupa Kumar *et al*., 2006). In comparison to baseline period of 1960-90, the mean annual temperature over India is projected to increase by 1.7–2.0°C by 2030s, 2.5–3.0°C by 2050s and 4.0–5.0°C by 2080s. In India, at presentthe blue and green water availability is above 1,300 m^3/capita/year threshold. However,with climate change, this is estimated to decrease to < 1,300 m^3/capita/year, implying that by 2050 India could be exposed to water stress. Risk is also to be addressed in terms of building resilience of crops, soils and farmers in rainfed areas.

Climate resilient agriculture (CRA) is a recent approach means the incorporation of adaptation, mitigation and other practices in agriculture which increases the capacity of the system to respond to various climate related disturbances by resisting damage and recovering quickly. Such perturbations and disturbances can include events such as drought, floods, heat/cold, wave, insect or pest population explosions and other perceived threats caused by changing climate.The two key strategies to climate resilient rained farming are, i.e. adaptation and mitigation to climate change.Some of the agronomic innovationsthat are likely to be adaptation and mitigation strategies to achieve climate resilient rainfed farming are discussed in this paper.

AGRONOMIC INNOVATIONS AS ADAPTATION STRATEGIES

a. Real-time contingency planning

In the early1970s, the innovation of contingent crop planning and mid-season correction and identification of weather aberrations, viz. (i) delayed onset of monsoon; (*ii*) early withdrawal of monsoon; (*iii*) intermittent dry spells of various durations; (*iv*) prolonged dry spells causing changes in the strategy; and v) prolonged monsoon,was unique from All India Coordinated Research for Dryland Agriculture (AICRPDA). Since then, AICRPDA developed contingency measures considering the weather aberrations, seasons, and predominant *kharif* and *rabi* crops with appropriate crop management strategies. Since 2010, ICAR-CRIDA in collaboration with Ministry of Agriculture, GoI, National Agricultural Research and Extension System (NARES) and development agenciesprepared District Agriculture Contingency Plans for 614 districts in the country. In order to establish a crop with optimum plant population during delayed onset of monsoon; to ensure better performance of crops during seasonal drought and extreme events, to improve productivity and income, a need was felt to validate contingency measures on real-time basis. For this, a unique approach of Real Time Contingency Planning (RTCP) was conceptualized in 2011 by AICRPDA under National Initiative on Climate Resilient Agriculture (NICRA) towards climate resilient rained farming (AICRPDA-NICRA, 2011–16). The RTCP is 'Any contingency measure, either technology related (land, soil, water, crop) or institutional and policy based, which is implemented based on real time weather pattern (including extreme events) in any crop growing season' (Srinivasarao *et al*.,2013a). Some of the key RTCP measures validated by AICRPDA are:

1. *Alternate crops/varieties for changing sowing windows:* Under delayed onset of monsoon, the RTCP interventions such as introduction of short duration variety, opening conservation furrows, sowing on ridge and furrow system enhanced moisture use efficiency and crop yields (Table.1).

2. *Coping with agricultural drought:* During early season drought, opening of conservation furrow such as in between two rows of pigeonpea in fingermillet + pigeonpea intercropping system (8 : 2) enhanced system productivity while during mid season drought, opening of conservation furrow, foliar sprays with chemicals and supplemental irrigation during dry spells increased yield of rained crops/cropping systems. 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. Similarly, at Agra, foliar spray of urea and KNO_3 at 2% each in pearlmillet helped in mitigating the dry spells during August and improved crop yield by 27% closely followed by KNO_3 @ 2% (22%) compared to water spray(AICRPDA-NICRA Annual Reports).

3. *Preparedness tocope with weather aberrations:* The preparedness to cope with weather aberrations is necessary and include various components of 'Preparedness' and 'Must To Do Practices', some of which that are likely to achieve climate resilient rainfed farming are:

4. *Building in-situ moisture reserves and ex-situ rainwater management:* Rainwater management is central issue for bringing any kind of resilience in rainfed farming. Improved water storage through *insitu* moisture conservation and stored runoff are basics for bringing resilience to drought or moisture stress conditions often encountered by the rainfed crops. Agroecology specific *in situ* moisture conservation practices is the first priority and excess runoff collection in farm ponds and its recycling during dry spells is the second important adaptation strategy. Treating land, before commencement of rains, through summer ploughing, broad bed furrow (BBF), raised and sunken bunds, compartmental bunding etc. facilitates the maximum intake of rainwater into soil profile. Ridgeand furrow system, sowing across the slope and paired row sowing are important water conservation measures which have proved to be highly effective not only to mitigate dry spells but also draining out of excess rainwater during heavy rains. The yield improvements with these technologies varied from 20 to 40% depending upon rainfall and its distribution. Mulching, though not a new practice, however with non-competing crop residues, cost effective and environmental friendly plastic film/gravel–sand materials significantly reduces the evaporation of soil moisture, increases water availability to crop plants, and decreases soil erosion caused by wind and water. Plastic mulching increases topsoil temperature during cool spring, promoting plant growth; during hot summer, straw mulching can moderate soil temperature, preventing the topsoil from reaching temperatures that inhibit plant growth. The BBF, raised bed and ridge and furrow systems can also be adopted as better planting techniques compared to flat bed systems to cope with drought and high intensity rainfall events.

The ex *situ* rainwater management with sound farm pond technology and efficiently utilizing the harvested rainwater with water saving micro irrigation technologies for life saving

Table 1. Delayed onset of monsoon- Alternate crops/varieties

Rainfed agroecology/delay in onset of South-west monsoon/ AICRPDA Centre	Crop/variety
Semiarid (hot dry), Inceptisols/15 days(Agra)	Clusterbean (RGC 1003), sesame (T 78)
Semiarid (hot moist), Vertisols/22 days (Akola)	Soybean (JS 9560)
Semiarid (hot dry), Vertisols/15 days (Arjia)	Horsegram (AK-41, AK-42, AK 22), sorghum (Pratap 1430)
Semiarid (hot moist), Alfisols/16 days (Bangalore)	Rice bean (RBL-1), horsegram (PHG-1), field bean (HA-1)
Perhumid (hot), Oxisols/18 days (Biswanath Chariali)	Rice (Gitesh, Ranjit)
Semiarid (hot dry), Inceptisols/20 days (Chianki)	Fingermillet (A 404), sorghum (CSV 20), Sesame (Shekhar), horsegram (Madhu, GHG-19)
Semiarid (hot moist), Vertisols/15 days (Indore)	Soybean (RVS 2001-4, JS 335)
Semi-arid (hot moist), Vertisols/18 days (Parbhani)	Pigeonpea (BDN 711), soybean (MAUS 71), moongbean (BM 4)
Semiarid (hot moist), Oxisols/25 days (Rajkot)	Groundnut (GG 20), sesame (G Sesame 2), castor (GCH 7)
Semiarid/Arid (hot dry), Entisols/21 days (SK Nagar)	Pearlmillet (GHB 558), clusterbean (GG 2)
Semiarid (hot dry), Vertisols/30 days (Vijayapura)	Pigeonpea (TS 3R), pearlmillet (ICTP 8203), mothbean (KBMB 1), horsegram (GPM 6)

Source: AICRPDA-NICRA Annual Reports

/supplemental/pre-sowingirrigation resulted in higher water productivity in rainfed production systems. These technologies from AICRPDA integrated into action plans and investments through dryland farming missions of various states and National Mission on Sustainable Agriculture aimed at climate resilient agriculture.

5. *Resilient crops and intercropping systems:* The choice of crops and varieties that fits well into changed climatic conditions is common denominator, particularly more relevant under highly complex rainfed production systems and areas frequented with weather aberrations. Sowing right variety of right crops at right time makes a significant difference towards attaining higher yields. An ideal variety should be high yielding, plastic enough to withstand against weather aberrations, tolerant to multiple abiotic and biotic stresses, responsive to augmented CO_2 levels and fits well to farming situations. A good intercropping system gives optimum productivity and higher LER in normal/good seasons, while brings reasonable yield for either of the crop in deficit rainfall seasons an insurance against weather aberrations (Ravindra Chary *et al*., 2012).In general, intercropping with additive series was found better than replacement series under most of drought situations.

b. Land useplanning at agriculturallandscape level

The experiences of AICRPDA from the National Agricultural Technology Project (NATP)- Mission Mode Project on Land Use Planning for Managing Agricultural Resources in Rainfed Agro-ecosystem operated in 13 microwatersheds indicated that scientific land use planning is one of the rational approaches for drought mitigation**.** Further, at agricultural landscape level in microwatersheds, with *Land Management Unit (LMU)* approach a resilient, less risk prone farming system based on the land requirements and farmers' capacities can be developed to mitigate the drought and also to address unabated land degradation and imminent climate change since these units are homogeneous and has a wider application (Ravindra Chary *et al*., 2005). As a first step, the cadastral level soil resource information was delineated into Soil Conservation Units and Soil Quality Units and secondly, the SCUs and SQUs were merged in GIS environment to delineate land parcels in to homogenous LMUs with farm boundaries. The LMUs would be operationalized at farm level for taking decisions on arable, non-arable and common lands for cropping, agroforestry, agrohorticulture, etc., and further, for leaving the most fragile land parcels for eco-restoration. Rainfed land use planning modules should be based on these units for risk minimization, enhanced land productivity and income, finally for drought proofing.

c. Cropping systems decisions based on LGP

Under changing climate scenario, many conventional practices and cropping systems are becoming redundant and ineffective, and thus need revalidation and modification in accordance to changing climate and soil-site conditions. The choice of the crops/variety/cropping system for an agro-ecosystem could further be narrowed down by matching crop requirements with prevailing location specific climatic and soil information. The length of growing period (LGP) was found to be a better index than rainfall for crop planning (Velayutham, 1999) with a potential for higher resource use efficiency and to reduce chances of crop failure. For example, with LGP of < 90 days, the short duration drought tolerant pulses such as mothbean and cereals of 10–12 weeks duration such as pearlmillet and minor millets could be cultivated in arid regions.

d. Crop diversification/intensification

Crop diversification is an important adaptation strategy to cope both with deficit and excess rainfall situations in premonsoon predominant rainfed cropping areas like north-eastern regions and high rainfall areas like eastern India. *Sali* rice cropped areas in north-eastern India often fail either due to drought and or floods, thus, crop diversification with efficient crops and varieties during *kharif* found to be risk resilient (AICRPDA-NICRA Annual Reports). Traditionally, double cropping including relay cropping is practiced in rainfed regions with >750 mm rainfall and in areas with > 150 soil moisture holding capacity. Out of the two crops, one could be short durations (usually legumes) and another, medium duration (usually cereals) for optimum use of available growing season. Similarly, relaying a short duration and fast growing crop in standing base crop provide good opportunity for efficient use of growing period, for example relay cropping of short duration *rabi* pulses in rice.

e. Cover cropping

In rainfed farming areas, the farmers generally keep the land fallow after the main crop/ season especially *kharif* season leading to loss of top soil, decline in soil fertility and crop yield over time. However, about 20–30% of annual rainfall, which occurs during the post rainy season (October to December), goes largely unutilized. Cover crops improve soil by speeding infiltration of excess surface water; relieving compaction and improving structure of over tilled soil, adding SOM that encourages beneficial soil microbial life and enhancing nutrient cycling. Cover cropping with quick growing species like sunhemp, moongbean etc. could cover the surface in 45 days and also reduce runoff and conserve rainwater *in-situ* (off-season rains). Though horsegram is not an assured crop for grain production during *rabi* season in a deficit rainfall year, it is an assured crop for biomass production. Studies have confirmed the possibility of on-farm generation of horsegram biomass by using off-season rainfall.

f. Biomass recycling

Indian agriculture produces about 500–550 million tonnes (Mt) of crop residues annually. These crop residues are used as animal feed, soil mulch, manure, fuel for domestic and industrial purposes etc. and thus are of tremendous value to farmers. However, a large portion of these crop residues, about 90–140 Mt annually, is burnt on-farm primarily to clear the fields to facilitate planting of succeeding crops (NAAS, 2012). There is renewed interest in the use of anaerobic digestion processes for efficient management and conversion of cattle dung and other agro-industrial wastes into clean renewable energy and organic fertilizer source. Similarly, few organizations in India have initiated research on efficient use of bioresidues for biochar production and its use in agriculture. At CRIDA, biochar from castor, cotton and pigeonpea stalks was produced by using a portable kiln (Venkatesh *et al.*, 2013) and initial results from field experimentation suggest that biochar application to soil helps in improving soil properties and crop yields.

g. Agroforestry systems

As a method of adapting agriculture to climate change, agroforestry systems have been shown to increase on-farm production resilience to climate variability by buffering crops from the effects of temperature and precipitation variation as well as strong winds associated with storms. The other co-benefits with agroforestry systems include enhanced nutrient cycling, integrated pest management, and increased resistance to diseases, which will additionally protect farm production (Beer *et al.*, 1998).Trees in agroforestry systems can tolerate to drought than crops, therefore it helps toavoid total failure on the farm and are highly valued by farmers because their products compensate forthe loss of crop yield. For example, in arid regions, *Zizyphusmauritiana* based systems (Solanki and RamNewaj, 1999) and silvipasture systems in which trees and/ or shrubs are combined with livestock and pasture for forage are profitable alternatives where arable cropping is not feasible due to low rainfall and constraints associated with crop production (Rai *et al.*, 1999).

h. Resilient integratedrained farming systems

The resilient integrated rained farming systems could be watershed based, farmer centric based, crop based, livestock based and agroforestry based. These farming systems have to be built on strengthening traditional farming systems with focus on livestock based IFSs in areas with < 500 mm rainfall; crop–livestock based IFSs in areas with 500–750 mm rainfall; crop-horticulture–livestock–poultry based IFSs in areas with 750–1,000 mm rainfall and multiple enterprise based on multiple water use based IFSs in areas with >1,000 mm rainfall. The rainwater management in a given hydrological unit is key for natural resource management and developing integrating arming systems on a watershed basis. The rainfed farming is predominantly small and marginal farmers centric. Keeping their economic conditions, there is a need to develop farmer centric rainfed farming systems that ensure food and nutrition security and for livelihood improvementto enhance their adaptation capacities to climate change.

AGRONOMIC INNOVATIONS AS MITIGATION STRATEGIES

a. Exploring conservation agriculture strategies in rainfed farming

Adoption of conservation agriculture (CA) increases water infiltration into the soil, reduces erosion, moderates soil temperature, suppresses weeds, improves soil aggregation, reduces soil compaction, increases surface SOM content, moderates emissions of GHGs, reduces production costs, and saves time and fallow period through direct seeding. The concerted research on CA in India has been carried out in irrigated areas of the IGP for improving productivity and associated economic gains. CA is gaining importance as an alternative strategy to sustain agricultural production due to the growing resource degradation problems, particularly under rainfed conditions. In addition to the three basic principles of CA, viz. (*i*). continuous minimum mechanical soil disturbance, (*ii*). permanent organic soil cover, and (*iii*). diversified crop rotations in the case of annual crops, introduction of the fourth principle is necessary forbuilding *in situ* moisture reserveswith agroecology specific land configuration for developing CA strategies in rainfed farming. The outcome of long term experiments on tillage and nutrient management in AICRPDA for developing conservation tillage strategies in rainfed agriculture laid sound foundation to Conservation agriculture research in rainfed production systems.

b. Carbon sequestration strategies

Soils hold the key to productivity and resilience to climate vagaries in rainfed agriculture in India. Integrated nutrient management and site specific nutrient management (SSNM) has the potential to mitigate effects of climate change. Judicious fertilizer application, a principal component of SSNM approach, has twofold benefits, i.e. reducing GHG emissions and at the same time improving crop yields. Maintaining or improving SOC concentration in rainfed dryland agroecosystems is a major agronomic challenge. Agronomic efficiency (AE) of added nutrients and partial factor productivity (PFP) of crops are maintained or enhanced with INM practices including application of organics in conjunction with fertilizers, but decline with application of only chemical fertilizers because of declining SOC concentration and soil quality with continuous cropping (Srinivasarao *et al.*, 2013). The SOC stocks in the soil profiles across the country show wide variations and follow the order Vertisols>Inceptisols>Alfisols>Aridisols.The rate of depletion of SOC can range from 0.15 Mg C/ha/y in rice based system to 0.92 Mg C/ha/y in groundnut–fingermillet system. To arrest this depletion C input of 1.10–3.47 Mg C/ha/y is required as a maintenance dose.The carbon footprints (Tg CE/ha/year) in rainfed areas were higher in cereals cropping systems followed by oilseed and pulse systems. The carbon footprints per unit amount of yield (TgCE/Mg grain) were also assessed. It showed higher for rice (2.8800) - lentil (6.1463) sequence in Inceptisols.

c. Land use diversification

Agroforestryhas a particular potential role in the mitigation of atmospheric accumulation of greenhouse gases (IPCC 2000). The land use diversification in rainfed farming with agroforestry systems isimportant for enhancing the resilience of the system for coping with the adverse impacts of climate change by maintaining SOM through the inputs of above and below ground litter and residues, and protecting the soil against erosion. The total carbon storage capacity of an agroforestry system depends on the growth and nature of the tree species, and varies from region to region.The average carbon storage potential in Indian agroforestry has been estimated to be 25 t C/ha over 96 million ha. The C sequestration and storage with some agroforestry systems in different agro ecological regions of India indicated a high SOC stock under agroforestry systems with a C storage of 1.1 to 18.6 Mg C/ha (Rai *et al*., 2009). The potential average C storage by agro-forestry systems is estimated at 9, 21, 50 and 63 Mg C/ha in the semiarid, sub-humid, humid and temperate regions, respectively.

d. Low-water requiring rainfed rice systems

A sizeable area of rice cultivation in India is under rainfed. The water saving technologies like direct seeded rice, zero tillage and other resource conservation practices consume lower water, and result in higher water productivity besides reducing GHG emissions. Early crop establishment through DSR also reduces the risk of yield loss from late-season drought, and the cost of additional irrigation to prevent such losses.

CONCLUSION

The impacts of climate change/ variability are likely to be more pronounced in rained farming. The two key strategies for climate resilient rainfed farming are adaptation and mitigation.The agroecology specific agronomic innovations/ practices such as real-time contingency planning, are likely to provide immediate short time responses for adaptation with enhanced productivity and income at farm level and enable smallholder farmers adapt to climate change in ways that maintain sustainable agricultural growth in rainfed areas.The agronomic innovations with long term strategies are needed or mitigation for which the focus of agronomic research should be shifted to *Climate Smart Agronomy*. Preparing rainfed farming for adaptation should therefore go hand in hand with proactive mitigation strategies.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Nutrient management for wheat system intensification: Food security and environmental sustenance

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Wheat is the third largest cereal produced in the world and it supplies over 20% of calories in human food around the globe. Wheat production and productivity directly influence human survival in developing countries and quality of life in industrial countries. Wheat is also one of the major cereals of India with an area of more than 30 million ha, with annual production of 90 million tonnes and productivity of 3.2 t/ha. However, the productivity can be increased as per the seed potential to meet the target of reaching 150 million tonnes yearly production by 2050. The major thrust needs to be given on agronomic management practices including balanced fertilizer recommendations. At present the recommendations available to farmers are 'blanket' in nature and do not take into account the spatial variability in indigenous nutrient supplying capacity of different farms and the variable resource endowment of farmers. Such recommendations often fail to supply required amount of nutrients to crops, leading to loss of productivity and farm profit. Studies have shown that there is yield loss up to more than 1 t/ha for wheat due to imbalanced nutrient management across different states of eastern India. A farm specific 4R Nutrient Stewardship compliant precision nutrient management is a need for farm profitability.

The *Nutrient Expert®* for wheat, developed and validated by IPNI and its partners such as CIMMYT, NARES, SAUs, and Industry Associates, is a recent innovation for developing field specific precision fertilizer recommendation tool for individual farmers. The tool is based on the principles of site-specific nutrient management (SSNM). It utilizes information provided by a farmer or a local expert to suggest a meaningful yield goal for his location and formulates a fertilizer management strategy required to attain the yield goal. The required information about the production system is gathered through a set of simple, easily answerable questions that analyses the current nutrient management practices and develops guidelines on fertilizer management that are tailored for a particular location, cropping system, farmer resource availability and considers the organic inputs as a part of the system nutrient balance. This decision support system is an easy-to-use, interactive computer-based tool that can rapidly provide nutrient recommendation for individual farmers' field in presence or absence of soil testing data.

METHODOLOGY

Experimental treatments include comparison of Nutrient Expert®(NE) based recommendation with farmers' fertilizer application practice (FFP) as well as state recommendation (SR). In the case of wheat on-farm validation trials (n=109) were conducted across major wheat growing states of India that included Bihar, Haryana, and Punjab in the year 2010–11 and 2011–12. The current study reports the data from 53 trials conducted in 2010–11 that included 10 in Bihar, 21 in Haryana, and 22 in Punjab, and 56 trials in 2011–12 in Bihar (n=11), Haryana (n=26), and Punjab (n=19). Among these 109 trials a total of 65 trials were conducted under conventional tillage (CT) and 44 trials (22 trials each year) were conducted under zero tillage (ZT) condition (Dutta *et al*., 2014).

RESULTS AND DISCUSSION

Farmers' field validation showed that nutrient recommendation from Nutrient Expert® achieved higher yields and profit over existing practices, with lesser environmental footprint than the existing practices.Present study highlights that the Nutrient Expert® – Wheat fertilizer decision support tool-based fertilizer recommendation was compared with existing fertilizer management practices in 109 on-farm sites in Punjab, Haryana and Bihar over a period of two years. The present study showed a significant ($p \leq 0.01$) increase in wheat yield through NE nutrient management treatments over FFP and state recommendation (SR) in both the years.

CONCLUSION

The present study suggests that large-scale implementation of Nutrient Expert®- nutrient management tool will provide the opportunity to bridge nutrient-related yield gaps in wheat and increase farm profitability in an environmentally sustainable manner.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Adaptation-led mitigation of climate change in Indian agriculture

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With the advent of Green Revolution (GR), India witnessed remarkable growth in food production and changed from net cereal importer to cereal surplus country. However, extensive use of agricultural inputs during GR era has resulted in many second generation problems in Indian agricultural systems. Declining water tables, increased salinity and water logging conditions(Aggarwal *et al.*, 2004), fatigue soils are some examples. The situation is further complicated by climate change and climatic variability. In India, farming is becoming increasingly risky due to increasing unpredictability in the timing and pattern of seasonal rainfall, variation in climate extremes including drought, floods and outbreak of biotic and abiotic stress.Realizing the impact of climate change, the Government of India (GoI)has developed the National Action Plan on Climate Change (NAPCC) which is being implemented through eight national missions outlining the priority activities to combat climate change. GoIhas also initiated a mega project “National Innovations on Climate Resilient Agriculture” (NICRA) with the objectives of conducting strategic research to test, pilot and promote various climate resilient technologies in the areas of crop, livestock and fisheries as well as enhancing capacity of national scientists on climate resilient agriculture.

On the other hand, Agriculture is second largest source of GHG emission in India accounting for 18% gross national emissions according to 2008 estimate (INCCA, 2010). Given that Indian agriculture is exceptionally vulnerable to climate change and yet plays a significant role on national GHG emission, it isimperative that production systems are resilient to various climatic pressures, intensified to meet the growing demand of food and more sustainable with minimum environmental impact. AlthoughIndia focuses mainly on adaptation in agricultural sector, it recently declared a voluntary goal of reducing the emissions intensity of its GDP by 20–25% over 2005 level by 2020 in its INDC in which agriculture may also contribute.

There are a wide range of agricultural practices that have the potential to increase adaptive capacity of production system, reduce emissions or enhance carbon storage yet increasing food production.Most of the agricultural practices designed and developed for climate change adaptation also provide mitigation benefits which has not been fully analyzed to our knowledge. Analyzing the mitigation co-benefit of adaptation actions provide the potential to take advantage of synergies and to minimize trade-offs between these objectives. Approaching adaptation and mitigation together also increases fund-use-efficiencies and provide opportunity to tap both adaptation and mitigation funds.

METHODOLOGICAL FRAMEWORK

Here, we analyze and present mitigation co-benefit of already recommended few adaptation practices based on the review of literature published from India. We then present opportunity for integrating adaptation and mitigation in the context of Indian agriculture. Through these concepts and analyses we highlight how Indian government can utilize both adaptation and mitigation funding for the same set of activities.

INTEGRATING CLIMATE CHANGE ADAPTATION AND MITIGATION IN AGRICULTURE

In agriculture, adaptation to climate change may be a short-term contingency plan in response to certain climatic extremes (e.g. change in crop or variety, change in planting method etc), a strategic plan usually recommended just before the season based on seasonal analysis (e.g. early warning systems, choice of seed/variety, water/fertilizer management, cropping systems etc) or a long-term plan (land-use change, breeding for different environmental stresses, establishing crop insurance systems etc). Most adaptation activities also confer mitigation co-benefits thereby contributing to moderate the effect of climate change (Fig. 1). In long run, such activities not only enhance resilience of farming system but also reduce the cost of adaptation by minimizing the impact of climate change. Based on the synthesis of available literature from India, we found out that majority of adaptation activities also have mitigation benefits (synergies), few adaptation activities have nothing to do with mitigation but not necessarily reduce the mitigation potential (no regret adaptation). Hardly any adaptation activity reduces mitigation potential and vice-versa. Further, few activities designed particularly for mitigation has nothing to do with adaptation but not necessarily reduce adaptive capacity (no regret mitigation). For example, keeping crop residues as organic mulch, minimum tillage and diversified cropping systems not only help cope with heat and drought stress and stabilize production during extreme weather events but also help sequester soil carbon and reduces GHG emission. Similarly, precision nutrient management techniques help crop grow healthy and sturdy capable of withstanding certain stresses. Precision nutrient management techniques also minimize the nutrient loss and increase nutrient-use-efficiency thereby reducing emission intensity (Sapkota *et al*., 2014). Proper weather advisory and early warning systems help farmers choose appropriate crop, variety and planting time/methods commensurate with forecasted weather and also minimize the loss of unnecessary production inputs thereby offsetting emission from those inputs.

Many of such practices are well-known and are being promoted under the banner of ecological intensification, sustainable land management, eco-agriculture, best management practices and more recently 'Climate-Smart Agriculture'.

CONCLUSION

While prioritizing climate smart agricultural practices for any location, priorities should be given to those having synergistic effect on both mitigation and adaption and then to no-regret adaption and mitigation activities. In case of the

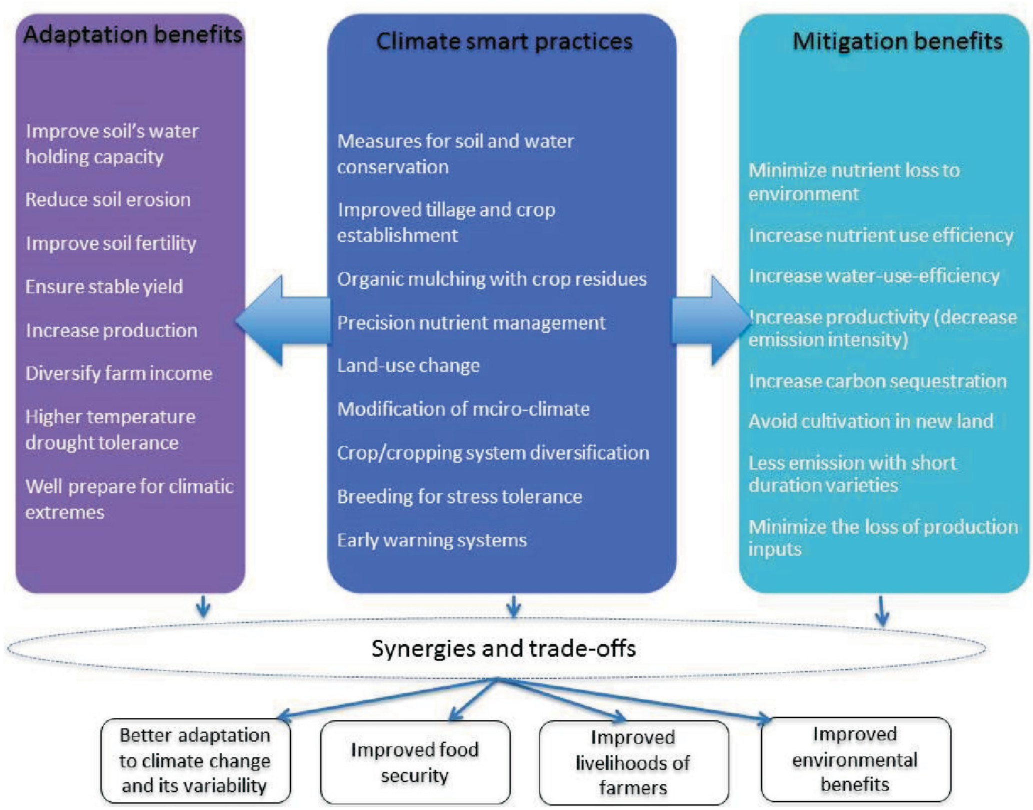

Fig. 1. Example of agricultural practices that provide both adaptation and mitigation benefits ultimately contributing to food security and livelihood improvement

practices that have trade-offs between adaptation and mitigation goals, the efforts should be made to minimize the trade-offs and selected based on the objective.

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Symposium 2
Organic Agriculture

Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Soil fertility, productivity and profitability of organic rice-based cropping systems

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Among different rice-based cropping systems the rice-wheat cropping system (RWCS) is one of the largest agricultural production systems of the world, occupying 13.5 million hectares of cultivated land in the Indo-Gangetic Plains (IGP) in South Asia and several million hectares in China (Ladha *et al.,* 2009). Presently, the IGP contributes nearly 42% to the total food grain production in India with the rice-based cropping systems (Shibu *et al.,* 2012). However, during recent years, a significant slowdown in the yield growth rate of RWCS has been observed. Key issues associated with the sustainability of this system include decline in soil organic matter (SOM) due to reduced inputs of bio-resources and lack of an adequate rotation (Shibu *et al.,* 2010); negative macro and micro-nutrient balances leading to depletion of soil fertility and nutrient deficiencies (Timsina *et al.,* 2006); deterioration in soil structure under continuously puddled soils in rice paddies (Saharawat *et al*., 2010); overexploitation of groundwater resources leading to a decline in the groundwater table (Hira, 2009); increased energy cost of pumping water, and deterioration of groundwater quality, increasing salinity (Tiwari *et al.,* 2009); the development of herbicide resistance and a shift in weed flora and pest populations (Hobbs *et al.,* 1997); poor management of crop residues, leading to their burning, and finally decreased total factor productivity or input-use efficiency, increased cost of cultivation and reduced profit margins (Hobbs and Morris, 1996).Overcoming these interacting abiotic constraints requires adoption of more integrated farming systems that build-up and maintain SOM, need less water and improve nutrient use efficiency (Prasad, 2005).Furthermore, the demand of rice and wheat crops for nutrients, especially nitrogen, is very high. One option is to include a dual-purpose summer legume in the rotation and supply nutrients through organic sources to sustain the cropping system. A recent study (Ponisio *et al*., 2015) concluded that two agricultural diversification practices, multi-cropping and crop rotations, substantially reduce the yield gap (to 9 + 4% and 8 + 5%, respectively) when the methods were applied in only organic systems. Therefore, diversification of RWCS by including mungbean in the rotation could be helpful in enhancing the productivity of the system.

Adoption of organic farming practices in basmati rice and wheat crops would also enhance income to the farmers as organic products fetch higher prices than conventional ones. During year 2013–14 the share of organic basmati rice was 6.0% to the total volume of organic products' export from India. Thus, research on organic farming opens new vistas in Indian Agriculture. Organic farming often should deal with a scarcity of readily available nutrients in contrast to inorganic farming which rely mostly on chemical fertilizers. The aim of nutrient management in organic systems is to optimize the use of on-farm resources and minimize losses. This study evaluated the effect of including mungbean (*Vigna radiata* L.) in rice–wheat cropping system on soil fertility, productivity and profitability of basmati rice and wheat crops. Further aim of the study was to find out the most promising nutrient management practices for better yields, returns and improved soil fertility.

METHODS AND MATERIALS

A long-term field experiment on organic farming of basmati rice-based cropping systems was started in year 2003 and is still on-going. The initial three years were considered as transitional (2003–2005) period and a truly organic experiment started since year 2006 onwards. This experiment is located at the research farm of Indian Agricultural Research Institute, New Delhi, India (28.4°N latitude, 77.1°E longitude, and elevation of 228.6 m above the msl). The soil of the experimental field is classified as a typical Ustochrept (sandy clay loam texture). Soil had 52.06% sand, 22.54% silt and 25.40% clay at the beginning of the experiment. It had medium levels of organic carbon (5.1 mg/kg soil), low levels of available nitrogen (73.1 mg/kg soil) and medium levels of available phosphorus (8.42 mg/kg soil) and available potassium (108.9 mg/kg soil) and had a pH 8.16 at the start of experiment. The experiment was laid out in a strip plot design with three replications. Treatments consisted of 2 rice-based cropping systems (basmati rice–wheat and basmati rice–wheat–mungbean) in columns, six combinations of different organic materials and biofertilizers [farmyard manure equivalent to 60 kg N/ha (FYM), vermicompost equivalent to 60 kg N/ha (VC), FYM + crop residue of preceding crop @ 3 t/ha for each rice, wheat and mungbean (CR), VC + CR, FYM + CR + biofertilizers and VC + CR +

biofertilizers] and control (no fertilizer applied) in rows. These treatments were applied to both rice and wheat, whereas, mungbean in rice–wheat–mungbean cropping system was grown on residual fertility. For biofertilizers, blue green algae (BGA), phosphate solubilizing bacteria (PSB) and cellulolytic culture used in rice, *Azotobacter*, PSB and cellulolytic culture in wheat and *Rhizobium* + PSB in mungbean. The rice crop is grown during rainy season (July to October), wheat during winter (November to mid-April) and mungbean during summer (mid-April to June).

RESULTS AND CONCLUSIONS

Averaged across nine years, rice–wheat–mungbean cropping system (RWMCS) produced 13.5 and 6.4% higher grain yields of basmati rice and wheat crops, respectively over rice–wheat cropping system (RWCS) (Table 1). Furthermore, RWMCS also gave 0.88 t/ha additional seed yield (average of nine years) of mungbean besides a significant improvement in soil fertility over RWCS. Levels of organic carbon, total N, available nitrogen, phosphorus, potassium and micronutrients increased significantly and substantially due to inclusion of mungbean in RWCS. Simultaneously the soil microbiological properties, viz. microbial biomass carbon, microbial biomass nitrogen and enzymatic (alkaline phosphatase, acid phosphatase, dehydrogenase, glucosidase, FDA hydrolysis, etc.) activities were also significantly higher in soils of RWMCS than in RWCS. With respect to profitability, the basmati RWMCS was more profitableover the traditional RWCS.Hence, inclusion of mungbean, a legume, in RWCS enhanced the yield, profits and soil fertility. Some studies on organic grain production identify legume crops as a proficient way of providing nitrogen (N) to high N-demanding grain crops (Goewie, 2002; Robson *et al.,* 2002; Mazzoncini *et al.,* 2004; Casagrande *et al.,* 2009). Their capacity to fix atmospheric N and make it available to non-fixing plants (Askegaard and Eriksen, 2007; Fustec *et al*., 2010) has made them of increasing interest in organic grain systems subject to N deficiency (David *et al*., 2005). All the nutrient management practices increased the grain yield of rice and wheat crops significantly over the control. The increase was most when biofertilizers and crop residues were combined either with farmyard manure (FYM) or vermicompost (VC). Furthermore, application of vermicompost + crop residue + biofertilizers (BGA + cellulolytic culture + PSB in rice, *Azotobactor* + cellulolytic culture + PSB in wheat, *Rhizobium* + PSB in mungbean) was most productive and FYM + crop residue + biofertilizers was most profitable for nutrient need of basmati rice-based cropping systems. Both these combinations also resulted in a significant improvement in soil chemical and biological properties. Diacono and Montemurro (2010) have also reported that organic manures improved the soil biological functions, e.g. microbial biomass carbon increased by up to 100% using high-rate compost treatments, and enzymatic activity increased by 30% with sludge addition. They further reported that long-lasting application of organic amendments increases organic carbon by up to 90% versus unfertilized soil, and regular addition of organic residues, particularly the composted ones, increases soil physical fertility, mainly by improving aggregate stability and decreasing soil bulk density.

Based on nine years of investigation we conclude that inclusion of mungbean in RWCS enhanced grain yield, soil fertility and profits over RWCS. Use of FYM with crop residues and biofertilizers gave maximum profits and sustained soil fertility.

Table 1. Mean grain yield of basmati rice, wheat and mungbean crops in organic rice–wheat and rice-wheat-mungbean cropping systems

Year	Rice–wheat (grain yield in t/ha)				Rice–wheat–mungbean (grain yield in t/ha)				
	Rice	Wheat	Total (Rice + wheat)	Mean (Rice + wheat)	Rice	Wheat	Total (Rice + Wheat)	Mean (Rice + wheat)	Mungbean
2006–07	4.26	3.57	7.83	3.92	4.55	3.82	8.37	4.19	0.86
2007–08	4.51	4.47	8.98	4.49	4.91	4.83	9.74	4.87	0.90
2008–09	4.30	3.71	8.01	4.01	4.60	3.80	8.40	4.20	0.98
2009–10	3.94	3.81	7.75	3.88	5.10	4.04	9.14	4.57	0.81
2010–11	4.49	3.38	7.87	3.94	5.18	3.78	8.96	4.48	0.95
2011–12	3.71	3.52	7.23	3.62	4.08	3.97	8.05	4.03	0.83
2012–13	3.88	3.61	7.49	3.75	4.33	3.87	8.20	4.10	0.87
2013–14	4.35	3.72	8.07	4.03	4.92	3.69	8.61	4.30	0.94
2014–15	3.89	3.68	7.57	3.78	4.62	3.82	8.44	4.22	0.84
Mean	4.14	3.72	7.86	3.93	4.70	3.96	8.65	4.33	0.88

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

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$ 72 billion. 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 ₹ 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, 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. 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 crops are 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 are not capable to meet the requirements. 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 world as also there is 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-à-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 and IFOAM. If such amendments are not made, there is little likelihood of farmers switching to organic livestock production. In India, over 80% holdings are < 1 ha 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 agriculture.

a. Agronomic interventions to help 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 needs to be found.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Organic and towards organic agriculture in India for safe and secured food

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The rate of national agricultural growth was not able to keep pace with population growth and virtually 'ship to mouth' situation prevailed during pre-green revolution period (up to 1960s). This was the major factor for introduction and large-scale popularization of the high yielding varieties (HYVs) of crops, which were highly responsive to the chemical fertilizers and water use. As a result, the total food grain production increased phenomenally – from mere 50.82 million tonnes in 1950–51 to 264 million tonnes in 2013–14 – indicating a 5-times increase. This increase can be primarily attributed to large-scale adoption of HYVs, combined with other green revolution technologies (GRTs) in cereal crops, expansion of gross irrigated area (22.56 million ha in 1950–51 to 89.36 million ha in 2010–11) and increase in fertilizer consumption (0.07 million tonnes in 1950–51 to 25.54 million tonnes in 2012–13). All of them put together have led to substantial increase in the productivity of crops, especially food grains (from 522 kg/ha in 1950–51 to 2,125 kg/ha in 2012–13) culminating into the change in the status of India from a food importer to net food exporter (currently, contribution of agriculture in total export value is 14.1%). The total factor productivity (TFP) growth score prepared by National Institute of Agricultural Economics and Policy Research has revealed that technology-driven growth has been highest in Punjab and lowest in Himachal Pradesh. It implies that some of the states like Himachal Pradesh, Uttarakhand, Madhya Pradesh, Rajasthan, Jharkhand and north-eastern region of India have not been influenced much by the modern inputs of agriculture like chemical fertilizers and pesticides. India's average fertilizer and pesticide consumption stands at 128.3 kg/ha and 0.31 kg a.i./ha, respectively. Moreover, despite all technological advancements, the nutrient use efficiency is on lower side (33% for N, 15% for P and 20% for K and micronutrients). On the other hand, it has been proved scientifically and convincingly that integrated use of organic manures with chemical fertilizers improves the use efficiencies of the latter owing to concurrent improvement of soil physical, chemical and biological properties. The water holding capacity of the soil also gets improved on account of regular use of organic manures.

APPROACH

Organic is more of a description of the agricultural methods used on a farm, rather than food itself and those methods combine tradition, innovation and science. Organic agriculture, in simple terms, requires a shift from intensive use of synthetic chemical fertilizers, insecticides, fungicides, herbicides,

PGRs, genetically engineered plants to extensive use of animal manures, beneficial soil microbes, bio-pesticides, bio-agents and indigenous technological knowledge, based on scientific principles of agricultural systems. Hence, two approaches namely integrated crop management (50% nutrients through chemical fertilizers and rest through organic manures with no use of synthetics for pest management) and organic management practices as per National Programme of Organic Production (NPOP) standards were evaluated in crops grown in cropping systems across India under Network Project on Organic Farming (NPOF).

TOWARDS ORGANIC AGRICULTURE

The scientific evidences clearly establish that conversion of high intensive agriculture areas to organic systems lead to reduction in crop yields considerably (up to 10–15%), especially during initial 3–4 years; before soil system regains and crop yields come to comparable level. The per cent change in the yield of major crops during conversion (1–3 years) and afterwards across the locations (includes high intensive, rainfed and hilly areas) indicates reduction in yield of crops (except soybean) during first 2 years and the mean reduction was found to be 6.5% in the first year and 1.7% in the second year (Table 1). In case of soybean and desi cotton (*Gossypium arboreum*), improvement in yield under organic management was observed to be 1 and 8% respectively. In overall, the yield starts improving or on par with chemical management from 3rd year onwards under organic management except wheat. In this scenario, if all the cultivated areas are brought into organic production systems, the national food production system may get jeopardized; hence a phased approach may be desirable. Considering this fact on one hand and looking into global scenario of organic agriculture Working Group on Horticulture, Plantation Crops and Organic Farming for the XI Five Year Plan (GOI, 2007) suggested a spread of organic farming on 1–5 per cent area in the high productive zones and larger spread in the less exploited areas, such as, rainfed and hill areas. The

Table 1. Mean yield of crops tested in cropping systems under organic management and yield trend over the years

Crop	No. of observations	Mean yield (kg/ha) under organic management	Yield trend under organic system over the years (% increase (+) or decrease (–) over inorganic input management)						
			1st year	2nd year	3rd year	4th year	5th year	6th year	7th year
Basmati rice	67	3,099	–13	–14	–3	2	2	8	7
Rice	56	3,639	–12	–13	5	2	1	2	1
heat	56	2,952	–15	–9	–7	–3	–7	–13	–4
Maize	55	4,541	–5	9	4	0	3	10	16
Chickpea	25	1,269	–10	5	9	3	0	1	5
Soybean	58	1697	1	1	5	0	3	0	12
Cotton *(desi)*	29	1243	8	9	11	12	11	14	12
Mean	–6.5	–1.7	3.4	2.3	1.9	3.1	7.0		

Intergovernmental Panel on Climate Change (IPCC) found that agriculture as practised today (chemical agriculture) accounts for about one fifth of the anthropogenic greenhouse effect, producing about 50 and 70%, respectively of the overall anthropogenic methane and nitrogen oxides emissions (Charyulu and Biswas, 2010). Assessment of soil C sequestration potential was made after 10 years of continuous organic cultivation resulted in 27% higher soil C stockunder integrated crop management compared to inorganic management clearly giving the environmental advantage. Further, production of safe food (chemical free) is also essentialas according to Pimentel (1995), only 0.1% of pesticide actually reaches the target pests and the rest go to non-target sectors. Hence, integrated approach of crop management (ICM)having fertilizers up to 50% and no synthetics/chemicals for pest managementcanbe considered as 'towards organic' approach; and at the same time, has been found to increase the use efficiency of all costly inputs especially nutrients and water, it would be appropriate to adopt it in the high intensive areas contributing major share to the food basket of the country. This approach will also contribute to 'more crop per drop and less land, less resource/ time and more production' strategies.

ORGANIC AGRICULTURE

India has a sizable cropped area in different states, which is more prone to weather vagaries; especially those located in rainfed, dryland and hilly areas. Increasing the agricultural productivity and income of the farmers as well as sustaining soil resource in these agricultural systems has always been a challenging task for researchers and policy planners. Presently, in these areas use of fertilizers and pesticides is minimal and much below the national average. At first instance, these are the niche areas which need to be targeted for organic production by devising proper strategies and identifying niche crops (crops which yield higher under organic production systems and have adequate market demand). The domestic and export markets must be exploited for increasing the income of the farmers in the region, as it is important to note that 78% of Indian organic consumers prefer Indian brand of organic and many other countries also require diversified organic foods of tropical fruits, vegetables, essential oils, flowers, herbs, spices and organic cotton from India. In addition, large-scale adoption of organic agriculture in such areas will not only help in conserving the environmentally fragile ecosystems but also help in supplementing overall food production of the country. This can be clearly brought out by the example of Sikkim–an agriculturally low productive state located in north-eastern hills region of the country. During 2002–03 (before Sikkim Organic Mission) fertilizer consumption was the highest (21.5 kg/ha), the productivity of rice was 1.43 t/ha but 11 years later, i.e. during 2013–14, it increased to 1.81 t/ha, and more interestingly, no yield reduction was observed during conversion period. Productivity increase in other crops was also noted to the tune of 11%, 17% and 24% in maize, finger millet and buckwheat, respectively. Further, under the organic management, build-up of C stock was higher by 28.2 and 63.1% than integrated and chemical management, respectively. The soil C sequestration rate in 0–60 cm soil depth under organic cultivation of crops was found to be 1.46 and 2.57 t/ha/yr compared to integrated and chemical application of soil nutrients, respectively. This study explicitly shows that continuous practice of raising the crops organically has good potential to sequester the C in the soil to offset the C emissions in the atmosphere (IIFSR, 2015).

Relative yield under organic and towards organic management: Rice (*Oryza sativa* L.), wheat (*Triticum aestivum* L.), and maize (*Zea mays* L.) provide about two-thirds of all energy in human diets, and four major cropping systems namely rice–rice, rice–wheat, rice–greengram and maize–wheat in which these cereals are grown occupying more than 16 m ha area greatly affects the livelihood and health of the urban and rural poor in India.Basmati rice, rice, maize, greengram, soybean and groundnut recorded higher relative yield of organic over inorganic management. Wheat, a main crop for food security, recorded 7% reduction (Table 2) in yield under organic over inorganic. However, wheat under integrated crop management registered 2% higher yield

Table 2. Average and range of relative yield (%) of crops under integrated crop management (towards organic) over inorganic management and organic over inorganic management

Crops	No. of locations	No. of yield entries	Integrated (towards organic) over inorganic management		Organic over inorganic management	
			Mean	Range	Mean	Range
Basmati rice	5	67	110	93–136	104	88–121
Rice	3	52	99	92-110	100	89–122
Wheat	8	55	102	90–114	93	78–113
Maize	6	37	119	85–153	110	62–137
Green gram	2	12	109	102–116	107	96–122
Soybean	2	54	103	98–114	104	96–123
Groundnut	3	16	107	103–111	103	83–116
Pea	5	21	120	96–162	125	94–162
Okra	2	10	109	97–125	118	90–142
Chilli	2	12	111	108–113	109	107–112
Onion	4	13	116	98–138	107	87–127
Garlic	2	9	120	114–126	104	86–121

Table 3. Per cent change in yield of major food crops at various locations under towards organic and organic management

Locations	% change in yield under towards organic (ICM) over inorganic				% change in yield under organic over inorganic			
	Basmati rice	Coarse rice	Wheat	Maize	Basmati rice	Coarse rice	Wheat	Maize
Irrigated regions								
Chhatisgarh	–	–	8.7	–	–	–	–13.8	–
Jharkhand	8.1	–	–2.5	–	14.0	–	–12.6	–
Madhya Pradesh	–3.7	–	–3.6	–	–7.4	–	–15.7	–
Maharashtra	–	–6.0	–	–	–	–7.7	–	–
Meghalaya	–	–5.9	–	–	–	–0.2	–	–
Punjab	6.4	9.7	–0.8	17.5	2.3	–3.6	–8.6	17.4
Tamil Nadu	–	–	–	6.8	–	–	–	–1.9
Uttarakhand	7.0	–	–2.1	–	2.0	–	–14.7	–
Uttar Pradesh	1.9	1.9	11.9	21.3	5.3	5.3	–9.3	15.1
Mean	3.9	–0.1	1.9	15.2	3.2	–1.6	–12.5	10.2
Rainfed/hilly regions								
Himachal Pradesh	–	–	–	38.0	–	–	–	13.5
Karnataka	–	–	13.4	18.5	–	–	15.0	19.9
Madhya Pradesh	–	–	5.5	–	–	–	4.0	–
Mean	–	–	9.5	28.3	–	–	9.5	16.7

than chemical management indicating the suitability of towards organic approach for wheat. Per cent change in yield of crops under towards organic and organic management in irrigated and rainfed/hilly region indicated under irrigated high intensive areas, basmati rice and maize recorded higher yield under both towards organic and organic approaches compared to chemical management. However coarse rice and wheat registered better performance under towards organic approach compared to organic practice (No change and + 1.9% yield of coarse rice and wheat under towards organic practice over inorganic practice). Organic management resulted in reduction in yield of coarse rice and wheat by 1.6 and 12.5% respectively in irrigated regions (Table 3). Under rainfed/hilly regions, maize performed better under organic management and even wheat registered positive yield change over inorganic clearly supporting the organic agriculture in rainfed and hilly regions will lead to improve the food security.

CONCLUSION

It can be concluded that, accelerated adoption of 'towards organic' (integrated crop management) approach for intensive agricultural areas (food hubs) and 'certified organic farming' with combination of tradition, innovation and science in the de-facto organic areas (hills) and rainfed/ dryland regions will contribute towards safe food security and climate resilience, besides increased income of farm households. This approach will also positively contribute to the cause of human, livestock and eco-system health, the basic objective of organic agriculture. Scientific organic farming needs to be promoted in the high intensive areas to keep the yield of crops at comparable level with chemical management. In rainfed/hilly areas, organic agriculture with scientific packages will result in significant improvement in productivity of crops.

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Symposium 3
Agriculture Diversification for Sustainable Resources

Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Evaluation of profitable alternate crops to chickpea under rainfed (*Cicer arietinum*) conditions in vertisols of Andhra Pradesh

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Field experiment was conducted during *rabi* 2012–13 at Regional Agricultural Research Station, Nandyal to evaluate the performance of profitable alternate crops to chickpea in black cotton soils of Andhra Pradesh. The soils were deep black with alkaline nature having pH of 8.5 and organic carbon of 0.56%. The available N, P_2O_5 and K_2O were 191, 20.6 and 498 kg/ha, respectively. The experiment was laid out in Randomized Block Design with three replications. The treatments consisted of different crops, viz. jowar, sunflower, foxtailmillet, blackgram, mustard, soybean, safflower and chickpea. A total rainfall of 746.6 mm was received during *kharif*, 2012 (June to September) whereas during *rabi* (October to December) only 73.0 mm was received. Therefore, 1 irrigation was provided at critical stage of the crop and water productivity was calculated.

The results revealed that none of the alternate crops were found to be as superior as chickpea in producing Chickpea Equivalent Yields (CEY) because chickpea produced significantly highest seed yield of 1,760 kg/ha. However, blackgram, safflower and mustard were found to be relatively better than other crops with Chickpea Equivalent Yields of 1,070, 861 and 833 kg/ha, respectively. These three crops also fetched the higher net returns of ₹ 30,312, 24,450 and 19,628/ha, respectively. As regards the water productivity, among all the crops, jowar topped the list with higher water productivity of 3.74 kg/m^3 and this was closely followed by foxtail millet and chickpea with water productivities of 3.64 and 3.52 kg/m^3, respectively which were comparable each other. The other crops which recorded reasonably good water productivity were safflower and blackgram with water productivity of 2.30 and 2,014 kg/m^3 respectively.

From this study, in can be concluded that chickpea was found to be the best crop for getting higher net returns and higher water productivity in black cotton soils of Andhra Pradesh. However, to avoid mono cropping and thereby to decrease the pest and disease buildup in chickpea, this crop can be rotated with other better crops like blackgram or safflower or mustard.

Table 1. Yield, bengalgram equivalent yields, gross and net returns and water productivity of alternate crops during 201112 and 2012–13

Treatments	Soil moisture (%)						Yield (kg/ha)		BGEY		Gross returns		Net returns		Water	
	2011–12			2012–13			(kg/ha)		(Rs/ha)		(Rs/ha)		productivity		(kg/m^3)	
	DAS			DAS												
	30	50	70	30	40	60	2011–12	2012–13	2011–12	2012–13	2011–12	2012–13	2011–12	2012–13	2011–12	2012–13
Jowar	19.7	17.7	15.9	21.3	19.5	18.7	948	1,865	325	559	11,377	22,380	2377	7380	1.90	3.73
Sunflower	20.4	18.6	17.5	20.0	22.8	20.3	413	806	331	645	11,570	25,793	1570	10,793	0.83	1.61
Foxtailmillet	21.4	17.6	15.6	20.6	24.1	20.0	1,554	1,821	577	637	20,207	25,491	13,207	15,491	3.11	3.64
Blackgram	23.3	18.2	15.3	20.0	15.5	14.5	1,034	1,070	1,034	1070	36,201	42,812	28,701	30,312	2.07	2.14
Mustard	21.7	17.2	15.3	21.0	18.3	17.2	988	741	1,129	833	39,521	29,628	32,021	19,628	1.98	1.48
Soyabean	20.4	17.7	15.9	20.2	20.9	18.6	340	639	155	399	5,435	15,971	-2,065	5,971	0.68	1.28
Safflower	21.6	17.7	15.9	21.2	17.6	15.8	909	1,148	649	861	22,730	34,450	15,730	24,450	1.82	2.30
Bengalgram	19.5	17.1	14.9	20.4	17.3	16.2	1,595	1,760	1,595	1,760	55,839	70,408	45,839	55,408	3.19	3.52
SEm±	1.1	0.9	1.2	0.8	1.7	1.1	–		93	87	–		–		0.25	0.47
CD (P=0.05)	NS	NS	NS	NS	5.3	3.3	–		284	266	–		–		0.77	1.05

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Productivity of different cropping systems as influenced by soil moisture conservation and nutrient management under rainfed situation

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Resource management is the crucial part in crop production under rainfed situations. Availability soil moisture and nutrient supply is the key to successful crop production in dryland areas (Kumar and Rana, 2007). It is therefore crucial that farming systems in these regions aim at making the maximum use of incident rainfall by ensuring that wasteful surface runoff is avoided. Hence, the conservation, development and management of available resources are of prime importance (Khanapara *et al.*, 2009). The information on the soil moisture as well as nutrient management is not much under the given situation, hence this study on the impact of moisture conservation techniques and nutrient management practices on growth and productivity of different cropping systems under rainfed situation has been taken under investigation.

METHODOLOGY

The experiment was conducted during *kharif* and *rabi* season of 2014–15 to 2015–16 study the impact of soil moisture conservation techniques on productivity and soil moisture content under different cropping systems, to study the influence of nutrient management practices on productivity and nutrient uptake of different cropping systems, and to evaluate the productive performance, economics and sustainability of the cropping systems under rainfed situations. The experiment was conducted in strip-plot design replicated thrice. The treatments were comprised offour cropping system i.e. pearlmillet-mustard, pearlmillet-chickpea, clusterbean-mustard and clusterbean-chickpea; four soil moisture conservation technique i.e. control, straw mulch (5 t/ha), farmyard manure (FYM) (5 t /ha), and straw mulch (2.5 t/ha) + farmyard manure (2.5 t/ha); and three nutrient management practices i.e. control, recommended dose of fertilizer (RDF) and 75% RDF + biofertilizer (BF). All the recommended practices except treatment were adopted. The soil test value based nutrient application was done. The net plot size was 4 × 4 m. The variety ‘Pusa Composite-443’ of pearlmillet and ‘RGC-1055’ of clusterbean was used as test crops during *kharif* season. The variety ‘Pusa-372’ of chickpea and ‘Pusa Taraq’ of mustard was used in *rabi* season experiment.

RESULTS

About 70 kg/ha of mustard and 50 kg/ha of chickpea yield was obtained more under the cropping of clusterbean over pearlmillet as preceding crop (Table 1). The seed yield of mustard (2.02 t/ha) and chickpea (982 kg/ha) was obtained significantly greater under the moisture conservation technique of straw mulch @ 2.5 t/ha with FYM @ 2.5 t/ha over straw mulch and FYM alone. While the technique of straw mulch and FYM were statistically at par but higher over control. The nutrient management practice of RDF gave higher quantity of mustard yield and chickpea yield as well but statistically at par with the application of 75% RDF + biofertilizer.Pearlmillet equivalent yield (PEY) was recorded higher in the cropping system of clusterbean-mustard (7.43 t/ha) followed by pearlmillet-mustard (Fig. 1). This might be because of higher price of mustard in both the systems. Straw mulch + FYM was found superior over straw mulch

Table 1. Impact of soil moisture and nutrient management on productivity of crops under different cropping systems

Treatment	Pearlmillet (t/ha)	Clusterbean (kg/ha)	Mustard (t/ha)	Chickpea (kg/ha)
Cropping system				
Pearlmillet–Mustard	2.64	–	1.81	–
Pearlmillet–Chickpea	2.80	–	–	904
Clusterbean–Mustard	–	971	1.87	–
Clusterbean–Chickpea	–	986	–	954
(P=0.05)	NS	NS	0.05	39
Moisture management				
Control	2.08	831	1.62	826
Straw mulch (5 t/ha)	2.96	955	1.84	938
FYM (5 t /ha)	2.74	913	1.76	922
SM (2.5 t/ha)+ FYM (2.5 t/ha)	3.15	1,008	1.98	961
(P=0.05)	0.29	41	0.12	22
Nutrient management				
Control	1.71	837	1.64	841
RDF	3.11	1,033	2.02	955
75% RDF + BF	2.92	1,014	1.98	941
(P=0.05)	0.31	44	0.14	24

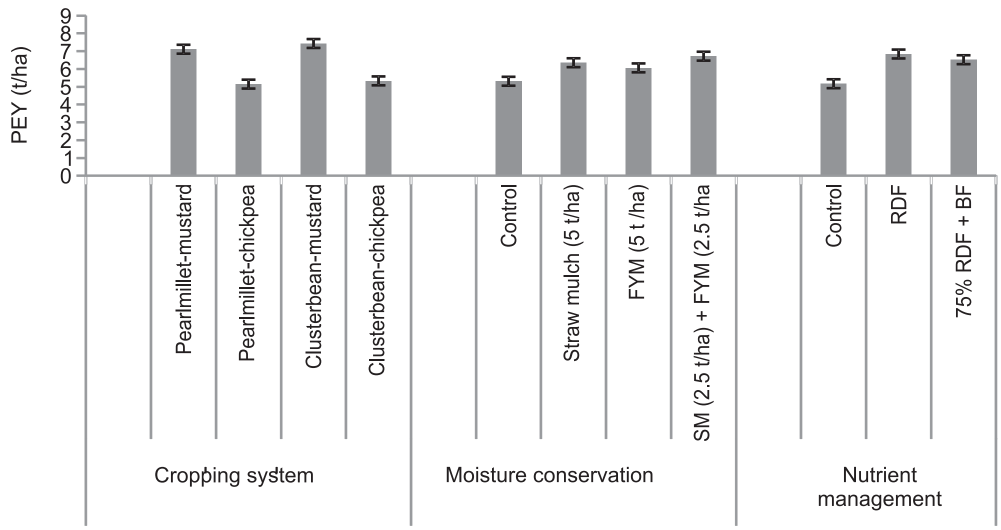

Fig. 1. Pearlmillet equivalent yield as influenced by soil moisture conservation and nutrient management with different cropping system

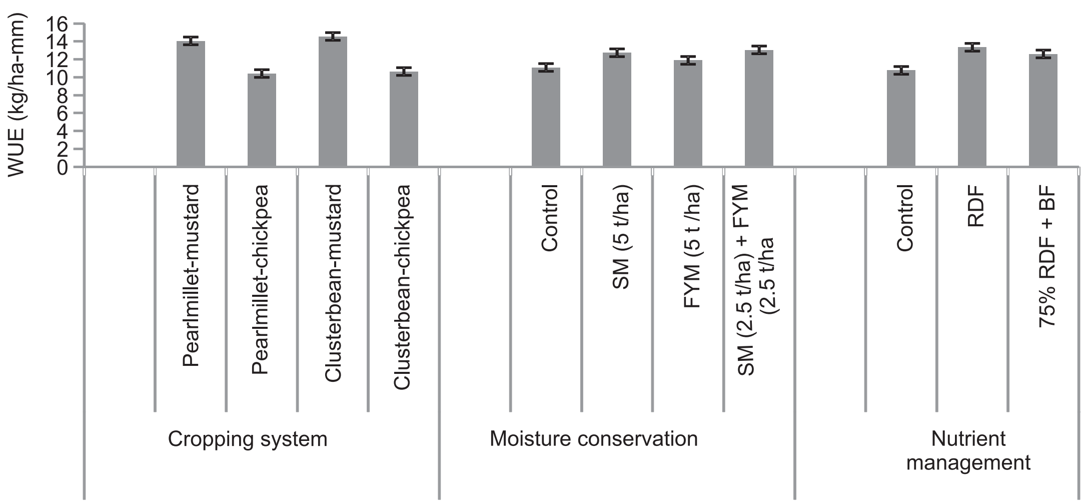

Fig. 2. Water use efficiency as influenced by soil moisture conservation and nutrient management with different cropping system.

alone for obtaining higher PEY (6.72 t/ha). Although greater PEY (6.84 t/ha) was obtained under RDF but statistically at par with 75% RDF + BF. The water use efficiency (WUE) was also calculated greater in the same set of treatments of the cropping system (14.5 kg/ha-mm), moisture conservation (13.0 kg/ha-mm) and nutrient management (13.3 kg/ha-mm) as discussed earlier in the case of PEY (Fig. 2).

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

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 kg a.i./ha. before sowing (Recommended Practice) (2)Application of Imazethaypr 40 g 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 g a.i./ha. (15–20 days after sowing), yield increased (20.69%), net return (50,400 ₹/ha.) and BCR (3.57) and followed by application of Pendimethalin 1 kg a.i./ha in case of yield (1.63 t/ha), yield increased (12.07%), net return (₹ 45,800/ha) and BCR (3.39). Because application of Imazethaypr 40 g/ha gave good result due to less weed infestation and this herbicide is effective for weed control.

Table 1. Effect of integrated weed management on yield and economics (pooled of 3 trials)

Technology option	Yield (t/ha)	Yield increased (%)	Net return (₹/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

CONCLUSION

The results concluded that the application of Imazethypr 40 g a.i./ha. (15–20 DAS) was found very effective and feasible for enhancing the grain yield and found economically viable.

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Evaluation of pigeonpea genotypes for intercropping with sorghum under South Gujarat condition: economic benefits

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Pigeonpea [*Cajanus cajan* (L.) Millsp] is a multipurpose leguminous crop that can provide food, fuel wood and fodder for the small scale farmer in subsistence agriculture. It is the fifth most important pulse crop mainly grown in the developing countries by resourcepoor farmers in drought prone areas and on degraded soils. It is a deep rooted and drought tolerant grain legume that adds substantial amount of organic matter to the soil and has the ability to fix up to 235 kg N/ha (Peoples *et al*., 1995) and produces more N per unit area from plant biomass than many other legumes. Pigeonpea has been reported to fix between 36.1–114 kg N/ha when intercropped with maize and 35.9–164.8 kg N/ha under intercropping with sorghum (Egbe, 2007). In traditional cropping systems, pigeonpea is intercropped or mixed with sorghum and the yield of pigeonpea on such fields are low, mainly due to such constraints as poor management of intercropping systems with regards to unimproved genotypes suitable for intercropping, spatial arrangement etc. Pigeonpea/sorghum intercropping has numerous advantages, but it is also known that pigeonpea genotypes that give high yields in sole cropping may not necessarily be the highest yielding in intercropping. Estimation of farm income benefits provides an alternative measure of potentials for various intercropping combinations. Some workers had estimated economic benefits of intercropped pigeonpea with sorghum by calculating gross returns, net returns, and sorghum equivalent yield. Hence, This study was carried out to document the economic benefits of intercropping ofsome newly introduced improved pigeonpea genotypes with sorghum in South Gujarat condition with a view to increasing and diversifying household incomes of farmers in the region.

METHODOLOGY

A field experiment was carried out during late *kharif* season of 2013 at the Agricultural Research Station, Navsari Agricultural University, Mangrol. The soil of the experiment site was clay in texture (clay 54.4%, sand 22.4% and silt 20.1%) with pH 7.8 and electrical conductivity (EC) 0.48 dS/m in the top 30 cm of soil. The soil was low in available nitrogen (298 kg/ha) and organic carbon (0.46%) and medium in available phosphorus (49) and rich in available potassium (528 kg/ha). Treatments comprised of seven cropping systems, viz. T_1-Sorghum + pigeonpea var. Vaishali (2:1), T_2-Sorghum + pigeonpea var. GT- 102 (2:1), T_3-Sorghum + pigeonpea var. AGT- 2 (2:1), T_4-Sole sorghum var.GJ-38, T_5-Sole pigeonpea var. Vaishali, T_6-Sole pigeonpea var. GT-102 and T_7-Sole pigeonpea var. AGT-2. The experiment was laid out in randomized block design with four replications. Three improved genotypes of pigeonpea var. Vaishali, Gujarat Tur-102 and Anand Gujarat Tur-2 and sorghum var. Gujarat Jowar-38 were used in the study and to find out suitable genotype of pigeonpea intercropping with sorghum. Pigeonpea and sorghum were sown either as sole crop or intercrop on ridges. Intercropping had a 1 : 2 (pigeonpea: sorghum) row proportion, such that one row of pigeonpea alternated with two rows of sorghum. The recommended dose of fertilizer of pigeonpea and sorghum was applied on area cover base. Sorghum yield equivalent was calculated by considering prices of two crops with the following formula (Prasad and Srivastava, 1991). The economic performance of the intercropping was evaluated to decide sorghum yield in intercropped with pigeonpea and additional sorghum yield justified adoption of this intercropping system by farmers.

RESULTS

The yield of pigeonpea genotype and sorghum varied with adopted different cropping systems (Table 1). In generally, the yield of pigeonpea genotypes and sorghum intercropping was depressed as compared to its yield in sole cropping. The depression in the yields of intercroppingpigeonpeagenotypes as compared to sole crop resulted due to inter-specific competition. This may be attributed to competition free environment in sole cropping and higher availability of water and nutrients, its uptake and further translocation to developing leaves, stem and seed. Among the different pigeonpea genotypes, Vaishali produced higher seed yield than GT-102 and AGT-2 in intercropping as well as sole cropping system. Vaishali recorded higher yield in the sole cropping (1,480 kg/ha) as well as in intercropping system (1,241 kg/ha) as compared to GT-102 and AGT-2. Better performance of Vaishali than other genotypes in both cropping systems in terms of seed yield and net benefit due

Table 1. Effect of pigeonpea + sorghum intercropping system on yield, sorghum equivalent yield and economics

Treatment	Grain yield (kg/ha)		Sorghum eq. yield (kg/ha)	Gross realization (₹/ha)	Cost of cultivation (₹/ha)	Net realization (₹/ha)	BCR
	Sorghum	Pigeonpea					
Sorghum + pigeonpea var. Vaishali (2:1)	2,864	1,241	6,174	89,546	22,535	67,011	2.97
Sorghum + pigeonpea var. GT-102 (2:1)	2,613	1,151	5,682	82,901	22,535	60,366	2.68
Sorghum + pigeonpea var. AGT-2 (2:1)	2,692	1,175	5,825	84,783	22,535	62,248	2.76
Sole sorghum var. GJ-38	3,154	–	3,154	51,392	19,192	32,200	1.68
Sole pigeonpea var. Vaishali	–	1,480	3,947	50,755	19,984	30,771	1.54
Sole pigeonpea var. GT-102	–	1,333	3,556	46,378	19,984	26,394	1.32
Sole pigeonpea var. AGT-2	–	1,380	3,680	47,784	19,984	27,800	1.39
SEm±	122	64	119				
CD (P=0.05)	389	192	353				

to its aggressive early growth, early maturity and profuse pod production several times in a production season. Table 1 indicated that the intercropping system recorded the higher sorghum equivalent yield than sole cropping system. Similarly, sorghum intercropping with pigeonpea genotype 'Vaishali' recorded higher sorghum equivalent yieldover rest of the pigeonpea genotypes. Higher sorghum equivalent yield realized under intercropping system was attributed to better performance and yield of both the component crops under intercropping system. Intercropping consistently gave higher net benefits than sole cropping in the pigeonpea/sorghum systems (Table 1). Pigeonpea genotype Vaishali intercropping with sorghum recorded maximum net realization (₹ 67,011) with BCR is 2.97. Higher net returns and BCR in pigeonpea genotype Vaishali intercropping with sorghum due to higher complementarities effect between these two component crops which produced higher biological output and more returns.

CONCLUSION

On the basis of the results and economics, it is concluded that pigeonpea intercropping with sorghum consistently resulted in higher sorghum equivalent yield and net returns than sole cropping. Pigeonpea genotype Vaishali proved superior in both the cropping systems than GT-102 and AGT-2 and intercropping with sorghum in 2 : 1 (pigeonpea: sorghum) row proportion provide higher net returns, suggesting potential increase in household income of farmers of South Gujarat.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Spatial arrangement and crop combination effect on sorghum and intercrops productivity in forage production system

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New Mexico has been one of the fastest growing dairy states in the country. Rate of dairy growth in West Texas is also increasing with animal density doubled over years (Texas Agriculture Statistics, 2004). Establishment of three large capacity cheese plants and favorable environment for the dairy industry are expected to accelerate dairy growth in the eastern New Mexico and West Texas (Fig. 1). In addition, West Texas has the highest concentration of beef cattle in the country. This large confined animal feeding operation in the region need large quantity of good quality forages. Water requirement of the cattle is minimal compared to the water required to produce large quantities of good quality silage needed by the cattle. Therefore, to sustain the fast growing animal feeding operations in the region, new crops and cropping systems are needed to maintain quality forage production with less water use.

Sorghum and Corn are major irrigated silage crops of dairy in Southern Great Plains of the United States. Corn need much more water to produce unit dry matter as compared to sorghum (Staggenborg *et al.,* 2008). However, both are poor in protein, rich in fibre and lower digestibility. In recent past efforts were made to identify forage crops and cropping systems with higher WUE and better nutritional quality. Sorghum silage quality can be improved with addition of protein rich legumes at significant proportion (Chengci *et al.*, 2004). If component crops in an intercropping system differ in crop height, the two species may compete for immediate resources like sunlight. Thus, the performance of the shorter crop may be adversely affected. The performances of more compact intercrops may be lower while it may be higher for taller intercrops when compared to monocrops.

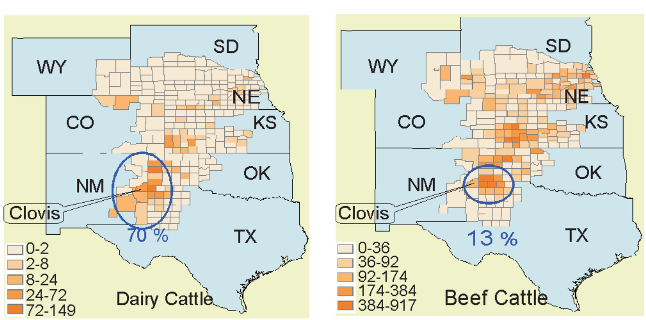

Fig. 1. Concentration of dairy (a) and beef (b) industries in the southern high plains (New Mexico and Oklahoma Panhandle) in relation to the outer counties in Ogallala aquifer states. The numbers are animal per sq. mile.

Besides plant height, intercrop population density plays an important role in yield determination in some intercropping systems. In a study conducted by Armstrong and Albrecht (2008) on the effect of planting density on forage yield and quality of corn and lablab intercrop, the addition of lablab to high yielding corn stands did not result in any benefits in terms of dry matter (DM) yield and crop value. Instead, corn yield was reduced with an increase in the density of bean up to 85,000 plants/ha. Moreover, CP concentration and feed nutrient value was increased only when beans were added to corn system at a low plant density. It should be noted that sorghum morphology and physiology is quite different compared to non-tillering corn. It may therefore be argued that sorghum-legume mixtures may give different results under different population density.

In terms of resource use and corresponding efficiencies, water, nutrients and solar radiation are the three most important resources for which intercrops may compete. The efficient use of these resources in an intercropping system is affected by various morphological and physiological features of the intercrops. Generally, dominant and subordinate pairs constitute an intercropping system. In most cases dominant crop grows taller and should have higher light saturation values (e.g. feature C_4 metabolic pathways) than the subordinate crops which should be more shade- tolerant thereby making most efficient use of the incident radiation. Another issues being that the dominant crop should have a more rapid and earlier growth cycle compared to the subordinate crop thereby the system could result in more efficient resource capture and higher overall biomass production (Awal *et al.*, 2006). Therefore, in an intercropping system, higher biomass production is mostly associated with early canopy development and higher radiation interception (Kevin, *et al*., 2006). The objectives of our studies were to identify potential legume species in modified row configuration and sorghum populations in sorghum-legume intercropping system. Performance evaluation of selected legumes based on biomass production, per cent contribution to total yield and total forage yield.

METHODOLOGY

Field studies were conducted at Agricultural Science Center at Clovis (34°26′ N, 103°12′ W, 1332 m) of NMSU, NM. Soils of experimental site was Olton silty clay loam with pH 7.7, initial soil available nitrate was 21.6 kg/ha, while 13 and 504 ppm of P and K respectively. The normal annual precipitation was 450 mm and temperature 22°C.Growing seasons were defined as May to early October months. Environmental variables collected during growing season include maximum and minimum air temperature and total precipitation. Sorghum and corn were grown as main plots and legume intercrops selected for the study presented in Table 1. Three row configurations were mixed, 1 : 1 and 2 : 2. For mixed intercropping sorghum and legume seeds were mixed at normal recommended rate and planted in a single row. In 2 : 2 row combinations sorghum was planted in paired rows at 37.5–112.5–37.5 cm and two rows of legumes planted in between sorghum rows. Sorghum and legumes were harvested at 2.5 cm above ground surface for biomass production throughout cropping season. Final biomass harvest was done at soft dough stage of sorghum and corn. Both main and legume intercrops were harvested separately in a 0.75 m^2 area. Sorghum samples from each treatment were chopped, sub sampled and oven dried at 60°C. Entire quantities of legumes were dried due to its small quantity. The legume contribution was worked out considering legume dry matter yield and total forage yield.

Table 1. Sorghum and corn intercropped with different legume species selected for the study

Sl. no	Selected species of the study	Variety or type
1	Sorghum (Sorghum bicolor L. Moench)	FS 5
2	Corn (Zea mays L.)	31G71
3	Lablab (Dolichos lablab L.) Sweet)	Rioverde
4	Cowpea (Vigna unguiculata L.) Walp.	Iron clay-50
5	Pigeonpea (Cajanus cajan L.) Millsp.	GA 2
6	Lima bean (Phaseolus limensis L.)	Willow leaf
7	Pole bean (Phaseolus vulgaris L)	Genuine corn field

Prior to chemical analysis, dried leaf and stem samples of sorghum and legumes were ground using a Wiley mill to pass through one mm screen. Ground legume sample was mixed with sorghum samples using per cent legume contribution to the total biomass on dry weight basis. The mixed samples were submitted to WARD laboratories (Kearney, NE) a national forage testing association certified laboratory for forage nutritive value analysis using near infrared reflectance spectroscopy. The major quality components includes crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), NDF digestibility of% NDF, total digestible nutrients (TDN) and in-vitro true dry matter digestibility (IVTDMD). Relative Forage Quality (RFQ) an estimate of how much available energy a non-lactating animal will get daily from a forage when it is fed only that particular forage. A mixed model was used to analyze combined multi years data. If the ANOVA for the multi-year combined data showed significant interaction effect between treatments and year, separate ANOVA was conducted for each individual year. The SAS 9.3 (SAS Inst., 2008) was used for all analyses.

RESULTS

Sorghum dry matter production was affected by cropping systems and spatial arrangement in all three years of study. In 2009, decreased sorghum DM was observed in lower sorghum density @ 19 plants/m^2 (11–17%) over normal density of sorghum @ 25 plants/m^2. But in 2008 and 2010,

Table 2. Quality analysis of sorghum, corn and legume samples from intercropping systems grown at ASC, Clovis, NM, USA (pooled over 2 years)

Cropping system	CP!	ADF	NDF	NDFd	IVTDMD	RFQ
	g/kg dry matter					
BMR*+ Limabean	81d	324bc	485abc	745c	876b	142abc
BMR+ Lablab	97b	319bc	477bc	713d	862b	135c
Sole BMR	70e	287d	463cd	818a	916a	150a
Brachytic sorghum + Limabean	90c	364a	503a	665ef	831c	122d
Brachytic sorghum + Lablab	97b	357a	495ab	668e	834c	125d
Sole Brachytic	79d	291d	444d	780b	902a	145abc
Corn+ Limabean	92c	313bc	473bc	618g	819c	149a
Corn + Lablab	108a	326b	469cd	620g	822c	137bc
Sole Corn	82d	304cd	477bc	640fg	829c	140bc
LSD	4	21	25	27	20	8

*BMR-Brown Midrib; !CP-Crude Protein; ADF-acid detergentfibre; NDF-Neutral detergent fibre; NDFD- NDF digestibility; IVTDMD-In-vitro true digestible dry matter, RFQ-Relative feed quality

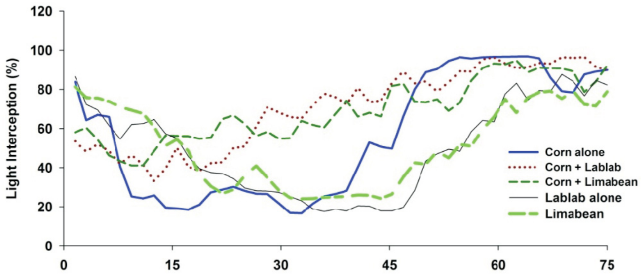

Fig.1. Light interception (*f*PAR) through the different crop canopies and distributed between crop rows (75 cm) in intercropping systems compared with respective sole crops. Data recorded at 64 DAS.

there was no difference with respect to sorghum and legume DM. There was no significant influence of intercrop legumes on sorghum and legume DM in all the site years. All are equally competitive as an intercrop with sorghum. The legume DM contribution towards total forage yield did not influence on magnitude DM reduction. Arrangement of component crops had significant influence on sorghum DM. Sorghum planted in paired rows resulted in decreased sorghum DM (5–10%) over legumes mixed or planted in alternate rows. However, total forage mixture yield difference was very marginal (<2.5%). Across arrangements and sorghum density the sorghum biomass yield at end of the season was 17.3–18.5, 13.1–15.7 and 18–20 t/ha in 2008,

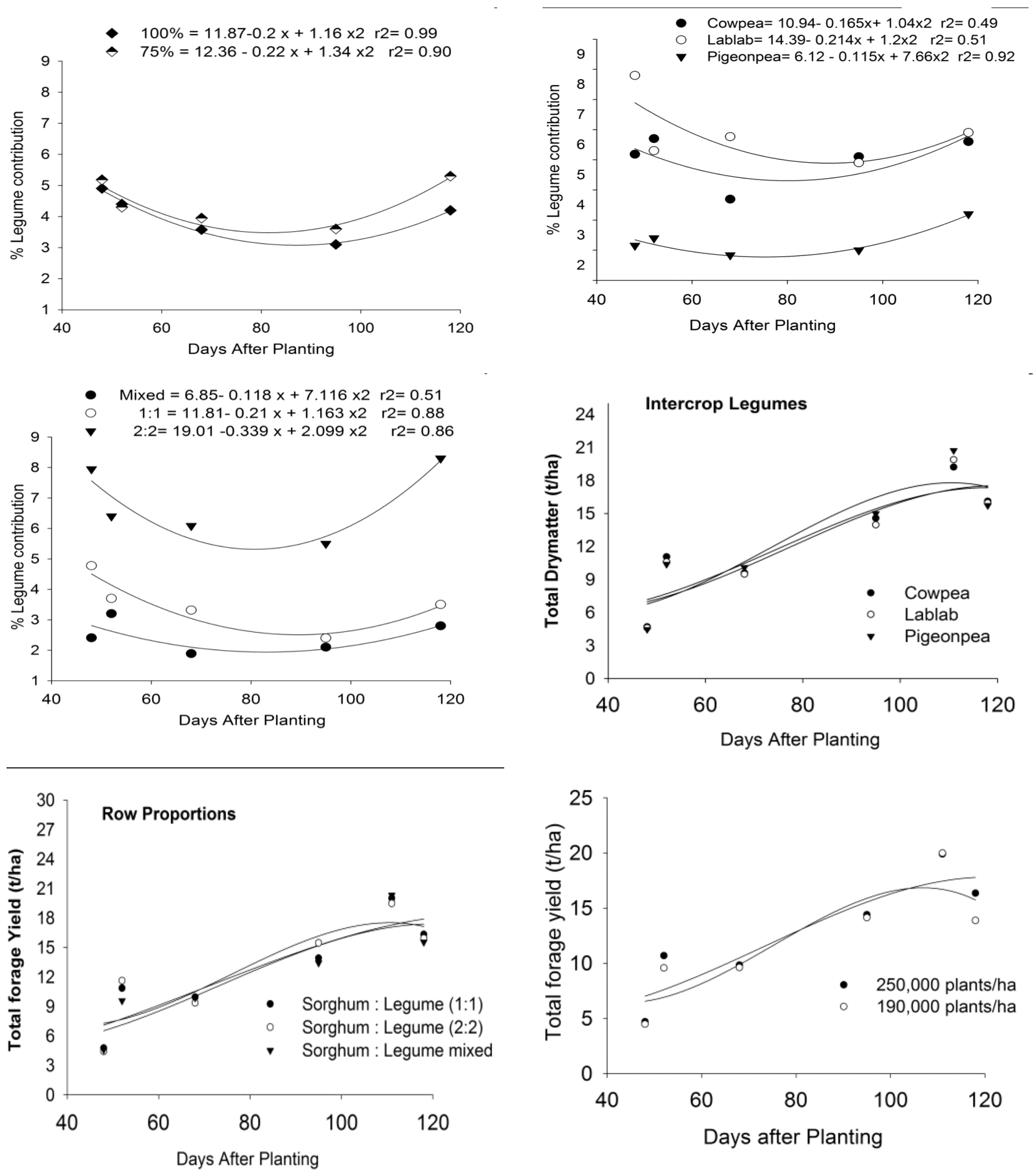

Fig 3. Seasonal pattern of legume contribution and total forage yield influenced by row proportions, sorghum populations and intercrop species in sorghum-legume intercropping systems in comparison to sole forage sorghum at Clovis, NM.

2009 and 2010 respectively. Sorghum density @ 19 plants/ m^2 intercrop with legumes resulted in higher legume proportion (5.3%) compared to normal density of 25 plants/ m^2 (4.2%) as that of sole crop. Lablab performs better as intercrop with sorghum compared to cowpea and pigeonpea. Over three season average, at the end of crop period it contributes 6% of total forage yield. Intercrops and sorghum planted at 2 : 2 ratio (8.3%) helps to increase legume contribution compared to 1 : 1 and mixed (2.8%) intercropping. Results of the study indicate sorghum plant density, species effect and row arrangement had significant influence on intercrop biomass and total forage yield. The tall multipurpose FS-5 sorghum type suppressed intercrop legume species. Its effect can reduce with lower density, and wider row spacing (2 : 2). Further, it suggested the importance of canopy modification to harness more light by intercrop canopy. Percentage of PAR interception was affected by cropping systems. The mean of PAR interception averaged over sampling dates by intercrop treatments higher than that of sole cropped corn and sorghum.

Another experiment wherein sorghum intercropped with polebean and lablab total biomass production and light interception was superior over respective sole crops. Among intercrops sorghum and lablab system was performed better than sorghum and polebean intercropping.This was related to lablab being a vining plant reaching the top of the corn canopy early-on during the growing season thereby efficiently competing for light with corn. The spatial transmission of PAR across the row with different crop canopies is shown in Fig. 2. Light interception and its distribution were varied between crop rows of sole crops and intercrops. In sole corn, all the radiation was reached the ground between distances of 20 to 60 cm of crop rows. As canopy development progressed, the row structure was clearly evidenced through a decrease in the fPAR. In intercrop canopies the fPAR variation was quite differ and maximum utilization due to introduction of intercrop in between crop rows of corn. Awal *et al.* (2006) also observed enhanced light interception in between crop rows of maize-peanut intercropping over sole corn.

Forage quality was significantly affected by crop mixtures in both years. Between intercrops tested lablab was found potential to improve CP over limabean and respective sole crops. The increased crude protein content in legumes mixed with sorghum or corn grown along with limabean or lablab as compared to respective sole crops. There were several significant interactions for fibre concentration and fibre composition. However there was no significant difference in ADF, NDF between limabean and lablab intercrop either with corn or sorghum and superior over sole crops. NDF digestibility was not great consistant across crop mixtures sole crops have higher NDFd than intercropping. Generally NDFd was greater for grasses than legumes (National Research Council, 2001), but the magnitude of this difference and the proportions of legume in these mixtures were not great enough to have a significant effect on the mixtures. Armsrong *et al.* (2008) also observed increased DM yield, CP concentration, fibre digestibility over other legume species intercropped with corn.

CONCLUSION

Forage dry weights achieved by the intercrops were greater than those by either corn or sorghum sole crops. The results of these experiments could provide some quantitative evidence for the hypothesis that greater environmental resources consumption by intercrops is primary cause of advantages. Better transmission of PAR through intercrop canopy. CP concentration was increased in lablab-corn/ sorghum mixtures, fibre and digestibility were compromised compared with monocultures. Lablab bean proved to have the best potential as an intercrop with corn or sorghum. It has better transmission and distribution of PAR across canopy, higher yields, and enhanced nutritional quality of feed.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Sustainable intensification of cereal-based systems in western IGP: Scalable evidence

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The productivity and sustainability of conventional tillage based scented RW systems are threatened because of inefficient use of natural resources and production inputs, increasing energy cost, labour shortages, growing changing climate induced variability (Jat *et al.*, 2016) and volatile *Basmati* market leading to diminishing farm profits. Therefore, it is imperative to develop, adapt and out-scale management practices which can address these challenges. Conservation agriculture (CA) based sustainable intensification through minimizing mechanical soil disturbance and permanent soil cover combined with appropriate crop diversification/intensification has shown potential to sustain productivity, improve profits while arresting natural resource degradation in intensive RW system of NW India (Gathala *et al.*, 2013). However, intensifying scented rice-wheat further is challenging due to long duration of the basmati varieties. We therefore undertaken a study with innovative approaches to intensify the scented rice-wheat rotation through inclusion of legume and CA based management optimization to improve crop and protein yields, farm profits, save water, while improving soil health.

METHODOLOGY

A farmer's participatory strategic research trial was conducted for continuous 4-years (2011–15) at Taraori village;the heartland of scented rice in Karnal, India. The experiment consisted of 6 combinations of tillage, crop establishment, residue management and legume integration in scented RW system. The treatments comprised of conventional till (CT) puddled transplanted rice (PTR) followed by CT wheat (CT PTR-CT W; farmers practice); CT PTR-CT W followed by CT mungbean (CT PTR-CT W-CT M); zero-till (ZT) direct seeded rice (DSR) followed by ZT wheat (ZT DSR-ZT W); ZT DSR-ZT W followed by relay mungbean (ZT DSR-ZT W- R M); ZT DSR-ZT W with full (100%) residue retention (ZT DSR-ZT W + R) and ZT DSR-ZT W- R M with full residue retention (ZT DSR-ZT W-R M + R). ZT. Data on yields (grain, protein), water use, and on carbon sustainability index were collected using the standard procedures. System productivity was calculated by considering the MSP of the concerned years. Net returns were calculated by deducting the total variable cost from the gross returns. The Carbon Sustainability Index (CSI) was computed using the methodology given by Lal (2004).

RESULTS

Data (4 years) related to system productivity, economic returns, protein yield, water use and CSI were subjected to pooled analysis. The results revealed that all the parameters had significant influence of tillage, crop establishment, residue management and mungbean inclusion in scented rice-wheat system. On pooled average basis, 36 and 33% higher wheat equivalent system yield was recorded with ZT DSR-ZT W-R M + R and ZT DSR-ZT W-R M, respectively over CT PTR-CT W system (14.91 t/ha). Irrigation water saving of35% (pooled average basis) was recorded with ZT DSR-ZT W + R, followed by ZT DSR-ZT W (26%) andZT DSR-ZT W- RM (19%). In conventional tillage based system intensification (CT PTR-CT W- CT M) consumed 10% more irrigation water compared to conventional practice (CT PTR-CT W). ZT DSR-ZT W-R M and ZT DSR-ZT W-R M + R recorded 44 and 42% higher net returns (pooled average basis) respectively compared to conventional system. The increase in net returns with CA based sustainable intensification over 4 years ranges from 35 to 51% with ZT DSR-ZT W-R M and 32–49% with ZT DSR-ZT W-R M + R compared to farmers practice. Whereas, integration of mungbean in to RW system increased the net returns by 29% irrespective of treatments. The positive impacts of CA based sustainable intensification in RW system under similar production ecologies were also reported by Gathala et al. (2013). On pooled average basis, highest protein yield was recorded with ZT DSR-ZT W -R M + R (1,043 kg/ha/yr), closely followed by ZT DSR-ZT W-R M and CT PTR-CT W- CT M. Mungbean integration in to RW system increased the protein yield by 38–150 kg/ha/yracross the years. Significantly higher (34–38%) carbon sustainability index was recorded with CA based management compared to

Table 1. Effect of sustainable intensification on yields, water use, net returns and carbonsustainability index in scented rice–wheat system (Pooled data of 4 years)

Treatments†	System grain yield (t/ha/yr)	System irrigation water use (cm/ha/yr)	System net returns (USD/ha/yr)	System protein yield (kg/ha/yr)	Carbon sustainability index (CSI)
CT PTR-CT W	14.91d	2168b	2570d	795f	11.03e
T PTR-CT W- CT M	18.48b	2378a	3255b	964c	11.31d
ZT DSR-ZT W	15.09cd	1578d	2822c	820e	15.13b
ZT DSR-ZT W-R M	18.85ab	1713c	3687a	1019b	15.38a
ZT DSR-ZT W + R	15.31c	1365f	2820c	852d	14.65c
ZT DSR-ZT W -R M + R	19.36a	1445e	3652a	1043a	14.87c

†Means followed by a similar lowercase letters within a column are not significantly different (p=0.05).

conventional practice (CT PTR-CT W) of RW system.

CONCLUSION

CA based management optimization of scented rice–wheat system provides opportunities for sustainable intensification while increasing system productivity by 4.45 t/ha/yr as well as higher protein yield (248 kg/ha/yr), save 72 cm irrigation water ha/yr, increase profit by US$ 1,082 ha/yr in addition to significantly better CSI over farmer practice. This is a win-win for farmers and planners to achieve the target of (*i*) more crop per drop, (*ii*) doubling farmers' income, (*iii*) improving soil health, and (*iv*) improved nutrition security while attaining Sustainable Development Goals (SDGs).

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Symposium 4

Integrated Farming Systems for Smallholder Farmers

Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Integrated farming system in dryland areas: goat and sheep rearing is an option

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At present, the farmers concentrate mainly on crop production which is subjected to a high degree of uncertainty in income and employment to the farmers. In this contest, integration of various agricultural enterprises, viz. cropping, animal husbandry, fishery, forestry etc. have great potentialities in the agricultural economy it is also suitable strategy for augmenting the income of a farm. In today's environment, increasing demand for meat in rural and urban areas can help small and part-time farmers earn good profits by trading with the goat and sheep farming. Because of less investment and maintenance costs for shed, it can be done in coordination with agriculture crops. It is benefited in such way productivity increment, sustainable growth in agriculture balanced diet, recycling of farm residues. In integrated farming, suitable for dryland of 1 hectare land with crop cultivation and goat rearing (20 females : 1 male). From 20 sheeps we can get 45 lambs in a year. Moreover, from sheep manure we get 200 kg N, 106 kg P and 91 kg K. it also gives 40 to 50 thousand rupees additional income. In our country, sheeps are largely dependent on Grazing land because of this sheep's productivity is low. Solving this problem tree kind fodder leaves, agri related products as daily feed will increase the productivity. Thus groundnut leaves, red gram bran, black gram bran and such as the feeding of the wood leaves like Barnyard, Neem, Tamarind, Subabool, Desmanthus, Portia, surrogates such as tree leaves Acacia, Kutaivelan, Velikattan and Raintree pods will give required nutrient-rich forage to the sheep. It removes fodder demand, increase meat production leads to getting additional income. During rainy season, sheeps get enough amount of green grass through the pasture. In this concentrated fodder include cereals, cakes, rice or wheat bran, mineral mixture.

Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Integrated farming systems for the under privileged farmers of North East

ANIS CHATERJEE

Action For Food Production (AFFP), New Delhi, India

The National Agricultural Innovation Project (NAIP) is a World Bank and Government of India funded country-wide initiative led by Indian Council of Agricultural Research (ICAR). As a part of the initiative, Action For Food Production (AFPRO) has implemented one project entitled 'Live better with the flood: an approach for sustainable livelihood security in district Dhemaji, Assam' as lead consortium partner along with the involvement of local NGO and Assam Agricultural University as consortium partner.

Dhemaji is one of the districts situated in the remote corner of North East India on the north bank of river Brahmaputra. Though the district is blessed with abundant natural resources, the benefits of development have not accrued to the poor community residing in Dhemji. Failure of developmental efforts in attaining planned objectives caused by recurrent flood given the community a painful past. In view of this distress situation, our project specially focused on the remote villages hidden in the district with an objective to improve the livelihood of the rural poor with efficient management of natural resources by enhancing productivity, profitability and diversity of farming system. The project focused on developing institutional mechanisms among the poor community for adopting innovative project approaches and establishing market linkages for income generation activities in a sustainable manner.

The project interventions recognized three phases of flood prone areas - Pre flood situation, During flood and Post flood operation. Adopting the Sustainable Livelihood Approach (SLA) Framework, livelihood interventions have been broadly categorized according to each phase. Integral components of the project, i.e. promotion of Integrated Farming Systems (IFS) and Restructured cropping patterns, resulted in increasing adaptive capacities of indigenous communities to water induced vulnerabilities of the region with improved agricultural productivity in a sustainable way.

Bridging between traditional agricultural practices and contemporary agricultural research is very important to achieve economic benefit of agricultural production. Through this project, AFPRO facilitated the bridging by establishing and strengthening Village Level Institutions and their linkage with the institutional framework of the Department of Agriculture (KrishiVigyan Kendra), which served as an effective medium for technical support to farmers on technological improvements, dissemination of information and relevant hand holding support. More than 3400 small and marginal farm families have been benefitted through this project. Technological interventions in Integrated Farming Systems and Restructuring of existing cropping pattern, Improved vegetable cultivation for additional income generation, Introduction of new crops and seeds, suitable for the Agro-Climatic and Soil conditions, have been implemented. To ensure sustainability of the project interventions, local community institutions were formed, developed and strengthened. The research results would be useful for farmers, extension workers and State Planning Departments to explore possibilities of replicating, in similar flood prone areas, in different States of India.

Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Multi-criteria decision making and optimization methodology for sustainable integrated farming systems

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In order to meet the multiple objectives of poverty reduction, food security, competitiveness and sustainability several researchers have recommended to adopt integrated farming systems (IFS). Integrated farming system is an approach in which different land-based enterprises, viz. crop, live stock, mushroom, apiary, fishery etc. are integrated within the bio-physical and socio-economic situations taking farmers preference and goal in to consideration. Farming system research/IFS is considered as a powerful tool for management of vast natural and human resources in developing countries. This is a multi-disciplinary approach and very effective for solving the problems of small and marginal farmers (Gangwar, 1993). Under the gradual shrinking of land holding in India and other developing countries, it is necessary to go for IFS to make farming more profitable and sustainable.

In agricultural research and development activities in India and other developing countries, the major emphasis is given to component and commodity based research projects involving developing animal breed, farm implement, crop variety and farm machinery, mostly conducted in isolation and at the institute. This component, commodity and discipline-based research have proved largely inadequate in addressing the multifarious problems of small farmers (Jha, 2003). Due to this, there has been a demand for holistic approach for technology generation and dissemination instead of traditional component approach in piecemeal and isolation. However, mechanisms are lacking to provide the whole farm picture or model of outcome of the farm activities before the farmers taking into consideration of various farm resources, viz. land, labour, capital, management; constraints, viz. physical, bio-physical, ecological, socio-economic etc.; and enterprise combinations in IFS perspectives, viz. crop, dairy, fishery, poultry, apiary, mushroom etc. Providing such a picture in the context of a farm or village or a region is a tedious process and difficult to calculate by human mind since number of factors are involved. Such problems can be overcome by the bio-economic modelling approaches.

The research in integrated farming systems (IFS) for the last few decades reveals that the enterprise planning and implementation are usually in component approach and in isolation, needs scientific and systematic approach. In this situation, optimization techniques are useful for resource allocation and designing of IFS in a scientific basis (Mahapatra and Behera, 2004). Farming system studies involving a number of enterprises and taking the physical, socio-economic and bio-physical environments into consideration are complicated, expensive and time-consuming (Mahapatra and Behera, 2004). There exists a chain of interactions among the components within the farming systems, and it becomes difficult to deal with such inter-linking complex systems manually. This is one of the reasons for slow progress in the field of farming systems research in India and elsewhere (Jha, 2003). This problem could be overcome by construction and application of suitable whole farm models (Dent, 1990). On the other hand, optimization techniques such as linear programming, goal programming and compromise programming proved useful for efficient resource allocation under various constraints (Taha, 2005). Optimization models optimize the use of farm resources, and can analyse farm response to policy change in an effective way (Loucks *et al.,* 1981). Among available, linear programming (LP) is one of the most applied solution methodology in agricultural planning to determine the optimal policy (Loucks *et al.*, 1981) in single and multiple objective framework. In this paper different bio-economic modelling techniques, which can help for optimal combination of the enterprises within the farming systems by taking farmers single and multi-objectives into consideration as well as an advanced modelling tool 'MODAM' which has potentiality to integrate the environment and ecological goal with economic goal in the context of a farm/ society or region are discussed briefly.

INTEGRATED FARMING SYSTEMS IN SINGLE OBJECTIVE FRAME WORK

Decision making is the most important aspect of any business and industry. Farming is a business and agriculture is also an industry. Hence, decision making plays an important role with regard to the problems concerning production of commodities. The main questions before the producer or the production manager/farmer are: (*i*) What to produce, (*ii*) How to produce, and (*iii*) How much to produce. In an integrated farming system, farmers face the similar problems with respect to production of different commodities/enterprises at the farm level.

Linear programming is a modelling tool that can assist in the solution of many problems in agriculture. In particular linear programming is useful in selecting the best alternative from a number of available courses of action. LP model are designed to 'optimize' a specific objective criterion subject to a set of constraints, the quality of the resulting solution depends on the completeness of the model in representing the real system.

INTEGRATED FARMING SYSTEMS IN MULTI-OBJECTIVES FRAME WORK

In real world IFS situations farmers face the difficulty of considering several objectives simultaneously, which are conflicting in nature such as farm return, capital requirement and labour employment. In addition farmers like to produce enough food for the farm family by utilizing his resources effectively including land. For this, compromise programming method can be effectively employed for achieving a practical and compromise solution in such situation (Behera *et al.*, 2008).

In the traditional mathematical programming approach to modeling agricultural decision making, the decision maker seeks to optimize a well-defined single objective. In reality, this is not always the case as the decision maker is often seeking an optimal compromise among several objectives, many of which can be in conflict, or trying to achieve satisfying levels of his goals (Romeo and Rehman, 1989). Two multi-criteria programming techniques, goal programming and compromise programming (both variants of linear programming), were used in a study of small-scale dairy farms in central Mexico by Val-Arreola *et al.* (2006). Compromise Programming (CP) is used to provide more insight into the problem which caters multiobjective needs of the farmers. Linear and nonlinear programming methodologies can be employed in CP environment to draw different scenarios' for comparison. This enables in developing holistic model. Compromise Programming methodology has been demonstrated for designing integrated farming system (Behera *et al.*, 2008).

MULTI-OBJECTIVE DECISION SUPPORT TOOL FOR AGRO-ECOSYSTEM MANAGEMENT (MODAM)

There is a need for a modelling tool to analyse agricultural sustainability as a combination of economic and ecological objectives. This model should be able to: (*i*) simulate effects of political and economic conditions on decisions about agricultural land use at farm level; (*ii*) screen current and new production technologies in a standardised form and show their effects on defined indicators of sustainability; and (*iii*) allow economic and ecological evaluation of production techniques at regional scale, including trade-offs among ecological and economic goals with respect to one farm or to a group of several farm types (regional approach).

Keeping above aspects in to considerations, a powerful bio-economic modelling tool was developed at ZALF, Germany (Zander and Kachele, 1999) which has the potentiality to simulate/combine/integrate various aspects of farming systems for agricultural decisions of economic and environment consequences due to certain level of management. In the bio-economic model MODAM, several farms are aggregated to regional model to evaluate the effects of different protection strategies and the methodology of developing region-farms. The model makes highly detailed studies and is used for verification of the economic aspects of the farm which is linked to the regional level. Model allows drawing different scenarios of agronomic and ecological and political decision making.

In summary, MODAM is an interactive modelling system, generating trade-off functions between ecological and economic objectives and helpful from the points of view: (*i*) interactive experimentation with the model increases knowledge and understanding of the behaviour of the real system, but also the understanding of conflicting positions of interest groups in land use; (*ii*) it allows analysis of the maximum goal achievement possible under given conditions and, hence, defines the boundaries of the multidimensional solution space; (*iii*) trade-off functions will show areas where a small decreases in achievement of the goal leads to much large realisation for another goal; this will allow simplification of the bargaining procedure by showing the consequences changing preferences: movement of indifference curve and new transaction; (*iv*) sensitivity analysis of the model will show where further research is necessary; and (*v*) scenarios of different conditions will help political decision makers to identify the most efficient instruments to realise the desired goal achievement in practise. The model therefore is useful tool in an interactive procedure for the definition of sustainability criteria.

DESCRIPTION OF THE MODEL

The Model show hierarchical linkage between the economic and ecological parts of the model. Where maps in the geographical information system (GIS) are available, the result of the model in the form of crop rotations and their technical, economic, and ecological coefficients can be transferred to the GIS for the graphical presentations.

THE STRUCTURE OF THE MODEL

The complexity of the selected system leads to a hierarchical structure of the economic and ecological modules that can also be applied to derive optimal solutions, if all possibilities are taken into accounts (Wossink *et al*., 1992). The model is based on the multiple goal linear programming approach. It consists of five levels of the hierarchically linked modules. The first level of the modules generates the technical coefficients. The second level calculates the economic coefficients of site-specific production techniques. The third evaluates the ecological effects of theses production techniques, and the fourth generates the linear programming model. The fifth level of models starts the subprogram which solves the equation system, analyses the results and prepares

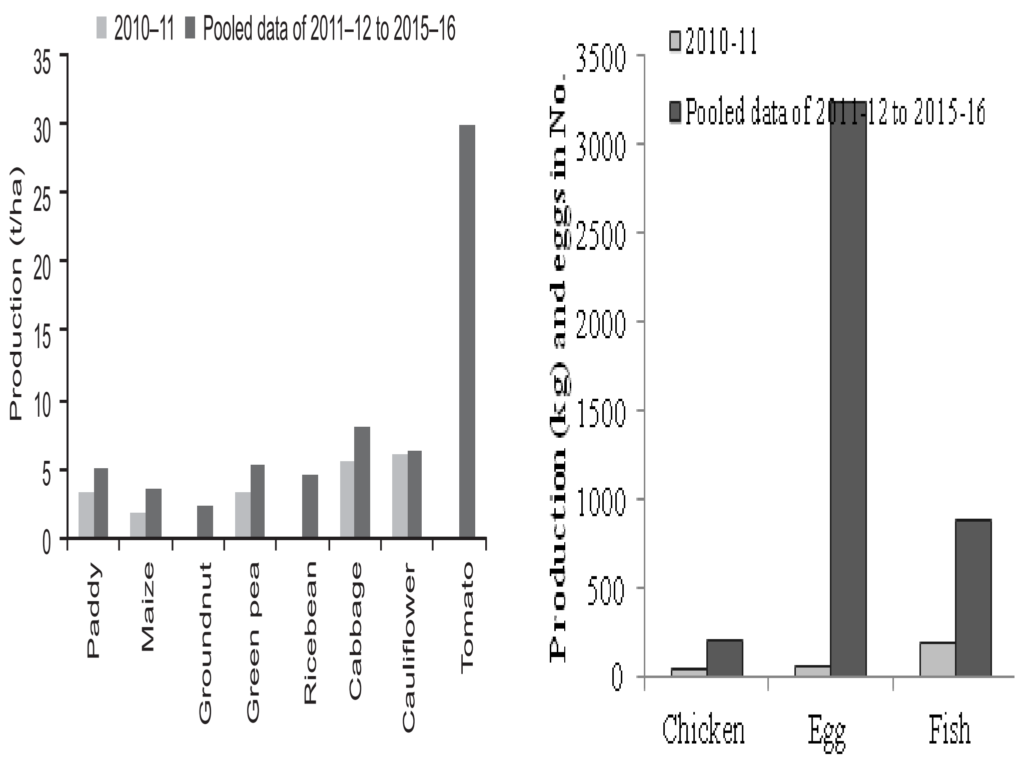

Fig. 1. Iterative definition of goals in the modules of MODAM (Source: Zander and Kachele, 1999)

the transfer of data to the Geographical Information System (Fig. 1).

CONCLUSION

In the context of present challenges to make small farms profitable not only in India, but also in most of the Asian and other developing countries, it is necessary to place an overall scenario for farm income and employment generation and other associated benefits before the farmers in village, regional and country level in order to motivate them towards farming. Placing such pictures before farmers will aid their confidence to adopt new technologies in an integrated manner for enhancing farm income and sustainability, thereby helping to improve the livelihoods of the farmers. Multi-criteria decision making and optimization methodology can prove as a potential approach for providing the whole farm picture by considering economic and ecological consequences. The modelling system, MODAM, is suitable for interactive research on multi-objective land use issues and is a tool to mediate in conflicts among competing groups of land uses, by generating information about economic and ecological effects of the particular decisions.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Impact of integrated farming system on farmer's livelihood and nutritional security as well as family employment

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Back in the 60s, world was going through severe food crises and India was tried to change from begging bowl to a bread basket. As we could no longer expand our production areas, the challenge was to increase the productivity to feed the fast growing population. The traditional agricultural systems were failing us. We needed to modernize our agriculture and we needed new technologies–as we were told. Taking this opportunity, we selected farmers from Churachandpur district of Manipur for the comparative study of integrated farming system development in Manipur with objectives to evaluate the suitable integration of enterprises in a given agro-climatic conditions for their livelihood and nutritional security as well as employment impact as compared to 2010–11.

METHODOLOGY

This study was conducted on the field of Henkpao (tribal farmers) in Tollen village, Churachandpur district of Manipur during 2011–12 to 2015–16. A model of integrated farming system was developed on farmer's field. Base line survey on socio-economic as well as their agriculture farming has been done in 2011–12. In 2015–16, survey was done to know the socio economic status of the farmers. The holding size of the farmer was enhanced from base year to 2015–16 due to technological interventions like terracing and thereby fallow land have been put for cultivation of crops. We kept the same enterprises which the farmer had interested (rice, groundnut, maize in *kharif* season, pea and mustard in *rabi* season, fishery, poultry, piggery, vegetable production, fruit cultivation, apiary and water management). Training and inputs were given to the farmers for adoption of scientific management practices in the integrated farming system.

RESULTS

The lower yield of cereals, pulses, vegetables and oilseeds in 2010–11 was mainly due to use of poor quality seeds, that he had procured from neighbouring farmers and use of conventional methods in rice cultivation with very poor nutrient and weed management. In 2010–11, rice productivity was 3.25 t/ha as compared to 5.1 t/ha in (mean 5 years) due to adoption of improved package of practices (Fig 1). Similarly other crops production was also enhanced significantly after implementation as compared to base year. Our results are in close agreement with Ansari *et al.* (2014) who found that adoption of improved package and practices on farmer's field in Manipur can increase the yield of crops as compared to conventional system. In this system, family members were gainfully employed due to production and maintenance of several components. A special feature of this system was value addition due to employment of family members and non-farming families. One small farmer absorbs 593 person days, out of which family labour absorption is 470 days person (MSSRF, 2009, Ansari *et al.*, 2013 and 2014). In our study, family members were employed 347, 559, 559, 566, 566 and 637 days in 2010–11, 2011–12, 2012–13, 2013–14, 2014–15 and 2015–16, respectively (Fig. 2).

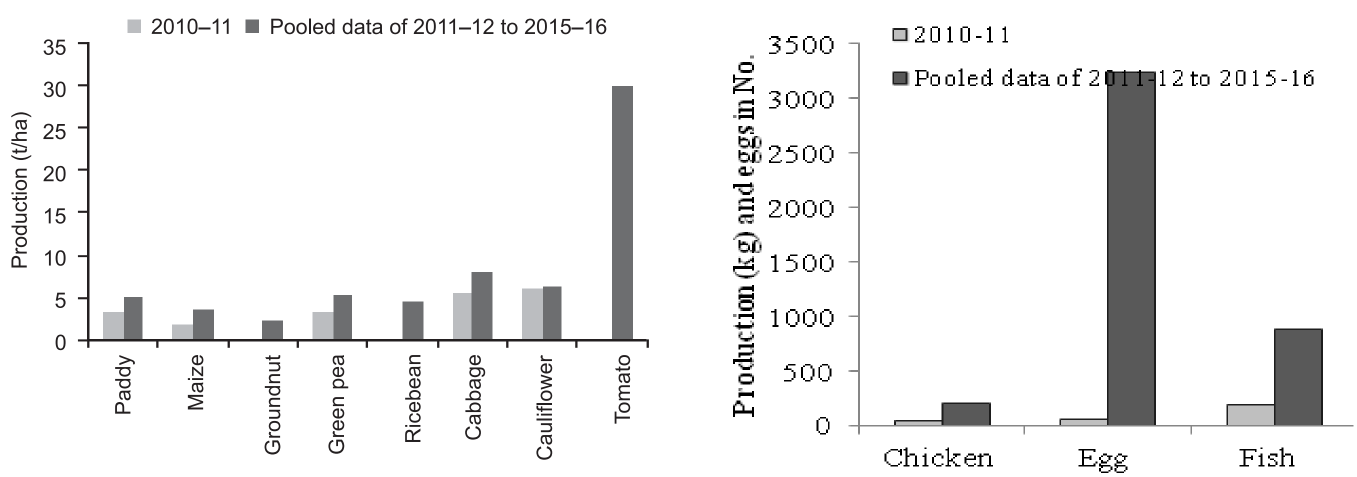

Fig. 1. Crop production, vegetable production, piggery, poultry and fishery under SIFS

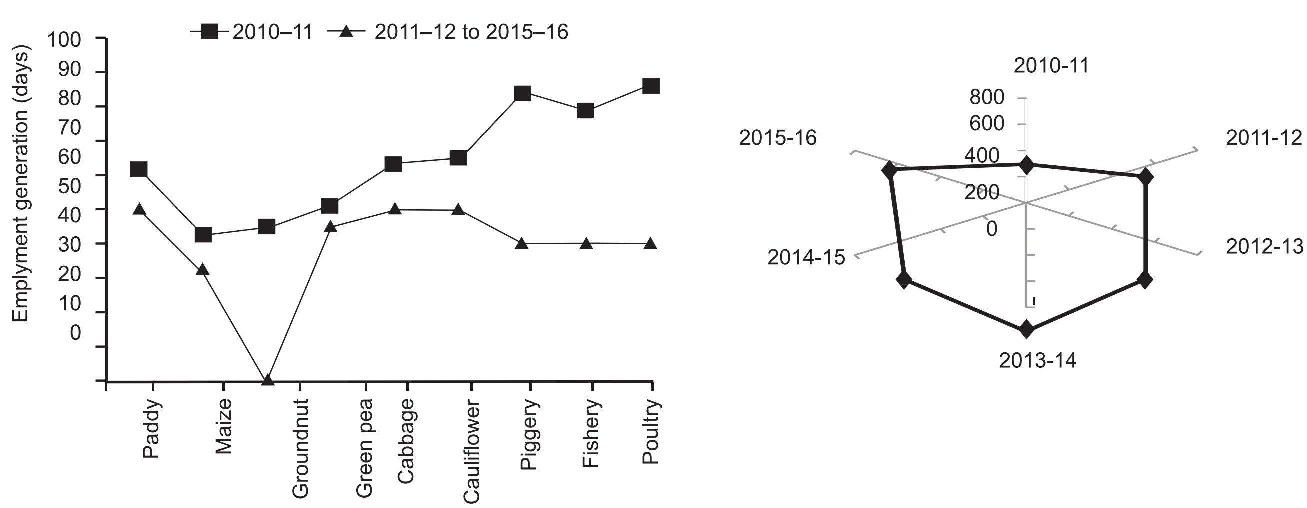

Fig. 2. Employment generation under various IFS components and total in a year

CONCLUSION

The study highlighted the impact of IFS on farm cash income. The farmers in the study area practised partial integration in 2010–11. After adoption of improved cultivars, better performing breeds/ strains and good management practices under integrated farming system gave more production, higher income generation and employment opportunities throughout the year. Net farm income realized by farmer who maintained crop–livestock–fish–horticulture integration on their field.It can be concluded that improved farming can play a significant role in increasing production, remunerative returns, and nutrition requirements as well as employment opportunities of tribal populations.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

The effect of rainfall amount and intensity on leaching of herbicides from stubble

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No-tillage (NT) with stubble retention is a widely used cropping system because of its benefits including reduced soil erosion, increased soil moisture, improved soil tilth, decreased fuel and labour costs, earlier sowing of crops, and improved yield potential and profit. The NT farming system in southern Australia is heavily reliant on herbicides for weed management, but the heavy crop residues may have a negative impact on the activity of herbicides applied. The herbicides can be intercepted by the crop residue and may not reach the soil surface without timely rainfall. The herbicide on the residue may also dissipate due to volatilization, photo-degradation and/ or microbial activity. A series of experiments were carried out to investigate how much herbicide was intercepted by wheat residue and retained following simulated rainfall. The experiments included three commonly used pre-emergent herbicides in southern Australia (trifluralin, prosulfocarb, pyroxasulfone). Simulated rainfall was applied with four amounts (0, 5, 10, and 20 mm), three different intensities (5, 10, and 20 mm/hr) and five application times (immediately after spraying herbicide, 6 hours, 1, 7, and 14 days after spraying herbicides). Four petri dishes, each with 50 g of dry soil, were placed onto plastic seedling trays, then the trays and soil were covered by the equivalent of 4 t/ha of crop residue and sprayed with herbicide. The trays were then put into a rainfall simulator and the rainfall treatments applied. Bioassays were developed to assess the herbicide activity/ availability in the soil and remaining on the residue, using two indicator plant species (cucumber, annual ryegrass). Increased amounts of rainfall leached more herbicide from the stubble into the soil and the sooner the rainfall occurred the more herbicide was leached. However, the intensity of rainfall had no significant effect on leaching of the herbicides from the crop residue into soil.

Symposium 5
Abiotic and Biotic (Weeds) Stresses Management

Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Chemical weed management in baby corn (*Zea mays*)

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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

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 does not require detasselling. The crop was sown on 10 June 2014 with a spacing of 45 cm × 20 cm and first harvest was done on 4 September 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

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. 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. 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. Weed free check recorded higher gross returns (₹ 209,164/ha) and it was followed by atrazine 50 WP @ 0.5 kg a.i./ha + 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 as POE application at 25 DAS. While, lower gross returns was recorded in weedy check (₹ 116,881/ha). Significantly higher net returns (₹ 155,145/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 @ 0.5 kg a.i./ha as PRE application. Significantly a lower (₹ 74,862/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 + pendimethalin 38.7 CS @ 0.5 kg 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 + pendimethalin 38.7 CS @ 0.5 kg a.i./ha as PRE application

Table 1. Weed control efficiency (WCE), yield and economics in baby corn as influenced by chemical weed management

Tr. No.	Treatment	WCE (%)	Greencob yield (t/ha)	Green Stalk yield (t/ha)	Gross returns (₹/ha)	Netreturns (₹/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	Pendimethalin 38.7 CS @ 1.0 kg 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./ha as 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 + pendimethalin 38.7 CS @ 0.5 kg 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 + pendimethalin 38.7 CS @ 0.5 kg 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 2, 4-D Sodium salt 80 WP @ 1.0 kg a.i./ha as POE application at 25 DAS	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	Pendimethalin 38.7 CS @ 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	70.4	9.24	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 parentheses indicate original values; Total weed count (x) data were transformed to $(x+0.5)^{1/2}$

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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Efficacy of pre and post emergent herbicides on summer black gram in sub-tropical belt of Jammu region under irrigated conditions

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Blackgram [*Vigna mungo* (L.) Hepper] is an important pulse crop in India. It is mostly cultivated during *kharif* season but being a short duration it is also suitable for summer season. Due to its initially slow growing, it is heavily infested with many grasses and broad-leaved weeds, which compete with the crop during initial growth stage resulting in reduced seed yield of blackgram. Unchecked weeds have been reported to cause a considerable reduction in the seed yield to the tune of 43.2 to 64.1% during *kharif* season (Chand *et al*., 2004). The degree of reduction in seed yield of blackgram due to weeds depends upon the density and duration of weed species. Hence, timely removal of weeds using a suitable weed control method is very much crucial to harvest optimum yields of blackgram. Hand weeding is laborious, time consuming, costly and tedious job, furthermore, timely unavailability of labour as well as season continuous rains do not permit timely hand weeding. Looking to situation, use of herbicides offers an alternative for possible effective control of weeds in blackgram. Therefore, an attempt has been made to study the efficacy of pre and post emergent herbicides on summer black gram in sub-tropical belt of Jammu region under irrigated conditions.

METHODOLOGY

The experiment was conducted during the summer seasons 2015 to evaluate the effect of different herbicidal treatments on plant height, dry matter accumulation, grain yield of summer blackgram and on associated weeds of blackgram. The herbicide treatments were applied as per the treatment details given in the Table 1. All the herbicides were applied by using a Knapsack sprayer fitted with flat-fan nozzle with spray volume of 500 litres water/ha. Data of weeds dry matter were recorded at 30 days after sowing of crop by using 1 m × 1 m quadrate and was subjected to square root transformation by adding 1 to original values prior to statistical analysis.

RESULTS

The experimental field was dominated by *Cyperus* spp., *Cynodon dactylon, Digitaria sangunalis, Solanum nigrum, Physalis minima* and *Phyllanthus niruri* weeds. Different weed management treatments had significant effect on weed dry matter. All the herbicidal weed management treatments recorded significantly lower weed dry matter as compared to weedy check. Among the herbicidal treatments, the lowest weed dry matter was recorded with pre-emergence application of imazethapyr + pendimethalin (RM) @ 1000 g/ha which was statistically at par with all the post-emergent applications of herbicides. The results are in conformity with Yadav *et al.* (2015). This was due to better control of both grassy as well as broad leaved weeds during early crop growth period.

Weed management treatment had a significant influence on growth and grain yield summer black gram. All the herbicidal weed management treatment recorded significantly higher plant height, dry matter of plant and grain yield of summer black gram as compared to weedy check. The highest plant height, dry matter of plant and grain yields were recorded with imazethapyr + pendimethalin (RM) @ 1000 g/ha which was statistically at par with the all the post-emergent applications of herbicides. These results were in close agreement with those reported by Kumar *et al.* (2015).

CONCLUSION

On the basis of one year it may be concluded that imazethapyr + pendimethalin (RM) 1000 g/ha as PE, imazethapyr 70 g/ha or 80 g/ha as POE at 3–4 leaf stage and imazethapyr + imazamox (RM) 70 g/ha or 80 g/ha as POE at 3–4 leaf stage give efficient control of weeds alongwith statistically at par grain yield of summer blackgram to the two hand weedings at 15 and 30 DAS.

Table 1. Effect of different weed management practices on plant height, plant dry matter, grain yield of summer black gram and dry matter of associated weeds

Treatments	Time of application	Plant height at 60 DAS (cm)	Plant dry matter at 60 DAS (g/plant)	Grain yield (kg/ha)	Weed dry matter (g/m^2) at 30 DAS
Imazethapyr 70 g/ha	PE	42.7	6.3	623	7.70 (58.3)
Imazethapyr 80 g/ha	PE	43.3	6.4	686	7.34 (53.0)
Imazethapyr 70 g/ha	3–4 leaf stage	44.7	7.6	730	6.82 (45.7)
Imazethapyr 80 g/ha	3–4 leaf stage	45.3	7.7	746	6.50 (41.3)
Imazethapyr + imazamox (RM) 70 g/ha	PE	43.0	6.3	666	7.41 (54.0)
Imazethapyr + imazamox (RM) 80 g/ha	PE	43.5	6.6	688	7.18 (50.7)
Imazethapyr + imazamox (RM) 70 g/ha	3–4 leaf stage	44.9	7.7	743	6.53 (41.7)
Imazethapyr + imazamox (RM) 80 g/ha	3–4 leaf stage	45.6	7.8	759	6.40 (40.0)
Pendimethalin 1000 g/ha	PE	42.5	6.2	620	7.67 (58.0)
Imazethapyr+ pendimethalin (RM) 1000 g/ha	PE	46.2	7.9	786	6.32 (39.0)
Hoeing (2)	15 & 30 DAS	47.0	8.0	820	5.25 (26.7)
Weedy check	–	40.0	5.5	316	10.40 (107.3)
Weed free	As and when needed	48.0	8.2	910	1.00 (0.0)
SEm (±)	–	1.6	0.3	33	0.2
(p=0.05)	–	4.6	1.0	96	0.6

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Effect of critical period of crop-weed competition on growth, yield and nutrient up-take of aerobic rice (*Oryza sativa*) under irrigated ecosystem

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Rice (*Oryza sativa* L.) has great significance as a source of energy and income seems overwhelming for millions of people in Asia, representing 90% of global rice production and consumption (Chauhan, 2012). Weed infestation in aerobic rice fields remains the single largest constraint limiting factor of their productivity. Therefore it 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. Critical period of weed control is the foundation of integrated weed management and, hence, can be considered the first step to design weed management strategy.

METHODOLOGY

A field experiment was conducted during *kharif* 2015 at Norman E. Borlaug, Crop Research Centre of G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand. The soil was calcareous, medium to moderately coarse textured, with pH 7.3, high in organic carbon (0.79%) and low in available nitrogen (236.6 kg/ha) and medium in available phosphorus (19.9 kg/ha) and available potash (178.6 kg/ha). The experiment was laid out in randomized block design with three replications. A set of twelve treatments consisting of weedy from sowing to maturity, weedy until 15, 30, 45, 60 and 75 DAS, and weed free from sowing to maturity, weed-free until 15, 30, 45, 60 and 75 DAS. Rice variety 'Pant dhan-18' was sown on 11th June, 2015 with 45 kg/ha seed rate. A common dose of fertilizer at 150 : 60 : 40 kg N : P : K/ha was applied through urea and NPK mixture (12 : 32 : 16). The 50% nitrogen and full dose of phosphorus and potash were applied as basal while remaining nitrogen was applied into two equal splits, i.e. 25% nitrogen was given at active tillering and 25% at panicle initiation stage. Weeds were collected at every 15 days interval up to 75 DAS and at 115 DAS (physiological maturity) and harvest stage to count the density and dry weight within the area of 0.25/m^2 quadrate.

A field experiment was conducted *kharif* 2015 at Norman E. Borlaug, Crop Research Centre of G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand,.India which is situated at 29° N latitude and 79.3° E longitudes and at an altitude of 243.84 meter above mean sea level, during the rainy (June–October) season of 2015 on a sily loam soil. The mean annual rainfall of Pantnagar is about 1,400 mm, of which almost 80 to 90 per cent is received during June to September and rest is received during winter season. The soil of the experimental field had 236.6 kg/ha alkaline permanganate oxidizable nitrogen (N), 19.9 kg/ha available phosphorus (P), 178.6 kg/ha 1 N ammonium acetate exchangeable potassium (K) and 0.75% organic carbon. The pH of soil was 7.4 (1 : 2.5 soil and water ratio; Prasad *et al*., 2006).

There were twelve treatments comprising weedy from sowing to maturity, weedy until 15, 30, 45, 60, and 75 days and weed free from sowing to maturity, weed free until 15, 30, 45, 60, and 75 days in experiment, laid out in a randomized block design with three replications.

The experimental field was disk-ploughed twice and levelled. A dose of nitrogen, phosphorus and potash were applied through NPK mixture (12 : 32 : 16) and urea along with Zinc Sulfate to the entire plot as basal application. Half of the nitrogen and full dose of phosphorus, potassium and zinc were placed in furrow just before seeding of rice. Remaining half of the nitrogen was top dressed in two equal splits, first at active tillering and second at panicle initiation stage of the crop.

Data on biomass accumulation (g/m^2), plant height, tillers/m^2, panicle length, grains/panicle, 1,000-grain weight and grain and straw yields from different weed free and weedy plots were recorded and measured separately. Data were analyzed using the F-test. Least significant difference (LSD) values at $P = 0.05$ were used to determine the significance of differences between treatment means.

RESULTS

Biomass accumulation by Pant Dhan 18 was adversely affected by the increasing length of weed competition period and, conversely, favourably influenced by the increasing span of weed-free period from 15 to 45 DAS. Maintaining weed-free conditions after 45 DAS failed to improve biomass accumulation of rice. Plant height (cm) recorded at 15, 30, 45, 60, 75, 115 and at harvest stage increased with increasing span of weed-free period from 15 to 45 DAS, over weedy situation beyond 45 days. The highest plant height at all stages was recorded with weed free from sowing to maturity. Weed free situation up to 45 DAS significantly increase tillers/m^2, dry matter accumulation, number of panicles, grains/panicle. However, 1,000-grain weight was influenced significantly due to crop-weed competition and the lowest 1,000-grain weight was recorded in weed free situation until 15 DAS which was statistically at par with weedy until 30 DAS or beyond and weed free situation until 30 DAS. The highest values of all the yield attributes were recorded with weed free from sowing to maturity. Weed free situation up to 45 days produced significantly higher grain yield (5.4 t/ha) compare to all weedy treatments, except weedy until 15 DAS The highest straw yield (7.9 t/ha) was obtained with weed free from sowing to maturity which was statistically at par with weed free situation until 45, 60 and 75 DAS and weedy until 15 DAS. Similarly biological yields were also significantly influenced due to crop-weed competition.

Highest nitrogen, phosphorus and potassium uptake at harvest stage by crop was recorded in weed free from sowing to maturity as compared to weedy plots beyond 30 days. All weed free plots recorded higher nitrogen, phosphorus and potassium uptake, except weed free until 15 or 30 DAS as compared to weedy until 30, 45, 60 and 75 DAS. In treatment weed free until 45 DAS, uptake of nitrogen, phosphorus and potassium was statistically at par with weed free until 60 or 75 DAS; weed free from sowing to maturity and weedy until 15 DAS at harvest stage of crop. Weed free situation until 30 DAS removed significantly higher nitrogen, phosphorus and potassium than weed free until 15 DAS and was at par with weedy until 30 DAS.

CONCLUSION

It is concluded that the period between 15 to 45 days in aerobic rice under irrigated situation likely to be crucial with regard to weed-free environment for better yield and higher economic return of crop.

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Assessment of chemical weed control in transplanted scented rice under farmers field of bundelkhand

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Rice is a major crop in the world, it feeds one third of the world population to whom it supplies almost two thirds of the food requirements. There are several reasons for low productivity and the one due to weed is the important. Weeds compete with rice for moisture, nutrients, light, temperature and space. A study was arranged to test different herbicides in transplanted scented rice under in Datia district of Bundelkhand region in Madhya Pradesh. The experiment was conducted on 10 locations at farmer's field for two consecutive kharif seasons of 2013 and 2014 with the weed control methods, i.e. T_1- Bispyribac sodium@30 g a.i/ha at 25 DAT, T_2- Butachlor @1 kg a.i./ha at 3–5 DAT, T_3- Two Hand Weeding at 20 and 40 DAT and T_4- Farmers practice (No weed control). Results revealed that maximum grain yield was produced under T_3 (49.14 q/ha) which is at par to T_1 (49.07 q/ha). Economically Treatment T_1 was found superior over all the treatments with highest net return (100111), B : C ratio (3.84).

INTRODUCTION

Rice is a major crop in the world, it feeds one third of the world population to whom it supplies almost two thirds of the food requirements. It is the most important cereal crop and is extensively grown in tropical and subtropical regions of the world. From an area of 44.07 million ha, India is producing about 103.4 million tones with an average productivity of 2.3 t/ha (FAO-2012). Rigorous efforts are being made under several research programme by scientists around the world to evolve different strategies for improving rice yield. There are several reasons for low productivity and the one due to weed is the important. Weeds compete with rice for moisture, nutrients, light, temperature and space. Uncontrolled weeds caused yield loss of 28 to 45% in transplanted rice (Singh *et al*., 2007; Manhas *et al*., 2012).

In rice, infestation of all types of monocot and dicot weed flora was observed. Like other cereal crops. In order to realize maximum benefit of applied monetary inputs, two to three hand weeding (HW) were most effective against all types of weeds in this crop (Halder and Patra, 2007). However, continuous rains during cropping season, scarcity and high wages of labour during weeding peaks particularly at early crop-weed competition make this operation difficult and uneconomic. Therefore, farmers need alternate weed management methodology and herbicides are one of the better substitutions of costly hand weeding. Among popular post emergence selective herbicides, Bispyribac Sodium in rice field, have the potentiality to keep the weed bellow the economic threshold level. So, Bispyribac Sodium is to be evaluated for their bio-efficacy of controlling wide range of weed flora, better crop growth and yield of rice.

METHODOLOGY

A study was arranged to test different herbicides in transplanted scented rice under in Datia district of Bundelkhand region in Madhya Pradesh. The experiment was conducted on 10 locations at farmer's field for two consecutive kharif seasons of 2013 and 2014. The study area is situated between 780 27′ 39.28″ E longitude to 250 39′ 25.24″ N latitude; and characterized with semi and sub tropical climate with extremes of temperature in summer 47°C and in winter 2°C.

These trials were planted on 10 farmer's field in the area of 0.4 ha each. The well adopted scented rice variety Pusa-1121 was used for experiment. A basal dose of 60 kg/ha N, 60 kg/ha P_2O_5 and 40 kg/ha K_2O was applied at the time of planting every year. The rest 60 kg/ha N is applied in two split doses after 30 and 45 days after transplanting. Seed rate was kept constant at 40 kg/ha for all the treatments. Weed control methods were adopted as per treatment, i.e. T_1-Bispyribac sodium @30 g a.i/ha at 25 DAT, T_2- Butachlor @1 kg a.i./ha at 3–5 DAT, T_3- Two Hand Weeding at 20 and 40 DAT and T_4- Farmers practice (No weed control). All the treatments were applied as per schedule both the year. The thin film of water is maintained at the time of herbicide application. The post emergence herbicide was sprayed at 2 or 3 leaf stage of weeds (15 DAT) by using knapsack sprayer. The soil of experiment field was low in Nitrogen (180–225 kg/ha), Medium in Phosphorus (12–18 kg/ha) and High in Potassium (350–400 kg/ha).pH of soils were ranged between 7.4 to 7.9, i.e. neutral in nature. Each plot was considered as a replication for statistical analysis under randomized block design.

RESULTS

Weed flora of the experimental site comprised of grasses (*Echinochloa crus-galli*, *Echinichloa colonum*, *Dactyloctenium aegyptium, Elusine indica*), sedges (*Cyperus rotundus*, *Cyperus iria*) and broad leaved (*Trianthema portulacastrum, Portulaca oleracea*) species.

Weed dry weight (g/m^2)

Maximum weed dry weight was recorded under T_4 treatment (farmer practice) 5.71 g/m^2 which was followed by T_2 (2.85 g/m^2)and with T_1 (2.68g/m^2), while minimum weed dry weight was recorded under two hand weeding at 20 and 40 days after transplanting (T_3) 2.12 g/m^2.

Weed density/m^2

The data revealed that number of weed count/m^2 was also similar to weed dry weight/M^2. The maximum weed/m^2 were recorded in farmers practice (5.824), which is folloed by Butachlore @1 kg a.i./ha (4.078) and Bispyribac sodium @ 30 g/ha (3.566). The minimum number of weed/m^2 was recorded in two hand weeding at 20 and 40 DAT (2.434). Our data showed effectiveness of manual weeding in limiting weed density and dry biomass merely owing to physical removal of the weeds as an effective tool for their management. Nonetheless, during later part of the growing season weeds were also suppressed by shading effect of rice in manually weeded plots due to quick and dense canopy closure (Baloch *et al*., 2005). Herbicides differed in respect of their efficacy and bispyribac sodium emerged as promising one in averting both density and dry matter accumulation by weeds. The performance of this herbicide could be attributed to reasonable suppression of both narrow and broad-leaved weeds and selectivity to rice crop as well. It is a member of

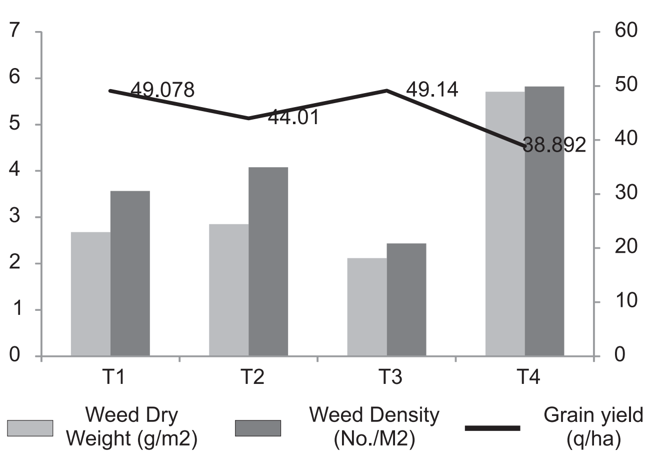

Fig. 1. Weed density, Weed dry weight and grain Yield of Paddy

pyrimidinyloxy benzoic chemical family and inhibits acetolactate synthase enzyme in susceptible plants thus retarding the synthesis of branch chain amino acids (Darren and Stephen, 2006). The findings of present study corroborate the previous findings of Ashraf *et al*. (2006), Hussain *et al.* (2008), Jaya Suria *et al.* (2011), Khaliq *et al*. (2011a,b) and Akbar *et al*. (2011) who concluded that herbicides are an effective mean of securing yield loss against weed infestation during critical period.

Weed Control Efficiency (WCE)

To determine the percentage weed control, the comparison was made with the number of weeds present in the control plots (weedy check) in which no weed control measures were adopted (Farmers practice). Significant differences were noticed among the treatment means. The data revealed that maximum WCE were recorded under two hand weeding at 20 and 40 DAT (62.87%) which is followed by Bispyribac sodium @ 30g/ha (53.06%) and butachlore @ 1 kg a.i./ha (50.09%). Tamilselvan and Budhar, (2001) and Bhattacharya *et al*. (2002) reported similar results as they concluded that weeds can be effectively controlled in the rice crop by the use of herbicides.

Number of tiller per hill

Weed control both by Chemical and physical means effected number of tillers per plant significantly during both the years. The highest numbers of tillers/plant were recorded in case of hand weeding (22.72). Data presented in Table 1 revealed that number of tiller per hill was significantly influenced by different weed management treatments. The application of chemical herbicides (Bispyribac sodium @30 g/ha) produce 22.628 tillers per hill which is significantly higher over Butachlore @ 1 kg a.i./ha and Farmers practice (18.036). Sandeep *et al*. (2002) were of the view that number of tillers/m^2 where the plots were kept weed free were better than the weedy check. Awan *et al*. (2002) reported that manual weed control produced more tillers than Acelor @ 250 ml/ ha and Command 3E @ 668 ml/ha.

Number of Effective Tiller per Hill

Number of effective tiller per hill was also affected by different weed management treatments. The maximum number of effective tiller per hill (13.73) was recorded under T_3 (Two hand weeding at 20 and 40 DAT) which is statistically at par with T_1 (Bispyribac sodium @ 30 g/ha) 13.31. The minimum effective tillers (9.07) were recorded in T_4 (Farmers practice).

Grain and straw yield (q/ha)

Maximum grain yield 49.14 q/ha) was recorded under the treatment of two hand weeding at 20 and 40 DAT which was statistically at par with the application of Bispyribac sodium @ 30 g/ha. (49.078 q/ha). the minimum yield was obtained under farmer practice 38.892 q/ha. Straw yield of rice was

Table 1. No. of Tiller/hill, No. of Effective tiller/hill, Weed dry weight, weed density and weed control efficiency of Paddy under different weed control treatment during 2012–13 and 2013–14

Treatment	No. of tiller/hill	No. of effective tiller/hill	Weed Dry Weight (g/m^2)	Weed Density (No./M^2)	Weed control Efficiency (%)
T_1- Bispyribac sodium@30 g a.i/ha at 25 DAT	22.628	13.314	2.68	3.566	53.06
T_2- Butachlor @1kg a.i./ha at 3 DAT	19.84	12.132	2.85	4.078	50.09
T_3-Two HW (20 and 40 DAT)	22.72	13.73	2.12	2.434	62.87
T_4- Farmers practice (No weed control)	18.036	9.07	5.71	5.824	–
SEm±	0.195	0.121	0.139	0.158	NA
CD@5%	0.601	0.374	0.428	0.488	NA

Table 2. Grain Yield, Straw Yield, cost of cultivation, Gross return, net Return and B:C ratio of paddy under different weed control treatment during 2012–13 and 2013–14

Treatment	Grain yield (q/ha)	Straw yield (q/ha)	Cost of cultivation (₹/ha)	Gross Return (₹/ha)	Net return (₹/ha)	B:C Ratio
T_1- Bispyribac sodium @ 30 g a.i./ha at 25 DAT	49.078	63.31	35,246	135,357	100,111	3.84
T_2- Butachlor @ 1 kg a.i./ha at 3 DAT	44.01	54.13	35,146	120,851	85,705	3.44
T_3-Two HW (20 and 40 DAT)	49.14	64.37	38,200	135,724	97,524	3.55
T_4- Farmers practice (No weed control)	38.892	47.45	34,046	106,720	72,674	3.13
SEm±	0.255	0.328	–	–	–	–
CD@5%	0.786	1.012	–	–	–	–

Sale Price = ₹ 2,500/q (Grain) and ₹ 200/q (Straw)

also following the same pattern as grain yield. Season long weed competition in weedy check reduced rice yield and yield related parameters. Unattended weed growth drastically reduced rice grain yield. Rice remains a poor weed competitor (Saito, 2010) and is particularly vulnerable to yield loss by weeds particularly during initial stage of development (Khaliq and Matloob, 2011). Number of Effective (panicle bearing) tillers, and grain yield were highest where weeds were controlled by manual weeding. Bispyribac sodium appeared at par with manual weeding for most of the yield attributes and yield as well. These treatments lessened weed crop competition during the crucial phase of rice crop establishment that was manifested as more panicles per unit area, increased kernel number and kernel weight over control. Higher rice yield in response to efficient weed control are reported elsewhere (Mahajan *et al*., 2009; Sandeep *et al*. (2002), Bhattacharya, *et al.* (2002), Raju, *et al*. (2003) Jaya Suria *et al*., 2011).

Economic analysis

The effectiveness of any production system is ultimately evaluated on the basis of its economics. Economic analysis is the basic consideration in determining which treatment gives the highest return while marginal analysis indicates the relative contribution of additional expenditures. A perusal of data revealed that there was an overall increase in net income in different weed control treatments over the control (Table 2).

Economic analysis of different treatments was done on the basis of prevailing market prices of input and output. The maximum net return (₹ 100111/ha) was obtained by the application of bispyribac sodium @ 30 g a.i./ha at 25 DAT followed by two hand weeding at 20 and 40 DAT (₹ 97,524/ha) and use of butachlor @ 1 kg a.i./ha (₹ 85,705/ha). The minimum net return was recorded under farmers practice (₹ 72,674/ha).

Application of bispyribac sodium @ 30 g a.i./ha gave maximum B : C ratio (3.84) followed by Two hand weeding at 20 and 40 DAT (3.55), Butachlor @ 1 kg a.i./ha at 3 DAT (3.44) and minimum B : C ratio was recorded under farmers practice (3.13). The cost effectiveness of bispyribac sodium as a post emergence herbicide for weed management in aerobic rice is in line with Mahajan *et al*. (2009).

CONCLUSION

Studies concluded that use of herbicides was an efficient and cost-effective method for weed control in transplanted scented rice in bundelkhand region. Manual weeding can be adopted where cheap labor is available.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Productivity and profitability of clusterbean as influenced by different weed management practices

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Clusterbean [*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 clusterbean is 5.15 m ha with a production of 2.46 m t green pod and a productivity of 478 kg/ha (Anonymous. 2013). As clusterbean 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 herbicide to obtain maximum productivity from clusterbean 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 clusterbean 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 clusterbean 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 clusterbean as influenced by different herbicidal weed management". The 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. Clusterbean seeds were sown at a spacing of 45 cm × 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 weed density and dry weight were transformed using square root transformation (Square root of (X + 0.25)) and analyzed statistically. Clusterbean yield was recorded from each plot and converted into kg/ha. 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

Table 1. Weed control efficiency, green pod yield and economics of 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/h, 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, Cluster bean green pod @ ₹ 10/kg, B : C – Benefit : cost ratio, DAS - Days after spraying, SL- Soluble liquids and EC- Emulsifiable concentrates.

gross returns (₹ 126,474/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 (₹ 125,658 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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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Effect of herbicides and mulch on weed control, productivity and economics of soybean in mollisols

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Soybean, also known as 'Golden Bean' is rich in protein (40–42%) and oil (20–22%) having about 85% unsaturated fatty acid. It provides high phytochemicals and good quality dietary fibre which protects human body against cancers and diabetes. Being a *kharif* crop, soybean faces a major threat from weeds during its vegetative growth, as the warm and humid climate under which it is grown is also favourable for the luxuriant growth of weeds. Late emergence, slow initial growth, wider spacing, poor canopy development provide an ideal condition for weed to grow and compete with the crop. Nainwal *et al*., 2010 from Pantnagar found that weeds controlled at 20 and 40 DAS (critical period of crop weed competition stage) gave higher seed yield of soybean. Farmers have to go for sequential weeding which adds to the cost of weed management. Sole dependence on pre or post emergence herbicides has resulted in the evolution of multiple herbicide resistance. Hence the herbicide use pattern should be rationalized to avoid future problems. Application of sulfentrazone, a new molecular herbicide resulted into reduction of sedges shoot number (95%) (Yelverton and Travis, 2012). Some herbicides like pendimethalin and imazethapyr are effective, but these need to be integrated with other methods for season-long weed control. Straw mulch adopted by farmers have been found to control weeds effectively with minimum inputs, conserve soil moisture and temperature for benefit of crops. Thus, sole dependence on any single herbicide may not provide a long lasting and effective weed management; therefore integration of different methods for weed management is the need of the hours.

METHODOLOGY

A field experiment was carried out in 2015 at Govind Ballabh Pant University of Agriculture and Technology, Pantnagar to investigate the effect of herbicides and mulch on weed control, seed yield and economics of soybean. The experimental soil was neutral (pH 7.2), medium in available nitrogen (320 kg/ha), available potassium (268 kg/ha) and organic carbon (0.55%) but high in available phosphorus (28.82 kg/ha). Twelve treatments were tested in Randomized Block Design with three replications. Soybean cv. PS-1347 was sown @ 80 kg seeds per hectare at row to row spacing of 45 cm. Pre-emergence application of herbicide was done on the next day after sowing and post-emergence application was done 20 days after sowing. Weed free plot was kept free from weeds all through the growing season by manual weeding. Weed Control Index(WCI) was calculated on the basis of dry weight of weeds. Weed index (WI) is a measure of the crop yield loss in different treatments in comparison to weed free. All the data obtained from the experiment were statistically analyzed using the *F*-test procedure given by

Gomez and Gomez (1984). Least significant difference (LSD) value at P=0.05 were used for determination of the significant differences between two means.

RESULTS

Higher the value of WCI of a herbicide, greater is the weed control by that treatment. The highest WCI was obtained in T_8: Pendimethalin 30 EC @1.0 kg/ha (PE) *fb* Imazethapyr 10 EC @ 0.1 kg/ha (PoE) + mulching of wheat straw @ 5 t/ha (25DAS) which was at par with T_9: Mulching of wheat straw @ 5 t/ha after 1st weeding (67.65%) Table 1. WI is the ultimate parameter towards appraisal of the superiority or inferiority of different treatments. Weed index value was lowest (6.9%) in Pendimethalin 30 EC @1.0 kg/ha (PE) *fb* Imazethapyr 10 EC @ 0.1 kg/ha (PoE) + 5 t/ha mulch (25 DAS) which clearly indicated that yield loss was less in this treatment and it was at par with Mulching @ 5 ton/ha after 1st weeding (7.5%) and Mulching of wheat straw @ 5 ton/ha *fb* Sulfentrazone 39.6 EC @ 0.3 kg/ha (PoE) (10.1%). Kumar and Das (2008) inferred that value of weed index was 8.4% in the plot where *in situ* mulching of *Sesbania* was done where as it was 13.1% in Imazethapyr applied plot. On an average, the increase in yield was to the tune of 122.9 per cent in case of weed free plot as compared to weedy check. The weed management practices produced significantly higher seed yield of soybean over weedy check. Reduction in seed yield was least in weed free followed by Pendimethalin 30 EC @1.0 kg/ha (PE) *fb* Imazethapyr 10 EC @ 0.1 kg/ha (PoE) + 5 t/ha mulch of wheat straw (25 DAS). The value was at par with Mulching of wheat straw @ 5 ton/ha after 1st weeding and Mulching of wheat straw @ 5 ton/ha *fb* Sulfentrazone 39.6 EC @ 0.3 kg/ha (PoE). The highest net return (₹ 67,692/ha) was observed in case of Pendimethalin 30 EC @ 1.0 kg/ha (PE) *fb* Imazethapyr 10 EC @ 0.1 kg/ha (PoE) + mulching of wheat straw @ 5 t/ha (25 DAS) because of higher seed yield in this treatment. Pendimethalin 30 EC @1.0 kg/ha (PE) *fb* Sulfentrazone 39.6 EC @ 0.3 kg/ha (PoE) gave the highest benefit cost: ratio (2.93) owing to more net return (₹ 66,919/ha) with low cost of cultivation. It was at par with Mulching of wheat straw @5 t/ha *fb* Sulfentrazone 39.6 EC @ 0.3 kg/ha (PoE) (2.82), Pendimethalin 30 EC @1.0 kg/ha (PE) *fb* Imazethapyr 10 EC @ 0.1 kg/ha (PoE) + Mulching of wheat straw @ 5 t/ha (25 DAS) (2.59) and Mulching of wheat straw @5 t/ha after 1st weeding (2.42).

CONCLUSION

It may be inferred that Pendimethalin 30 EC @1.0 kg/ha (PE) *fb* Imazethapyr 10 EC @ 0.1 kg/ha (PoE) + mulching of wheat straw @5 t/ha (25DAS), Mulching of wheat straw @ 5 t/ha after 1st weeding and Mulching of wheat straw @ 5 t/ha *fb* Sulfentrazone 39.6 EC @ 0.3 kg/ha (PoE) were at par in controlling weeds and yield performance. So, any of these treatments may be an alternative to hand weeding for efficient weed control and achieving more seed yield of soybean. On the basis of B : C ratio, Pendimethalin 30 EC @ 1.0 kg/ha (PE) *fb* Sulfentrazone 39.6 EC @ 0.3 kg/ha (PoE) recorded the highest value and it was at par with Mulching of wheat

Table 1. Effect of herbicide and mulch on WCI, WI, Seed Yield, Net Return and B:C

No.	Treatment	Weed control index (%)	Weed index (%)	Seed yield (kg/ha)	Net return (₹/ha)	B:C
T_1	Pendimethalin 30 EC @ 1.0 kg/ha (PE)	53.48	31.5	1,917	47,319	2.18
T_2	Sulfentrazone 39.6 EC @ 0.3 kg/ha (PoE)	57.29	29.4	1,976	49,211	2.24
T_3	Imazethapyr 10 EC @ 0.1 kg/ha (PoE)	54.20	32.8	1,879	46,478	2.19
T_4	Mulching of wheat straw @ 5t/ha	41.25	34.4	1,835	43,530	1.93
T_5	Pendimethalin 30 EC @ 1 kg/ha (PE) *fb* Sulfentrazone 39.6 EC @ 0.3 kg/ha (PoE)	59.43	10.9	2,493	66,919	2.93
T_6	Pendimethalin 30 EC @ 1 kg/ha (PE) *fb* Imazethapyr 10 EC @ 0.1 kg/ha (PoE)	60.77	13.8	2,412	63,244	2.68
T_7	Pendimethalin 30 EC @ 1 kg/ha (PE) *fb* mulching of wheat straw @ 5 t/ha at 7 DAS	56.16	30.2	1,954	46,151	1.90
T_8	Pendimethalin 30 EC @ 1 kg/ha (PE) *fb* Imazethapyr 10 EC @ 0.1 kg/ha (PoE) + mulching of wheat straw @5 t/ha (25DAS)	67.65	6.9	2,605	67,692	2.59
T_9	Mulching of wheat straw @5 t/ha after 1st weeding	65.98	7.5	2,587	65,962	2.42
T_{10}	Mulching of wheat straw @5 t/ha *fb* Sulfentrazone 39.6 EC @ 0.3 kg/ha (PoE)	63.02	10.1	2,514	66,838	2.82
T_{11}	Weedy check	0	55.1	1,255	25,150	1.25
T_{12}	Weed free	100	0	2,797	67,162	2.00
	SEm±	3.15	1.49	127.44	4,588.03	0.19
	CD at 5%	9.24	4.36	373.77	13,456.08	0.55

straw @5 t/ha *fb* Sulfentrazone 39.6 EC @ 0.3 kg/ha (PoE). So, Sulfentrazone, a new molecule herbicide, proved to be potent when applied with mulch.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Effect of intercropping and weed control measures on growth and yield of pearlmillet

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Pearlmillet [*Pennisetum glaucum* (L.) Br. Emend stuntz.] Popularly known as *Bajra* ranks fourth in India, it is most important cereal crop next to rice, wheat and sorghum. It has the greatest potential among all the millets and adapted to drought and poor soil fertility, but responds well to good management and higher fertility levels. India is the largest producer of pearlmillet. The arable land is precious and scarce resource. So to increase production, the cropping intensity and efficient utilization of available resources seems more feasible over increasing area under cultivation. Farmers in the arid and semi arid regions generally mixed/intercropped pearlmillet with other legumes to increase productivity per unit area and avoid to risk of failure of either of the crops. Weed infestation is considered as one of the most important constraint that limits yields in intercropping system. Pearlmillet and legume intercropping, being a rainy season system, suffers badly due to severe competition by mixed weed flora. Conventional methods of weed control being weather dependent, laborious, time consuming and costly due to high cost of labour and mechanical means being less efficient in controlling weeds compare to use of herbicides, there is need to explore suitable herbicide(s), which may be effective and economically viable for both monoculture and intercropping.

METHODOLOGY

The present investigation entitled, 'Effect of Weed Control Measures in Pearlmillet – Legumes Intercropping System in Arid Western Rajasthan' was conducted at the Instructional Farm, College of Agriculture, Swami Keshwanand Rajasthan Agricultural University, Bikaner during *kharif* 2014.The experiment was laid out in split plot design and replicated thrice. Main plot consists five intercropping treatments, viz. sole pearlmillet, sole clusterbean, sole mothbean, pearlmillet + clusterbean and pearlmillet + mothbean and sub plot consists four weed control treatments, viz. weedy check, hand weeding twice at 20 and 45 DAS, pendimethalin at 0.75 kg/ha as pre-emergence and imazethapyr 40 g/ha as post emergence. The soil of the experimental field was loamy sand in texture and slightly alkaline in reaction. The status of soil was poor in organic carbon and low in available nitrogen, medium in phosphorus and high in available potassium.

RESULTS

Effective tillers per plant of pearlmillet were significantly, higher in intercropping system either with clusterbean or mothbean as compared to pearlmillet sole. Higher number of effective tillers in intercropping treatments may be due to lower pearlmillet population and wider space available for more growth and development of pearlmillet. Other growth characteristics, viz. plant height, dry matter accumulation and length of ear head were not influenced significantly by

Table 1. Effect of intercropping and weed control measures on growth and yield of pearl millet

Treatment	Plant height (cm)	Dry matter (g/plant)	Effective tillers/ plant	Length of ear head (cm)	Yield (t/ha)	
					Grain	Straw
Intercropping						
Pearl millet sole	163.10	25.94	1.75	21.73	0.91	1.72
Cluster bean sole	–	–	–	–	–	–
Moth bean sole	–	–	–	–	–	–
PM+CB (1:2)	161.73	30.84	2.26	22.19	0.38	0.66
PM+MB (1:2)	161.48	31.23	2.25	22.74	0.38	0.68
SEm±	2.96	1.22	0.11	0.60	0.02	0.057
CD (P=0.05)	NS	NS	0.43	NS	0.08	0.225
Weed control						
Weedy check	157.99	26.80	1.64	20.73	0.50	0.99
Two hand weeding at 20 and 35 DAS	173.58	35.03	2.84	23.87	0.65	1.24
Pendimethalin 0.75 kg/ha as PE	168.01	31.97	2.43	23.07	0.57	1.07
Imazethapyr 40 g/ha at 25 DAS as PoE	148.83	23.56	1.42	21.21	0.50	0.79
SEm±	2.61	1.07	0.09	0.44	0.023	0.035
CD (P=0.05)	7.76	3.19	0.26	1.32	0.07	0.105

intercropping. Grain and straw yield of pearlmillet increased considerably in pearlmillet sole as compared to both intercropping system with clusterbean and mothbean. Significant difference by intercropping system in grain and straw yield of pearlmillet were due to the virtue of the row ratio of intercropping system. These findings are in close conformity of those reported by Patel and Sadhu (2013). All the weed control measures (except imazethapyr at 40 g/ha) considerably increased dry matter production, effective tillers per plant, ear length of pearlmillet over weedy check. All weed control measures (except imazethapyr at 40 g/ha) produced significantly higher grain and straw yield of pearlmillet over weedy check. The higher grain yield obtained due to hand weeding treatment was associated with lower dry matter production of weeds under this treatment which posed less competition and better soil environment. Herbicidal weed control measures controlled the different type of weeds effectively but these treatments failed to produce higher yields of pearlmillet. This might be due to some phytotoxic effect on growth and yield attributing character pearlmillet. Imazethapyr which is non-selective to cereals has showed phytotoxic effect which caused injury to pearlmillet and reduced yield (Qian *et al*., 2011).

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Foliar application of urea and thiourea on growth and yield attributes of lentil (*Lens culinaris*) under moisture stress conditions

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Lentil (*Lens culinaris*) is an important and popular annual legume in the world for its highly valued grain in human and animal nutrition because of its high lysine and tryptophan content, it's consumption with wheat or rice provides a balance in essential amino acids. The crop has great significance in cereal-based cropping systems, rainfed areas in particular, because of its cultivation improves soil nitrogen, carbon and organic matter status, thus providing sustainability in production systems. (Sarker and Kumar, 2011; Abraham, 2015). Shortage of water during the crop growth period has become the major impediments for cultivation of pulses in rice fallow particular. Under such conditions, application of sulfhydryl compounds like thiourea can be a potential alternative to improve photosynthetic efficiency, assimilate partitioning and increased growth and yield (Anitha *et al.,* 2004). Therefore an investigation was conducted to evaluate the effect and quality of sulfhydryl bio-regulator spray on growth and yield of lentil as well as to work out the economics of different treatments for production of lentil under restricted irrigation conditions.

METHODOLOGY

A field experiment was conducted during *rabi* season 2012–13 on clay loam soil with medium in fertility and acidic in reaction (pH 5.4) at Central Agricultural University, Imphal, Manipur. The experiment was laid out in randomized block design with replicated thrice. There were totally 13 treatment combinations comprising of water sprays, urea sprays and thiourea spray at different concentrations including farmers practice, viz. T_1-Control (No spray), T_2-Water spray at pre flowering, T_3-Water spray at pod intiation, T_4-Water spray at pre-flowering + pod intiation, T_5-Urea 2% spray at pre flowering, T_6-Urea 2% spray at pod intiation, T_7-Urea 2% spray at pre-flowering + pod intiation, T_8-Thiourea 500 ppm at pre flowering, T_9-Thiourea 500 ppm at pod intiation, T_{10}-Thiourea 500 ppm at pre flowering + pod intiation, T_{11}-Thiourea 1000ppm at pre flowering, T_{12}-Thiourea 1000ppm at pod intiation, T_{13} -Thiourea 1000 ppm at pre flowering + pod intiation.

The crop experienced favorable weather conditions with the total rainfall of 283.3 mm received during the crop growth period. The highest in the month of October (161.5 mm) whereas, lowest in February (1.7 mm). The range of monthly maximum and minimum temperature was 29.4°C to 17.50°C and 23.10°C to 3.0°C respectively. Mean relative humidity was lowest in February (32%), While the highest value was recorded in December (88.70%).

Soil was medium in nitrogen (285.38 kg/ha), low in phosphorus (18.78 kg/ha) and medium in potassium (324 kg/ha) and adequate in sulphur (16.32 mg kg/soil). Sowing of the crop at right time helped in matching the crop growth to favorable climatic conditions. The crop did not experience any biotic stress during its growth period. Observations on growth and yield attributes were recorded at different intervals and at the time of harvest and the data were statistically analyzed.

RESULTS

The application of 1,000 ppm thiourea at pre flowering plus pod initiation stages significantly increased plant height (34.1 cm), number of branches per plant (7.07) and total dry matter accumulation (19.52 g/plant). Similarly, the higher number of nodules (16.3/plant) with the application of thiourea @500ppm at pre flowering plus pod initiation and nodules dry weight (17.36 mg/plant) was recorded with thiourea @ 1,000 ppm at pre flowering (Table.1). Its due to increase in the meristematic activity of apical tissues and its stimulatory effects on cell division thereby increasing shoot length and Improved leaf area by sulphur nutrition provided greater surface area for production and partitioning of photo-assimilates towards growing sinks and higher activity of Nitrate reductase, Yadav (2005) and Itanna (2005) were reported similar results.

Significantly higher seed (15.9 q/ha) and stover (33.0 q/ha) yield was recorded due to foliar application of thiourea @ 1,000 ppm at pre-flowering plus pod initiation which was on par with application of thiourea @ 500 ppm at flowering and pod initiations stage (15.3 q/ha) and thiurea application

Table 1. Effect of thiourea foliar spray on growth and growth parameters of lentil

Treatments	Plant height at harvest (cm)	No. of branches/ plant at harvest	Total dry wt. at harvest (g/plant)	No. Nodules/ plant at 45 DAS	Nodules dry wt. at 45 DAS (mg/plant)	Days to 50% flowering	Days to maturity
T_1	25.9	4.13	11.74	14.3	13.87	84	144
T_2	26.9	4.13	12.83	14.5	13.82	84	144
T_3	27.3	4.27	13.82	14.5	15.25	84	143
T_4	28.1	4.67	14.78	14.6	14.8	83	143
T_5	28.8	4.67	15.26	14.8	14.66	81	142
T_6	29.3	4.8	16.07	14.9	15.19	81	142
T_7	30.1	5.6	16.62	15.9	16.3	78	141
T_8	29.9	5.73	16.47	15.5	16.36	79	140
T_9	30.4	5.93	17.16	15.5	16.16	79	139
T_{10}	32.7	6.6	18.84	16.3	16.94	77	136
T_{11}	31.2	6.6	18.66	15.9	17.36	78	137
T_{12}	32.1	7.07	19.11	16.1	16.7	78	135
T_{13}	34.1	7.07	19.52	16.1	17.12	77	136
SEM±	1.2	0.17	0.5	0.5	0.65	4.48	4.12
C D (0.05)	3.5	0.5	1.47	1.4	1.9	NS	NS

Table 2. Effect of thiourea foliar spray on yield, yield parameters and economics of lentil

Treatments	No. of pods/plant	No. of seeds/pod	100 seeds weight	Seed yield (q/ha)	Stover yield (q/ha)	Harvest index (%)	Net returns (₹/ha)	B:C Ratio
T_1	46.7	1.4	1.71	9.1	18.3	33.3	24,955	1.54
T_2	47.7	1.6	1.7	9.3	18.8	33.1	25,277	1.53
T_3	49.5	1.65	1.77	9.8	19.3	33.6	27,443	1.66
T_4	53.5	1.67	1.78	10.1	20.2	33.3	28,615	1.69
T_5	52.8	1.73	1.83	10.3	21	32.9	29,721	1.78
T_6	57.3	1.75	1.95	11	22.4	32.8	32,622	1.96
T_7	61.3	1.8	1.86	12.7	26.9	32.4	39,886	2.32
T_8	63.2	1.8	1.82	13	26	33.4	41,593	2.43
T_9	64	1.87	1.87	14.4	28.1	33.9	47,658	2.78
T_{10}	72.5	1.93	1.85	15.3	30.7	33.4	50,795	2.81
T_{11}	70	1.87	1.88	14.8	29.6	32.5	46,681	2.64
T_{12}	72.7	1.9	1.98	15.5	30.7	33.6	52,199	2.95
T_{13}	73.8	1.93	1.97	15.9	33	32.7	53,055	2.84
SEM±	3.2	0.09	0.07	0.5	1.3	1.1		
C D (0.05)	9.3	0.26	NS	1.4	3.7	NS		

at 1,000 ppm at flowering initiation stage (15.5 q/ha) (Table 2). However T_{13} was recorded 74.43 per cent increased in seed yield over no spray (control) might be due to increased photosynthetic efficiency and canopy photosynthesis on account of the biological activity of -SH group and favorable impact on the photosynthetic production or its partitioning. These results are in conformity with the findings of Kumar *et al.* (2010) and Mathur *et al.* (2006).

Maximum net return of (₹ 53,055/ha) and B : C ratio (1 : 2.95) were found in foliar spray of thiourea @ 1,000 ppm at pre-flowering plus pod initiation and foliar spray of thiourea @ 1,000 ppm at pod initiation, respectively (Table.2). This might be due to greater seed yield under this treatment. The results are in conformity with the findings of (Rehman *et al.*, 2013).

CONCLUSION

Lentil respond well to foliar application of thiourea @ 1,000 ppm or 500 ppm at pre-flowering and pod initiation helps in better growth and development, which induces higher dry matter accumulation/plant, better root growth of the crop with nodules inturn leads to better nutrient uptake and higher seed and stover yield under restricted moisture stress conditions.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Effect of integrated weed management on weed control, yield attributes and yield of aerobic rice

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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 a.i./ha at 15–20 DAS, T_2-POE-Byspyribac-sodium (10% SC) @ 35 g a.i./ha at 15–20 DAS + one hoeing at 45 DAS, T_3 -PE-Pendimethalin (30 EC) @ 1 kg a.i/ha at 3–4 DAS + POE-Bispyribac-sodium (10% SC) @ 35 g a.i./ha at 15–20 DAS, T_4 -PE-Butachlor (50 EC) @ 1.5 kg a.i/ha at 3–4 DAS + POE-Bispyribac-sodium (10% SC) @ 35 g a.i./ha at 15–20 DAS, T_5 -PE-Pendimethalin (30 EC) @ 1.00 kg a.i./ha at 3–4 DAS + POE-MSM + CME (20 WP) @ 40 g a.i./ha at 25–30 DAS, T_6 -PE-Butachlor (50 EC) @ 1 kg a.i./ha at 3–4 DAS + POE-MSM+CME (20 WP) @ 40 g a.i./ha at 25–30 DAS, T_7 -POE-Azimsulfuron @ 20–30 g a.i./ha at 20 DAS, T_8 -PE-Butachlor @ 1 kg a.i./ha + 1 HW at 30 DAS, T_9-2 HW at 20 & 45 DAS + 2 hoeing at 25 & 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 × 4.5 m and 3.0 m × 3.6 m, respectively. Variety used for experimental study was PBNR-03-02 with recommended dose of fertilizer of 80 : 50 : 50 NPK kg/ha and 60 kg seed rate/ha. Sowing was done by hand drilling on 2nd July, 2013. Experimental results revealed that, 2 hand weeding + 2 hoeing (T_9) recorded significantly higher grain yield (37.06 q/ha), straw yield (58 q/ha), and NMR (₹ 29,650/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 kg a.i./ha + 1 HW (T_8) recorded the highest grain (37.06 q) and straw (58 q) yield, and NMR (₹ 30,550/ha) than rest of the herbicides or integrations of herbicides. Amongst, application of single herbicide or combination of two herbicides, PE-Pendimethalin (30 EC) @ 1.00 kg a.i./ha + POE-Bispyribac-sodium (10% SC) @ 35 g a.i./ha (T_3) recorded the highest grain (35 q) and straw yield (55

Table 1. Effect of different weed management treatments on grain yield (q/ha), weed density, weed dry weight (g/m^2) and weed control efficiency (%)

Treatments	Grain yield (q/ha)	Weed density at 60 DAS		Weed dry weight at 60 DAS (g/m^2)		WCE(%)
		Monocot and sedges	Dicot	Monocot and sedges	Dicot	
T_1 - POE-Bispyribac-sodium (10% SC) @ 35 g a.i./ha	25.50	3.15 (7.05)	4.96 (19.90)	3.93 (11.83)	6.28 (33.42)	57.71
T_2 - POE-Bispyribac-sodium (10% SC) @ 35 g a.i./ha fb one hoeing	33.00	2.95 (6.03)	4.37 (15.03)	3.42 (8.56)	5.12 (21.37)	72.02
T_3 - PE-Pendimethalin (30EC) @1.00 kg a.i./ha fb POEBispyribac sodium (10%SC) @ 35 g a.i./ha	35.00	3.14 (7.02)	3.96 (12.00)	3.56 (9.41)	4.58 (16.66)	75.63
T_4 - PE-Butachlor (50EC)@ 1.5 kga.i./ha fb POE Bispyribac- sodium (10%SC) @ 35 g a.i./ha	34.00	2.75 (5.10)	4.24 (14.01)	3.43(8.61)	4.94 (19.77)	73.47
T_5 -PE-Pendimethalin (30EC) @1.00 kg a.i./ha fb POE- Mesulfuron methyal + chlorimuron(20WP) @ 40g a.i./ha	29.00	2.51 (4.06)	4.38 (15.06)	3.36 (8.18)	5.28 (22.85)	71.00
T_6 - PE-Butachlor (30EC)@ 1.00 kg a.i./ha fb POE Almix (20WP) @ 40 g a.i./ha	28.00	2.94 (6.00)	4.75 (18.07)	3.34 (8.09)	5.43 (24.38)	69.96
T_7 - POE-Azimsulfuron @ 20–30 g a.i./ha	24.00	3.16 (7.09)	4.54 (16.40)	4.28 (14.31)	5.43 (25.97)	62.35
T_8- PE-Butachlor @ 1.00 kg a.i./ha fb1HW	36.00	2.92 (5.88)	3.7 (10.00)	4.02 (12.46)	5.59 (21.21)	68.55
T_9- 2 Hand weeding fb 2 hoeing	37.06	2.74 (5.05)	3.56 (9.38)	3.92 (11.74)	5.10 (17.58)	77.57
T_{10}- 3 Need based hand weeding	39.00	2.23 (3.00)	2.52 (4.12)	2.00 (2.26)	2.26 (3.11)	94.79
T_{11}- Unweeded control	15.00	3.50 (9.06)	6.48(35.80)	4.89 (17.62)	9.95 (89.38)	–
SEm+	0.65	0.14	0.34	0.20	1.17	–
C.D. at 5%	1.95	0.45	1.07	0.62	3.63	–
General mean		2.70	4.01	3.80	5.52	71.80

Figures in parentheses are transformed values.

q) and NMR (₹ 28,980/ha) than rest of the herbicides or herbicide combinations and was at par with PE-Butachlor (50 EC) @ 1.5 kg a.i./ ha + POE-Bispyribac-sodium (10% SC) @ 35 g a.i./ha (T_4). Amongst herbicides and combination of herbicides, PE-Pendimethalin (30 EC) @ 1 kg a.i./ha + POE-Bispyribac-sodium (10% SC) @ 35 g a.i./ 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 a.i./ha + POE-Bispyribac-sodium (10% SC) @ 35 g a.i./ha (T_4) at 60 DAS. Per cent NMR loss due to unweeded control (T_{11}) was 90.01 comparable to weed free plot. Per cent reduction in NMR with PE - Butachlor @ 1 kg a.i./ ha + 1 HW (T_8) and PE-Pendimethalin (30 EC) @ 1 kg a.i./ha + POE- Bispyribac-sodium (10% SC) @ 35 g a.i./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 a.i./ha at 10–15 DAS along with pre emergence application of pendimethalin (30 EC) @1 kg a.i. per ha or butachlor (50 EC) @ 1.5 kg a.i./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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Residual effect of herbicides applied in wheat on the establishment of succeeding crops

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Wheat performs better under strip (single pass) tillage than under conventional full tillage (3-4 pass) practice. The adoption of this resource saving strip tillage for wheat is highly impeded by heavy weed infestation. Manual weed control is now becoming impracticable because of labour scarcity and higher wage rates. Herbicide can be the best alternative to manual weed control. However, the residue of herbicides applied in wheat crop may persist in the soil and affect the succeeding crops (Bedmar *et al.,* 2006). The information on the residual effect of herbicides applied in wheat on the succeeding crops like jute, mungbean and sunflower are highly scarce. The present study was therefore conducted to examine the residual effect of herbicides applied in wheat on the germination and early growth of the succeeding crops like jute, mungbean and sunflower.

METHODOLOGY

The experiment was conducted at Agronomy Field Laboratory of Bangladesh Agricultural University; Mymensingh (24°75 N latitude and 90°50 E longitude, 18 m altitude) during November 2013 to June 2014 on well drained a medium high land clay loam soil having a p^H value of 6.8. Twelve treatment combinations of eight herbicides namely three pre-emergence (pendimethalin, pretilachlor and thiasulfuron), two early post-emergence (ethoxysulfuran and pyrazosulfuran ethyl) and three post-emergence (carfentrazone-ethyl, 2,4-D and carfentrazone-ethyl + isoproteuron) herbicides, viz. T_1= No weeding, T_2= Weed free (4 hand weeding), T_3=Pendimethalin fb Pendimethalin, T_4 = Pretilachlor fb Pretilachlor, T_5 = Pendimethalin fb Ethoxysulfuran, T_6 = pretilachlor fb Ethoxysulfuran, T_7 = Pendimethalin fb Carfentrazone-ethyl, T_8 = Pretilachlor fb carfentrazone-ethyl, T_9 = Pendimethalin fb 2,4-D, T_{10} = Pretilachlor fb 2,4-D, T_{11} = Triasulfuron fb Carfentrazone-ethyl + Isoproteuron and T_{12} = Triasulfuron fb 2, 4-D were included in a randomized complete block design (RCBD) with three replications. Herbicides were applied at 3, 15 and 25 DAS in the wheat field as per treatment specification. Three micro-plots (1 m × 1 m) were prepared in each unit plot (4 m × 2.5 m) of after harvest of wheat to test the performance of jute, mungbean and sunflower. Plant population, shoot and root length and leaf chlorophyll content (SPAD value) of each crop were recorded at 25 DAS. The collected data were subjected to statistical analysis and mean differences among the treatments were adjudged by LSD test.

RESULTS

The herbicides applied in the wheat did not have any

Table 1. Residual effect of herbicides on SPAD value and shoot length of jute, mung bean and sunflower at 25 days after sowing during 2014

Treatment	SPAD value			Shoot length (cm)		
	Jute	Mung bean	Sunflower	Jute	Mung bean	Sunflower
No weeding	24.50	36.59	23.05	21.69	26.80	24.55
Weed free	25.40	36.63	26.00	24.69	27.47	24.65
Pendimethalin fb Pendimethalin	29.90	35.50	28.00	30.86	28.51	31.49
Pretilachlor fb Pretilachlor	31.15	37.25	32.36	30.25	28.75	27.86
Pendimethalin fb Ethoxysulfuran	29.10	37.20	26.72	28.06	28.37	32.13
Pyrazosulfuran Ethyl fb Ethoxysulfuran	30.87	36.65	27.37	24.80	27.08	32.39
Pendimethalin fb Carfentrazone-ethyl	27.83	35.47	27.90	31.71	29.68	30.02
Pretilachlor fb Carfentrazone-ethyl	26.63	36.53	23.73	25.51	25.57	27.49
Pendimethalin fb 2,4-D	29.40	36.65	27.92	29.73	30.69	30.46
Pretilachlor fb 2,4-D	25.70	36.67	25.57	22.68	30.31	28.25
Traisulfuron fb (Carfentrazone-ethyl + Isoproteuron)	28.57	36.20	26.50	22.30	28.84	28.57
Traisulfuron fb 2,4-D	32.83	34.20	26.75	32.19	24.65	27.47
Level of significance	**	*	NS	**	*	**

significant effect on plant population of jute, mung bean and sunflower. Khokhar and Charak (2011) reported that sulfosulfuron, isoproteuron and clodinofop had no adverse effect on germination of maize, green gram and cucumber. Sangeetha *et al*. (2012) also reported that Imazethapyr had no effect on the succeeding crops like sunflower and pearlmillet. Herbicide applied in wheat had significant effect on leaf chlorophyll content (SPAD values) in jute and mung bean but not in sunflower (Table 1). However, for all the three crops the SPAD values were higher in herbicide treated plots than the no weeding plots. Shoot length was affected significantly by herbicide treatments for the three crops (Table 1). Root length was influenced by herbicide treatment for sunflower but not for jute and mung bean. For all the three crops shoot length and root length were higher in herbicide treated plots than the weed free and the unweeded control plots. Although Triasulfuron fb 2, 4-D treatment reduced the shoot length in mung bean but not in jute and sunflower. This result indicates that herbicides applied in wheat had no residual effect on the succeeding crops like jute, mung bean and sunflower. Kewat *et al.* (2001) found that the residue of pendimethalin applied in soybean reached non-detectable level after harvest of soybean.

CONCLUSION

The pre-emergence, early post-emergence and post emergence herbicides used in wheat has no residual adverse effect on emergence and early growth of the succeeding crops like jute, mung bean and sunflower.

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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 backpack 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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Weed management in summer okra

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Okra is one of the most popular vegetables in tropical or sub-tropical region. Okra suffers heavy yield losses due to weed infestation owing to congenial environmental conditions for luxurious weed growth coupled with wider row spacing and slow growth at early stages. Yield losses due to weeds varied from 40 to 80% depending on the type of flora, their intensity and stages (Patel *et al*., 2004). The most critical period of weed competition in okra is up to 2–6 weeks after sowing. Scarcity of manpower at critical period of crop-weed competition, costly herbicides and their availability in desired quantity are also problematic. It was, therefore, considered necessary to undertake a study to find the performance of various pre-emergence as well as post emergence herbicides applied with other weed management practices so that reduce the farmers extra expenditure incurred on manual weeding in scorching summer conditions.

METHODOLOGY

A field experiment was conducted during summer season of 2013–14 at the College Farm, N. M. College of Agriculture, Navsari Agricultural University, Navsari to study the weed management practices in summer okra (*Abelmoschus esculentus* L. Moench) under south Gujarat condition. The experiment consisted of ten weed management treatments, viz., W_1: Stale seed bed, W_2: Pendimethalin 1.0 kg/ha pre-emergence, W_3: Oxyfluorfen 0.24 kg/ha pre-emergence, W_4: Pendimethalin1.0 kg/ha as Pre-emergence + Quizalofop ethyl 0.040 kg/ha at 30 DAS), W_5: Oxyfluorfen 0.24 kg/ha as pre-emergence + Quizalofop ethyl 0.040 kg/ha at 30 DAS, W_6: Quizalofop ethyl 0.040 kg/ha at 20 DAS + One hand weeding at 40 DAS, W_7: One hand weeding + Straw mulch 3 t/ha at 20 DAS, W_8: Two hand weeding at 20 & 40 DAS, W_9: Three hand weeding at 20, 40 and 60 DAS and W_{10}: Weedy check (control) were evaluated on okra *cv.* hybrid. The experiment was laid out in randomized block design with four replications. The data on dry weed weight (g/m^2) at 90 DAS was collected from plots of different treatments. Fresh pod yield (q/ha) was recorded by adding the weight of pods at different pickings. The weed control efficiency was calculated as per standard method.

RESULTS

All weed management practices significantly improved the growth (plant height) and yield attributes (number of nodes/main stem, number of fruit/plant and fruit yield/plant) of coriander over weedy check (Table 1). Data clearly show that, plant height, number of nodes/main stem, number of fruit/plant and fruit yield/plant were significantly higher with three hand weeding treatment. However, all the weed management treatments produced significantly higher fresh fruit yield than weedy check. Higher fresh fruit yield (16.8, 14.3 and 13.9 t/ha, respectively) were obtained under treatment three hand weeding at 20, 40 and 60 das followed by treatments two hand weeding at 20 and 40 DAS and pendimethalin1.0 kg/ha as pre-emergence + quizalofop ethyl 0.040 kg/ha at 30 DAS during the course of investigations. This might be due to proper weed management treatments controlled weeds effectively, reduced the competition from the weeds to a greater extent and thus helped in faster growth and development of okra crop, resulting in obtaining higher values of all yield attributing characters. From the economics point of view, the highest net profit of 105,233/ha was obtained from treatment three hand weeding at 20, 40 and 60 das followed by treatments two hand weeding at 20 and 40 das (₹ 83,442/ha) and pendimethalin 1.0 kg/ha as pre-emergence + quizalofop ethyl 0.040 kg/ha at 30 DAS (₹ 82,277/ha) (Fig. 1).

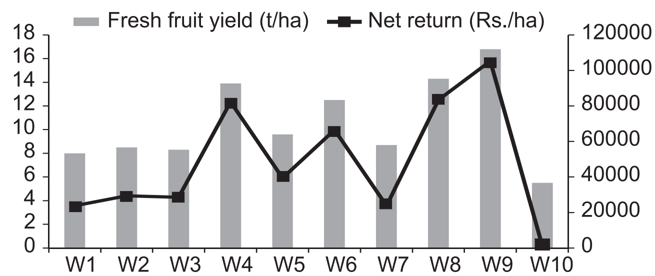

Fig. 1. Yield and economics of okra crop as influenced by weed management

CONCLUSION

From the experiment, it is noted that adopting two hand

Table 1. Dry weight of weeds, WCE, yield and yield attributes of okra at harvest as influenced by weed management

Treatment	Dry weight of weeds (kg/ha)	Weed control efficiency (%)	Plant height (cm)	Number of nodes/ main stem	Number of fruit/ plant	Fruit yield/ plant (g)
Stale seed bed	556.0	45.9	32.0	12.3	6.6	64.7
Pendimethalin 1.0 kg/ha (PE)	502.8	51.2	33.3	13.3	8.7	91.9
Oxyfluorfen 0.24 kg/ha (PE)	649.9	37.2	31.4	12.8	6.7	67.0
Pendimethalin 1.0 kg/ha (PE) *fb* Quizalofop ethyl 0.040 kg/ha at 30 DAS	281.5	73.1	40.0	16.5	9.4	111.4
Oxyfluorfen 0.24 kg/ha (PE) *fb* Quizalofop ethyl 0.040 kg/ha at 30 DAS	537.9	48.1	34.8	13.2	7.1	79.4
Quizalofop ethyl 0.040 kg/ha at 20 DAS *fb* One hand weeding at 40 DAS	299.6	70.9	37.7	16.2	9.2	110.1
One hand weeding *fb* Straw mulch 3 t/ha at 20 DAS	470.7	54.2	35.5	14.9	7.3	80.5
Two hand weeding at 20 & 40 DAS	183.5	82.1	42.2	16.8	10.3	126.1
Weed free check (Three hand weeding at 20, 40 and 60 DAS)	119.4	88.4	48.5	19.0	11.6	144.2
Weedy check (Control)	1047.1	0.0	26.2	11.1	4.0	44.4
CD (P=0.05)	85.76	–	5.17	2.41	1.22	10.42

weeding at 20 and 40 DAS for achieving higher and profitable fruit yield of okra. Alternatively, where farm labours are scare, application of pendimethalin 1.0 kg/ha as pre-emergence + quizalofop ethyl 0.04 kg/ha at 30 DAS (W_4) is also found remunerative.

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Bioefficacy of pyrazosulfuron and bensulfuron methyl in combination with pretilachlor on weeds in transplanted rice under kashmir conditions

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In Jammu and Kahmir, State the rice crop occupies an area of 2.65 lakh hactares with a production of around 454.8 thousand tonnes out of which Kashmir valley alone accounts for 62% of the production (Economic Survey, 2014–15). The very low annual growth rate of rice yield observed for the last two decades is a cause for concern with regard to food security. Due to abundant sunshine with nearly pest free environment Kashmir region is suitable for very good rice yields. In spite of this fact the average productivity (around 2.2 t/ha) is far below the potential yields (6–7 t/ha). This lower productivity is due to inappropriate management related to nutrients, weeds and water includinglow and imbalanced use of manures and fertilizers, faulty irrigation and cultural practices and poor weed control practices. Weed competition is going to be the major constraint in achieving higher productivity. Weed infestation in rice has been established as one of the important factors responsible for lower productivity as the weed flora under transplanted conditions cause a yield reduction upto 76% (Singh *et al.,* 2004). Out of the losses due to various biotic stresses, weeds are known to account for 45% of the losses. Keeping in view the above facts a field experiment entitled 'bioefficacy of pyrazosulfuron and bensulfuron methyl in combination with pretilachlor on weeds in transplanted rice under kashmir conditions' was conducted at Mountain Research Centre for Field Crops (between 34° N latitude and 74° E longitude at an altitude of 1560 amsl), Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir during *kharif* 2014 and 2015. The soil of the experimental field was neutral in reaction with low N and medium P, K and OC. The experiment comprised of six treatments (W_1: Pretilachlor + Bensulfuron methyl, W_2: Pretilachlor + pyrazosulfuron, W_3: Butachlor, W_4: Hand weeding twice (15 & 30 DAT), W_5: Weed free and W_6: Weedy check) replicated four times in a randomized block design. Major weed species infesting the field were; *Echinocloacrusgali* L.*, Echinocloacolona* L., *Cyperusiria* L.*, Cyperus difformis* L.*, Marsilia quadrifolia* L.*, Potamogeton distinctus*, A. Benn., *Ammania baccifera* L. and *Monochoria vaginalis*. The results revealed that application of Pretilachlor + Bensulfuron methyl, on an average caused a reduction of 7.44 and 79% in weed population as compared to butachlor and weedy check, respectively. Likewise Pretilachlor+pyrazosulfuron application also proved effective in controlling the weeds and reduced their density by 10.25% compared to commonly used butachlor. Among the tested herbicides, lowest weed dry matter of 9.45 (3.22) g/m^2 was recorded with Pretilachlor + pyrazosulfuron application. Application of Pretilachlor + Bensulfuron methyl exhibited a superiority of 11.09% in reducing the dry weight of weeds as compared to Butachlor and the corresponding figure for Pretilachlor + pyrazosulfuron was 17.06. Combination application of Pretilachlor + pyrazosulfuron recorded considerably higher grain yield of 7.27 t /ha than butachlor (6.74 t /ha) and control (4.17 t / ha). The superiority exhibited by Pretilachlor + pyrazosulfuron was 7.35 and 7.76% during 2014 and 2015, respectively.

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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 a multinutrient 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 (Uttar Pradesh). 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/ha available 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 (F_3), 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 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/ha was applied to different 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 0.5 m × 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°C 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 2014 respectively. 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 calculated 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 *Cynodon dactylon* among the grassy weeds. *Parthenium*

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./m^2)	Total weed dry weight (g /m^2)	Weed control efficiency (%)	Nutrient depletion (kg/ha)		
Fertility levels				Grain yield	Net returns (₹/ha)	B C ratio
Control	6.99(70.34)	7.03(68.26)	56.40	900.33	17,550.48	2.19
100% RDF	6.40(57.82)	6.30(52.88)	60.03	1,096.98	22,486.75	2.37
75% RDF+ 2% urea spray at pre-flowering and pod initiation	6.72(63.57)	6.42(54.94)	56.99	1,027.41	19,491.01	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	1,283.08	22,783.24	2.00
100% RDF + 2% urea spray at pre-flowering and pod initiation	6.16(53.49)	5.99(47.62)	60.14	1,136.59	23,218.09	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	1,028.37	14,270.28	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	18,653.62	2.17
Weed free	0.71(0.00)	0.71(0.00)	100.00	1,230.94	18,293.52	1.71
Pendimethalin 1.0 kg/ha	6.91(47.47)	6.84(46.54)	64.64	1,042.53	20,293.67	2.16
Imazethapyr 37.5 g/ha	5.59(30.85)	6.43(40.93)	68.87	1,088.05	22,625.76	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.

hysterophorus, *Fumaria parviflora*, *Anagallis arvensis*, *Vicia sativa*, *Melilotus indica*, *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 1). 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 ₹ 22,625.76/ha with B : C 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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Weed flora and crop production system in cold desert climatic condition of Ladakh

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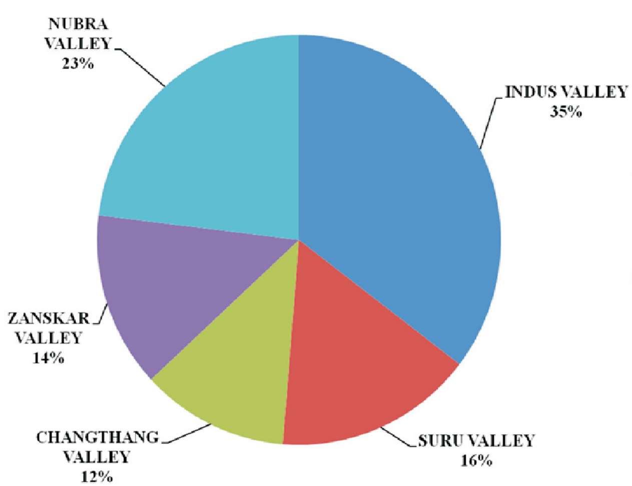
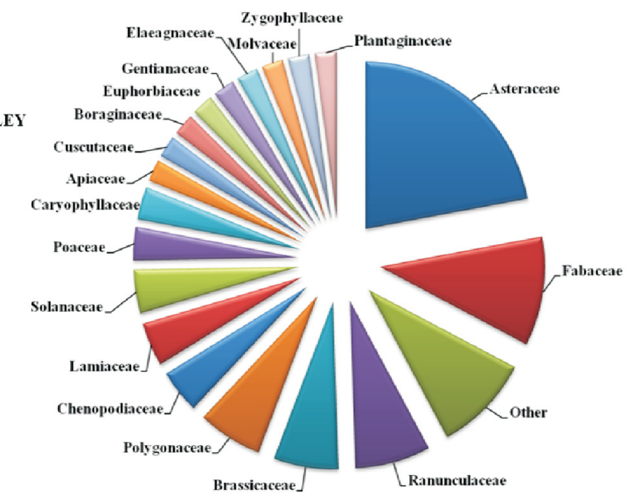
Ladakh is known as trans-himalayan cold desert region situated on the top of great Himalaya. It comprises five valleys (Indus, Nubra, Changthang, Zanskar, Suru), each famous for its location and altitudinal variation. Weeds are most obnoxious for crop cultivation in this region, in addition to this, abiotic stress like water, light and nutrient. Weeds have wider adoptability and they can survive in almost each and every stressful situation. In study an effort has been made to study the weed flora common in the cold desert of Ladakh. Some of the common weed flora characterized and gradation was done with respect to their dominancy, population, antioxidant activity and toxicity effect on human and animal health. Total 120 ecotypes selected which were dominant in the region like *convolvulus arvensis,Anagalis arvensis, Tribulus terestris, Rubia cordifolia, Emilia Sanchmilia, M. alba, Chenopodium album, artimisia*, *Amranthus viridis* etc.. In three years of the study, it observed that the manual uprooting of weeds was not effective because it required lot of manpower. It was also observed that such weeds were more efficient in utilizing photoperiod, light intensity, nutrients resulting in faster growth compared to crop plants.



% age pf weed population in Ladakh valley



% age of weed family

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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 1,188 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 to 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 × 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 (1,977.25 kg/ha), straw (5,783.75 kg/ha) and biological yield (7,761 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),

Table 1. Effect of weed control on yield and harvest index of mustard

Treatment	Yield (kg/ha)			Harvest index (%)
	Seed	Straw	Biological	
Weedy check	1,166.75	3,943.00	5,109.75	22.88
One hand weeding 20 DAS	1,655.00	4,894.75	6,549.75	25.27
Two hand weeding 20 and 40 DAS	1,955.25	5,568.25	7,523.50	26.03
Fenoxaprop-p-ethyl 0.075 kg/ha 10 DAS	1,491.00	4,694.75	6,185.75	24.10
Fluazifop-p-butyl 0.055 kg/ha 10 DAS	1,499.25	4,700.50	6,199.75	24.31
Fluazifop-p-butyl 0.055 kg/ha 10 DAS + one hoeing 40 DAS	1,914.00	5,222.25	7,136.25	26.86
Isoproturon 1.25 kg/ha 30 DAS	1,389.50	4,557.00	5,946.50	23.47
Weed free check	1,977.25	5,783.75	7,761.00	25.48
SEm ±	63.26	161.27	158.31	1.08
CD (P=0.05)	183.58	467.95	459.38	NS

phosphorus (25.31 kg/ha) and potassium (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 (₹ 56,337/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 55,225/ha and 2.51.

CONCLUSION

It is concluded that two hand weeding 20 and 40 DAS recorded the highest seed yield of mustard 1,955.25 kg/ha.

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Bioefficacy of bispyribac sodium (10SC) for weed management in direct seeded rice

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Direct seeding of rice is the common process of crop establishment in rainfed lowland ecosystems of eastern India where the crop is dry sown in the month of June just before the onset of monsoon in dry soil some of which are bunded and others are unbunded. 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. As the weeds and rice emerge simultaneously in DSR, the proper time and method of weed control remains a complex phenomenon (Khaliq *et al.*, 2011). Timing of weed emergence and the pressure exerted to the crop through interference are highly correlated so that resultant yield losses are usually higher when weeds emerge earlier or simultaneously with crop. An effective early weed management technology is imperative for any DSR production technology aiming at achieving higher productivity and profitability. The choice of the weed management methods depends upon climatic conditions, soil type, technology available, type of rice culture, the farmer’s

Table 1. Weed dry wight. WCE, Grain yield (t/ha), Straw yield (t/ha), harvest index and weed index as influenced by weed control methods in rice

Treatments	Weed dry weight (g m^2)	WCE (%)	Grain yield (t/ha)	Straw yield (t/ha)	Harvest index (%)	Weed index (%)
T_1 - Bispyribac sodium (10SC) @ 10 g/ha	135.5	46.3	4.1	5.3	43.6	14.5
T_2 - Bispyribac sodium (10SC) @ 20 g/ha	58.2	76.9	4.5	5.2	46.4	6.3
T_3 - Bispyribac sodium (10SC) @ 30 g/ha	34.8	86.2	4.8	5.4	47.1	–
T_4 Bispyribac sodium (10SC) @ 20 g/ha (market)	72.6	71.2	4.3	5.7	43.0	10.4
T_5 - Pretilachlor @ 750 g/ha	82.3	67.4	4.2	5.6	42.9	12.5
T_6 - 2 hand weedings	22.7	91.0	4.0	5.4	42.6	16.7
T_7 - control	252.4	0	2.9	4.4	39.8	39.6
SEm±	6.57	–	0.12	0.23	–	–
CD (P=0.05)	17.62	–	0.34	0.65	–	–

economic situation and yield target, and is evaluated in terms of the cost of weed control in comparison with the estimated value of the resulting yield increase. Manual weeding, although efficient in controlling weeds, has been restricted due to several economical and technological factors. Over the years, chemical weed control in DSR has emerged as promising solution of weed problem and expanded manifold as it is easy, quick, economical and feasible. Several pre-emergence herbicides applied either alone or supplemented with hand weeding have been reported to provide fairly adequate weed suppression in DSR.

Keeping the above facts in view the present field experiment was conducted at the Agronomy main research farm, college of agriculture, OUAT, Bhubaneswar during kharif season of 2014. The soil of the experimental site was sandy loam soil with pH 6.35, available N, P_2O_5 and K_2O 176, 18.46, and 221.27 kg/ha respectively. A randomized block design (RBD) was tested for seven treatments with 3 replications. The plot size was 6 × 4 m^2. Seven treatments included Bispyribac sodium (10SC) at different doses of 10, 20, 30 g/ha and Bispyribac sodium (10SC) (market) @ 20 g/ha. Pretilachlor @ 750 g/ha and control were taken for comparison. Weed density and weed dry weight data were recorded at 60 DAT. Two hand weeding were done to keep the crop weed-free, in the respective treatment. Rice variety pooja was taken as experimental crop. Weed density was recorded with the help of a quadrant (0.5 × 0.5 m^2) placed randomly at two spots in each plot. 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. The most problematic weeds of the experimental plot were *Echinochloa colona*, *E. Crusgalli*, *Digitaria sanguinalis*, *Dactyloctenium aegyptium*, *Leptochloa chinensis*, *Eleusine indica*, *Paspalum distinchum*, *Ischaemum rugos, Trianthema monogyna*, *Commelina benghalensis*, *Caesulia axillaris*, *Sphenoclea zeylaica, Marsila minuta, Ludwigia parviflora.*, *Monochoria vaginalis*, *Cyperus rotundus, Cyperus iria, Fimbristylis milliaceae.*

Yield of DSR varied significantly among various weed control treatments (Table 1). Significantly higher grain yield (4.8 t/ha) was observed in Byspyribac sodium (10SC) @ 30 g/ha which was 65.5% higher than control (2.9 t/ha). The next to it Bispyribac sodium (10SC) @ 20 g/ha recorded with grain yield of 4.5 t/ha (55.2% more than weedy check). Significantly higher yields obtained with these treatments might be due to better weed control and higher weed control efficiency with less weed competition and lesser phytotoxicity injury as well as better growth characteristics. The lowest grain yield (2.9 t/ha) was noticed in weedy check as a consequence of the highest removal of nutrients and moisture by weeds and severe crop weed competition resulting in poor yield.

Bispyribac sodium (10SC) market @ 20 g/ha) recorded significantly higher stover yield (5.7 t/ha). 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. Highest harvest index (47.1%) was recorded in Bispyribac sodium (10SC) @ 30 g/ha followed by Byspyribac sodium (10SC) @ 20 g/ha), i.e. 46.4%. The lowest harvest index was recorded in control (39.8%).Weedy check recorded the highest yield loss of 39.6%. Similar results are also reported by Pathak *et al.* (2011) and khaliq *et al.* (2012).

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Effect of integrated weed management practices on weeds, growth, yield and economics of clusterbean

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Clusterbean commonly known as "Guar" is an important drought hardy leguminous crop which is basically cultivated mostly in the arid and semiarid regions of tropical India during *kharif* season. Clusterbean is mainly cultivated in 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 due to weed infestation is to the tune of 53.7% has been observed (Saxena *et al.,* 2004). Although weeds pose problem during entire crop growth period, however initial one month of the crop is especially critical. Therefore, weed control needs to be restored to exploit the yield potential of this crop. 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 herbicides which may be effective and economically viable.

–A field experiment was conducted on clusterbean during *kharif,* 2013 at the Instructional Farm, Agricultural Research Station, S.K. Rajasthan Agricultural University, Bikaner. The soil of the experimental field was loamy sand in texture, alkaline in reaction (pH 8.22), low in organic carbon (0.08%), available nitrogen (78.0 kg/ha), available phosphorus (22.0 kg/ha) but medium in potassium (210.0 kg/ha). The 16 treatments *i.e.* Weedy check, weed free, pendimethalin 0.75 kg/ha PE, pendimethalin 0.75 kg/ha + hand weeding at 30 DAS, imazethapyr 40 g/ha (25 DAS), imazethapyr 50 g/ha (25 DAS), imazethapyr 60 g/ha (25 DAS), imazethapyr 40 g/ha (25 DAS) + hand weeding at 40 DAS, imazethapyr 50 g/ha (25 DAS) + hand weeding at 40 DAS, imazethapyr 60 g/ha (25 DAS) + hand weeding at 40 DAS, imazethapyr + imazamox 40 g/ha (25 DAS), imazethapyr + imazamox 60 g/ha (25 DAS), imazethapyr + imazamox 80 g ha^{-1} (25 DAS), imazethapyr + imazamox 40 g ha^{-1} (25 DAS) + hand weeding at 40 DAS, imazethapyr + imazamox 60 g ha^{-1} (25 DAS) + hand weeding at 40 DAS and imazethapyr + imazamox 80 g ha^{-1} (25 DAS) +hand weeding at 40 DAS were laid out in randomized block design and replicated thrice. The recommended dose of 20 kg N and 40 kg P_2O_5 was applied to the crop.

In experimental field clusterbean was heavily infested with mixed flora of broad leaved and grassy weeds chiefly consisted of *Amaranthus spinosus* L., *Euphorbia hirta* L., *Aristida depressa* L., *Portulaca oleracea* L., *Digera arvensis* Forsk., *Gisekia poiedious, Cenchrus biflorus* L., *Tribulus terrestris* L., *Aerva tomentosa* Forsk., *Corchorus tridense* L., *Eleusine verticillata* L., *Eragrostis tennela* and *Trianthema portulacastrum* L.

All the weed control treatments significantly reduced weed density and dry weight of broad leaved, grassy and total weeds at 60 DAS over weedy check (Table 1). The minimum dry weight of broad leaved, grassy and total weeds was recorded under weed free treatment followed by pendimethalin, imazethapyr and imazethapyr + imazamox. At 60 DAS, maximum weed control efficiency was observed with weed free treatment (100%) followed by pendimethalin 0.75 kg/ha alone. Among the herbicides the lowest weed control efficiency was recorded with application of imazethapyr 40 g/ha. The lowest weed index was recorded under pendimethalin 0.75 kg/ha + hand weeding 30 DAS. The effectivity of this treatment was due to the fact that weed free treatment controlled the early as well as late flushes of weeds up to the most critical stage of crop weed competition. Hand weedings twice removed the weeds completely and created condition which were more favourable for crop growth and ultimately resulted in lowest density of later emerged weeds and their lowest biomass with higher weed control efficiency during the crop growth period. The results of study also corroborate with the findings of Punia *et al.* (2011), Sangeetha *et al.* (2013) and Singh *et al.* (2014).

All weed management practices adopted during the experimentation resulted in significant increase in growth parameters (Table 2) like plant height and dry matter production of clusterbean at harvest compared to weedy check. In general, the aforesaid improvements seems to be on account of their direct impact through least crop-weed competition whereas indirect effect might be on account of least competition for plant growth inputs, viz., light, space, water, nutrients etc. Similarly, under reduced density and dry weight of weeds, crop plant get sufficient space for optimum growth as early as possible (Gupta *et al.*, 1990). The yield

Table 1. Effect of weed control measures on weed density, weed dry weight and weed control efficiency at 60 DAS and weed index in clusterbean

Treatment	Weed density (no./m^2)			Weed dry weight (g/m^2)			Weed conterol effeciency (%)	Weed index (%)
	Broad leaved	Broad leaved	Broad leaved	Broad leaved	Grassy	Total		
Weedy check(W_1)	9.63(92.29)	9.63(92.29)	9.63(92.29)	90.90	12.34	103.24	0.00	48.35
Weed free(W_2)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.00	0.00	0.00	100.00	0.00
Pendimethalin 0.75 kg/ha PE(W_3)	2.59(6.20)	2.59(6.20)	2.59(6.20)	6.64	0.04	6.68	99.62	3.03
W_3 + HW 30 DAS(W_4)	1.00(0.51)	1.00(0.51)	1.00(0.51)	0.56	0.01	0.57	95.38	2.69
Imazethapyr 40 g/ha 25 DAS(W_5)	4.12(16.47)	4.12(16.47)	4.12(16.47)	18.11	5.19	23.30	75.38	11.12
Imazethapyr 50 g/ha 25 DAS(W_6)	3.99(15.45)	3.99(15.45)	3.99(15.45)	17.50	5.03	22.53	76.87	10.54
Imazethapyr 60 g/ha 25 DAS(W_7)	3.89(14.64)	3.89(14.64)	3.89(14.64)	17.41	5.08	22.49	77.93	10.24
W_5 + HW 40 DAS(W_8)	1.59(2.03)	1.59(2.03)	1.59(2.03)	2.28	0.51	2.79	97.35	7.87
W_6 + HW 40 DAS(W_9)	1.41(1.47)	1.41(1.47)	1.41(1.47)	1.70	0.31	2.01	98.20	7.13
W_7 + HW 40 DAS(W_{10})	1.22(0.98)	1.22(0.98)	1.22(0.98)	1.19	0.20	1.39	98.85	6.59
Imazethapyr+Imazamox 40 g ha^{-1} 25 DAS (W_{11})	3.72(13.37)	3.72(13.37)	3.72(13.37)	23.44	0.94	24.38	87.73	8.96
Imazethapyr+Imazamox 60 g ha^{-1} 25 DAS (W_{12})	3.60(12.48)	3.60(12.48)	3.60(12.48)	22.93	0.94	23.87	88.42	8.73
Imazethapyr+Imazamox 80 g ha^{-1} 25 DAS (W_{13})	3.58(12.29)	3.58(12.29)	3.58(12.29)	23.30	0.96	24.26	88.67	8.54
W_{11} + HW 40 DAS(W_{14})	1.41(1.47)	1.41(1.47)	1.41(1.47)	2.64	0.28	2.92	98.20	5.58
W_{12} + HW 40 DAS(W_{15})	1.26(1.08)	1.26(1.08)	1.26(1.08)	1.99	0.15	2.14	98.85	5.16
W_{13} + HW 40 DAS(W_{16})	1.00(0.49)	1.00(0.49)	1.00(0.49)	0.95	0.06	1.01	99.49	4.64
SEm±	0.40	0.40	0.40	2.13	0.24	1.90	–	–
CD (P=0.05)	1.17	1.17	1.17	6.15	0.71	5.51	–	–

HW= Hand weeding DAS=Day after sowing Figures in parenthesis are original values Transformed values $\sqrt{(x + 0.5)}$

Table 2. Effect of weed control measures on growth, yield parameters, yields and economics of clusterbean

Treatment	Plant height (cm)	Chlorophyll content at 60 DAS (mg/g)	Dry matter accumulation (gm row length)	Pods/ plant (No.)	Seeds/ pod (No.)	Seed yield (kg/ha)	Straw yield (kg/ha)	Biological yield (kg/ha)	Net returns (₹/ha)	Benefit: cost ratio
Weedy check (W_1)	71.3	1.47	89.5	28.7	2.65	767	2,183	2,950.0	21,527	2.28
Weed free (W_2)	115.0	2.29	170.5	40.2	3.72	1,485	4,140	5,625.4	54,608	3.81
Pendimethalin 0.75 kg/ha PE (W_3)	112.5	2.24	164.1	38.0	3.67	1,440	3,973	5,413.1	53,277	3.88
W_3 + HW 30 DAS (W_4)	112.7	2.24	167.3	38.7	3.68	1,445	4,070	5,515.3	52,347	3.64
Imazethapyr 40 g/ha 25 DAS (W_5)	85.1	1.70	149.3	36.7	3.47	1,319	3,604	4,924.6	47,226	3.56
Imazethapyr 50 g/ha 25 DAS (W_6)	85.6	1.71	154.4	38.7	3.37	1,328	3,761	5,090.0	47,890	3.59
Imazethapyr 60 g/ha 25 DAS (W_7)	86.0	1.72	153.6	38.8	3.31	1,333	3,735	5,068.4	48,049	3.60
W_5 + HW 40 DAS (W_8)	86.6	1.73	156.5	39.5	3.38	1,368	3,794	5,163.0	48,407	3.44
W_6 + HW 40 DAS (W_9)	87.1	1.75	155.4	39.8	3.42	1,379	3,747	5,126.8	48,818	3.47
W_7 + HW 40 DAS (W_{10})	87.5	1.75	157.5	39.1	3.50	1,387	3,808	5,195.5	49,287	3.49
Imazethapyr + Imazamox 40 g/ha 25 DAS (W_{11})	93.4	1.87	155.8	39.4	3.37	1,352	3,788	5,140.6	48,997	3.65
Imazethapyr + Imazamox 60 g/ha 25 DAS (W_{12})	93.9	1.88	153.3	40.0	3.34	1355	3,701	5,057.0	48,995	3.65
Imazethapyr+Imazamox 80 g/ha 25 DAS (W_{13})	94.4	1.89	155.5	38.7	3.38	1358	3,766	5,124.9	49,235	3.67
W_{11} + HW 40 DAS (W_{14})	93.8	1.88	158.0	39.1	3.54	1402	3,810	5,212.6	49,964	3.52
W_{12} + HW 40 DAS (W_{15})	94.3	1.89	161.7	40.0	3.55	1408	3,926	5,334.4	50,444	3.55
W_{13} + HW 40 DAS (W_{16})	94.9	1.90	161.4	39.0	3.52	1416	3,907	5,323.6	50,761	3.56
SEm±	6.46	0.10	10.38	1.83	0.06	96.93	223.90	248.44	4,399.44	0.23
CD (P=0.05)	18.67	0.28	29.98	5.30	0.17	279.97	646.67	717.55	12,707	0.66

attributing characters, viz. pods/plant and seeds/pod were significantly improved under various weed control treatments as compared to weedy check and the effect was more pronounced with weed free treatment closely followed by rest of the weed control treatments. Thus, reduced crop-weed competition resulted into overall improvement in crop growth as reflected by plant height, chlorophyll content and dry matter accumulation consequently resulted into better development of reproductive structure and translocation of photosynthates to the sink. The results corroborate with the findings of Kumar *et al.* (2003). It is evident from results that superiority of weed free treatment over all weed control methods significantly enhanced yield components, viz. pods/plant and seed/pods with concomitant increased in seed, straw and biological yield. The reduced crop weed competition caused significant increase in growth characters and yield ultimately led to higher seed yield of clusterbean.

The maximum net returns of ₹ 54,608/ha was obtained with weed free treatment followed by ₹ 53,277/ha with pendimethalin 0.75 kg/ha alone. As far as maximum benefit: cost ratio was also obtained with pendimethalin 0.75 kg/ha alone (3.88) followed by weed free treatment (3.81) over weedy check.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Long term tillage and weed management methods in maize-sunflower cropping system under irrigated ecosystem

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Tillage system and crop rotation have significant long-term effects on soil productivity and on weed management practices. Tillage practices combined with effective weed control method is to be identified for efficient weed management. Hence, a long term field experiment to assess the influence of tillage and weed management methods in maize-sunflower cropping system was conducted with the objective to evaluate different tillage and weed management methods on weed diversity, productivity and profitability of maize-sunflower cropping system.

METHODOLOGY

Long term tillage experiment was conducted with maize–sunflower cropping system in black clay soils under irrigated conditions from *kharif* 2010 to *rabi* 2014–15 at the Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore. Field trial with the following tillage and weed management methods was laid out in split plot design with three replication.

Treatments

Main plot (Tillage methods)

Maize (*kharif*)	Sunflower (*rabi*)
T_1 - Zero tillage	Zero tillage
T_2 - Zero tillage	Conventional tillage
T_3 - Conventional tillage	Zero tillage
T_4 - Conventional tillage	Conventional tillage

Sub plot (Weed management methods)

W_1 - Hand weeding (HW) on 25 and 45 DAS	HW on 25 and 45 DAS
W_2 - Atrazine 0.5 kg/ha + HW on 45 DAS	Pendimethalin 1.0 kg/ha + HW on 45 DAS
W_3 - Unweeded check	Unweeded check

RESULTS

Significantly lower total weed density was recorded in conventional tillage in CT-CT system. PE atrazine at 0.5 kg/ha + HW on 45 DAS recorded lower weed density and it was followed by HW on 25 and 45 DAS in maize at 60 DAS. Lower weed dry weight was recorded in conventional tillage in CT-CT system and PE atrazine 0.5 kg/ha + HW on 45 DAS. In sunflower, conventional tillage and PE pendimethalin 1.0 kg/ha + HW on 45 DAS recorded significantly lower weed density at 60 DAS as earlier reported by Baskaran and Kavimani (2014). Conventional tillage in CT-CT system registered lower weed dry weight when compared to zero tillage in ZT-ZT system. Similarly, PE pendimethalin 1 kg/ha + HW on 45 DAS (W_2) recorded considerably lower weed dry weight. Higher weed control efficiency was recorded in conventional tillage in CT-CT system. PE atrazine at 0.5 kg/ha+ HW on 45 DAS recorded higher weed control efficiency in maize. Similarly, in sunflower, higher weed control efficiency was obtained in conventional tillage in CT-CT system and PE pendimethalin 1 kg/ha + HW on 45 DAS (W_2) recorded higher weed control efficiency. Conventional tillage method in CT-CT system recorded significantly higher (5,098 kg/ha) grain yield of maize. Higher grain yield was recorded in atrazine at 0.5 kg/ha + HW on 45 DAS with 5187 kg/ha. Conventional tillage in CT-CT system recorded considerably higher seed yield (3,061 kg/ha) of sunflower. PE pendimethalin 1 kg/ha + HW on 45 DAS recorded significantly higher seed yield of 3,533 kg/ha. Baskaran and Kavimani (2014a) reported higher productivity of maize-sunflower cropping system with integrated weed management methods. Higher net return (₹ 35,546/ha) and B : C ratio of 2.39 was recorded in conventional tillage in CT-CT system. Higher net return of ₹ 34,974/ha and B : C ratio (2.28) was recorded in PE atrazine at 0.5 kg/ha + HW on 45 DAS in maize. Conventional tillage in CT-CT system recorded higher net return (₹ 22,250/ha) and B : C ratio of 2.07. Higher net return of ₹ 17,150/ha and B : C ratio (1.75) was recorded in PE pendimethalin1.0 kg/ha + HW on 45 DAS (W_2).

CONCLUSION

Lower density and dry weight of weeds and higher weed control efficiency with higher yields and economic returns were recorded in CT-CT (both in maize and sunflower) and with the application of atrazine 0.5 kg/ha for maize and pendimethalin 1 kg/ha for sunflower + HW on 45 DAS.

Table 2. Tillage and weed management methods on weed control efficiency and yield in maize-sunflower cropping system (mean of five years)

Treatments	Weed control efficiency (%) at 60 DAS		Grain yield (kg/ha)	
	Maize	Sunflower	Maize	Sunflower
Tillage methods				
T_1 (ZT-ZT)	59.10	45.98	4,113	2,760
T_2 (ZT-CT)	62.13	67.90	4,315	2,977
T_3 (CT-ZT)	73.38	64.13	4,875	2,411
T_4 (CT-CT)	77.02	74.34	5,098	3,061
SEm	–	–	217	126
CD(P=0.05)	–	–	496	252
Weed management methods				
W_1 (HW Twice)	59.10	70.85	5,013	3,438
W_2 (Herbicide)	62.13	78.40	5,187	3,533
W_3 (Unweeded check)	–	–	3,050	2,618
SEm	–	–	232	143
CD (P=0.05)	–	–	516	287

Table 1. Tillage and weed management methods on weed density and weed dry weight in maize-sunflower cropping system (mean of five years)

Treatments	Weed density (No./m^2) at 60 DAS		Weed dry weight (g/m^2) at 60 DAS	
	Maize	Sunflower	Maize	Sunflower
Tillage methods				
T_1 (ZT-ZT)	6.14 (35.65)	8.23 (65.67)	4.73 (20.36)	5.76 (31.27)
T_2 (ZT-CT)	5.75 (31.06)	6.51 (40.33)	4.57 (18.85)	4.53 (18.58)
T_3 (CT-ZT)	5.15 (24.57)	7.19 (49.67)	3.91 (13.25)	4.77 (20.76)
T_4 (CT-CT)	4.34 (16.8)	5.57 (29.00)	3.67 (11.44)	4.10 (14.85)
SEm	0.14	0.27	0.18	0.18
CD(P=0.05)	0.29	1.07	0.35	0.38
Weed management methods				
W_1 (HW Twice)	5.10 (24.03)	7.37 (52.33)	4.73 (20.38)	4.34 (16.87)
W_2 (Herbicide)	4.63 (19.48)	4.97 (22.67)	4.41 (17.46)	3.80 (12.50)
W_3 (Unweeded check)	5.85 (32.25)	14.07 (196.00)	7.20 (49.78)	7.73 (57.89)
SEm	0.17	0.33	0.19	0.21
CD (P=0.05)	0.36	0.68	0.42	0.44

Square root transformed values; Figures in parenthesis are original values

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

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 and 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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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Temperature extremes: Impact on wheat over a sub-humid climatic environment of Bihar, India: A simulation study

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Climate change is expected to increase the frequency of extreme heat events (IPCC, 2014) and observations already confirms their increasing trends in many parts of the world (Mishra *et al*., 2015). Extreme events are expected to effect the volatility of yields and are seen as the principle immediate threat to global crop production (Lobell *et al*., 2013). However, there has been little research conducted in India to quantify the impact of heat wave shocks on crop production. Bihar has been traditionally vulnerable to natural disasters on account of its unique geo-climatic conditions. Floods, droughts, cyclones, earthquakes, landslides, fire incidents, heat and cold waves have been recurrent phenomena. The purpose of this study was to analyze the trends, variability in temperature and to determine the frequency and magnitude of temperature extremes (heat waves) for anticipating and calculating their effects on wheat crop phenology and yield which will help to develop adaptation strategies to offset these impacts.

METHODOLOGY

Bihar (24°N and 27°N, 82°E and 88°E) lies in the alluvial plains of India covering a total area of 94,163 km^2 lying at an average altitude of 52.73 m above sea level. In this study, long term weather data (1969–2014) of Sabour in Bhagalpur district (Zone IIIA) obtained from National Data Center, Pune was used in analysis to determinethe trends and variability in temperature. Frequency and magnitude of temperature extremes (heat and severe heat waves) were also determined used the criteria provided by the India Meteorological Department (IMD, 2002).CERES-Wheat model (DSSAT v4.6) was calibrated and validated usingfield experimental data of seven years (2008–2014), of wheat var. HD 2733, (sowing range 15–24 November) conducted at theResearch Farm (wheat section), Bihar Agricultural University, Sabour, Bhagalpur, Bihar. After calibration and validation of model, sensitivity analysis was performed to quantify the impact of extreme maximum temperature on wheat. Several criteria like root mean squared error (RMSE), Model efficiency (ME), D-index, (an index of agreement) were used for cross-comparisons between model runs for better model performance. Moreover, linear regression was also applied between simulations and observations to evaluate model performance.

RESULTS

The trend analysis exhibited quite good variation over the time (year) and reveals thatin period of 45 years, the region has experienced 251 number of heat events (including severe heat events). Although the region on an average is experiencing ≥8 heat wave days per hot weather season (March–June) but, these heat wave episodes have been observed to decrease at the rate of 0.15/year. The decreasing

Table 1. Impact of heat waves stress at different crop growth stages on phonology and yield of wheat var. HD 2733 using CERES-wheat (DSSAT v4.6 model)

Treatment	Crop growth stages					
	Booting-Anthesis			Anthesis-Milk		
	Days to anthesis	Days to physiological maturity	Yield (kg/ha)	Days to anthesis	Days to physiological maturity	Yield (kg/ha)
Normal(No heat stress	92.33	124.00	4926	92.33	124.0	4,926
Temperature increased by 5°C	89.00	118.82	3840	91.00	117.0	3,690
Deviation from normal(Days/Percent)	–3.33	–5.18	–22.04	–1.33	–7.00	–25.09
Temperature increased by 7°C	87.33	116.00	3,660	90.00	115.0	3,495
Deviation from normal(Days/Percent)	–5.00	–8.00	–25.70	–2.33	–9.00	–29.05
D-index (An index of agreement)	0.87 (Over 7 years of simulation)					

trend was significant at 95% level of confidence. The different growth and development stages of wheat cultivar (HD 2733) occurred earlier and was deleterious in extreme temperature induced treatments compared to ambient conditions (Table 1). Under normal field conditions, days taken to anthesis and physiological maturity were recorded to be 92.33 and 124 days (average over 7 years) respectively.On exposing the crop to high temperature heat stress (+5°C and +7°C) at booting to anthesis stage, the days taken for attaining these phenological stages were significantly reduced to 89 and 87.33 days (for anthesis) and 89.0 and 87.33 days (for physiological maturity) respectively. However, the magnitude of stress was more pounced on physiological maturity in treatments receiving heat stress at anthesis to milk stage. The days taken to physiological maturity were observed to be 117 days at +5°C and 115 days at +7°C over normal. Owing to higher temperature stress, the final yield reduction was observed to be 25.09 and 29.05 per cent at temperature of +5°C and +7°C respectively, which can be attributed to increased the rate of grain filling and reduced the grain filling duration.

CONCLUSION

The elevated temperature (heat stress) on wheat affects the crop duration by attaining the phonological stages earlier with low accumulated growing degree days. This reduction in grain yield may be due to the direct effect of temperature wheat development especially high temperature at flowering stage leading to spikelet sterility and, therefore, yield loss. Adjustment of planting dates to avoid heat stress during flowering and maturity of crop can be the viable option and some of candidate genotypes like Sabour Shrestha, DWB 107 and DWB 14 has also been tested and were found effective in mitigating higher temperature stress in the study region.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Sesbania brown manuring effects on weeds infestation and performance of dry-DSR as compared to farmers' practice and chemical control method

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Rice is the most important leading cereal crop of the world, and more than half of the world's population depends on rice for their daily sustenance (Chauhan and Johnson, 2011). Various types of changes are being occurred for the rice production system and the shifting from transplanted to direct seeding is one out of those. It is suggested that alternate method of planting, i.e. Dry-DSR is gaining popularity regarding its high water use, labor use and energy use efficiencies. The effective weed management is a major challenge for farmers when adopting dry DSR because of weed flora shifts toward more difficult-to-control and competitive grasses and sedges. Higher weed infestation is a major problem in dry-DSR causing major loss to rice production worldwide. *Sesbania* followed by 2, 4-D was more effective in suppressing broad leaves and sedges and less effective on grasses (Kumar and Ladha, 2011). It helps in adding about 15 kg N/ha along with smothering of weeds and conserving moisture (Gaire *et al.*, 2013). Thus, the major part is to evaluate its effect on weeds and on the performance of dry direct seeded rice through this experiment.

METHODOLOGY

The experiment was carried out at Agronomy Farm of Agriculture and Forestry University (AFU), Rampur, Chitwan. The site is located 9.8 km South-West from Bharatpur, headquarter of Chitwan district. This location is

Table 1. Grain yield (kg/ha), straw yield (kg/ha), above ground biomass (kg/ha) and harvest index as influenced by the different weed management practices at Agronomy Farm, AFU Rampur, Chitwan, Nepal

Treatment	Grain yield	Straw yield	AGBM	HI
2 hand weeding	4,112.16[a]	6,502.44[a]	10,038.90[a]	0.35
Chemical practice	2,929.60[b]	5,997.76[a]	8,230.67[b]	0.27
*Sesbania*co-culture	4,309.13[a]	5,498.59[a]	9,204.43[ab]	0.40
Weed free	4,823.27[a]	6,764.17[a]	10,654.18[a]	0.37
Weedy check	440.96[c]	999.47[b]	1,378.70[c]	0.76
SEm ±	282.20	534.6	465.5	0.29
LSD (P=0.05)	889.2	1,684.6	1,466.9	Ns

situated at 27° 37′ N latitude and 84° 25′ E longitude with the elevation of 256 m above mean sea level (Thapa and Dangol, 1988). Rice variety 'US-312' via line sowing and seed of *Sesbania rostrata* via broadcasting were sown together manually on 7th of June, 2014. The soil of experimental plot was sandy loam which had medium type of total N (0.2%), available P (46.62 kg/ha) and organic carbon (1.9%) but low in available K (82.8 kg/ha). Five treatments were tested in Complete Randomized Block Design and replicated three times. The treatments were Farmers' practice (2 hand weeding first at 28 DAS and another at 40 DAS), Chemical practice (Bispyribac sodium as post emergence @ 25 g a.i./ha at 25 DAS), *Sesbania* co-culture (100 kg *Sesbania*/ha and knocking down at 28 DAS), Weed free (hand removal of weeds at 10 days' interval), and Weedy check (No weed management). Each 20 m^2 plot had 20 rows of 5 m length, with an inter-row spacing of 0.2 m. The fertilizer was applied in the form of urea, di-ammonium phosphate (DAP), and murate of potash (MOP) whereas the recommended dose of NPK in each experimental plot was 150:80:80 kg/ha. One third of nitrogen, full dose of phosphorus and potash were applied as basal dose at final land preparation. Remaining two third dose of Nitrogen was applied at tillering stage and panicle initiation stage in equal split. Zinc sulphate @ 25 kg/ha was also applied at final land preparation for correction of zinc deficiency in soil.

RESULTS

The major weeds infesting in dry DSR during experiment were *Cynodon dactylon, Echinochloa colana, Setariaglauca, Paspalum scrobiculatum, Para grass, Melochia corchorifolia, Cyperus iria, Fimbristylis miliaceae,* etc. The mean weed index was 24.57% during the experiment and was recorded significant effect of all the weed management practices on weed index. The weed index ranged from lowest (7.27%) in *Sesbania* co-culture to highest (90.55%) in weedy check. The weed index in weed free plot was zero because the weeds were completely removed at each 10 days' interval. Weedy check produced higher weed index as compared to other treatments due to presence of invasive number of weeds as never removed from the plot. *Sesbania* co-culture had lower weed index in comparison of both the farmers' practice and post emergence application of bispyribac sodium @ 25 g a.i./ha. The fast growing *Sesbania* suppress the population of weed species at early growth stage which causes lower weed population in co-cultured plot. The highest grain yield (4,823.27 kg/ha) was observed in weed free plot as compared to other treatments and statistically similar with the yield of 2 hand weeding and *Sesbania* co-culture. The lower yield (440.96 kg/ha) in weedy check might be due to competition from weeds which reduced LAI and allowed less light transmission producing less biosynthate and ultimately low dry matter production. The co-culture of rice and *Sesbania* had produced significantly more grain yield as compared to bispyribac sodium @ 25 g a.i./ha and weedy check. Similarly, the straw yield was found highest (6,764.17 kg/ha) with weed free plot as statistically similar with all other treatments except weedy check. The above ground biomass on *Sesbania* co-culture treatment was found statistically similar with the 2 hand weeding and weed free plot and also with the application of bispyribac sodium @ 25 g a.i./ha. There were not significant differences among the weed management treatments to the harvesting index.

CONCLUSION

From the co-culture experiment of dry-DSR and *Sesbania*, was found better than that of the farmer's practice and chemical control practice for achieving higher yield and weed control.

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Symposium 6

Efficient Soil, Water and Energy Management

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Yield attributesand yield of soybean as influenced by antitranspirants and mulches

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Soybean [*Glycine max* (L.) Merrill] is considered as the most important food grain legumes in the world utilize mainly for oil production. It is cheapest and richest source of high quality protein (40–42% protein). In recent years it has become largest oilseed crop in India, with a productivity of 13.5 q/ha. Lack of moisture during reproductive stage is one of the factors that limit the growth of soybean. If availability of moisture is not enough or transpiration rate is high the plant will experience drought. In India soybean is largely grown as rainfed crop and due to reduced soil moisture availability during pod filling and seed development stage crop suffers from water stress resulting in fewer and smaller grain. Stage of plant growth and duration of drought stress are important for the degree of the impact on growth and final yield of soybean (Valimohammadi *et al.,* 2014). The loss in yield can be reduced by adopting soil moisture conservation techniques. Therefore adoption of mulches helps in reducing water loss from soil. Similarly requirement of water during reproductive phase can be largely reduced by using antitranspirant. Use of antitranspirant increases water stress use efficiency by reducing frequency of irrigation. Film forming type antitranspirants like glycerol and stomatal closing types like $MgCO_3$, Na_2CO_3 have resulted in increase in yield attributing characters and yield (Valimohammadi *et al.,* 2014). Hence the study was carried out to find the influence of antitranspirants and mulches on growth and yield of soybean.

METHODOLOGY

A field experiment was carried out at the Crop research Centre of Govind Ballabh Pant University of Agriculture and Technology, Pantnagar during *kharif* 2014. The experimental soil belong to Haldi series (coarse loamy, mixed, thermic, Typic Hapludolls) and showed silty clay loam texture, 0.54 per cent in organic carbon, 0.066 per cent total nitrogen, 21.2 kg P_2O_5 per ha available phosphorus, 160.6kg K_2O per ha available potassium with pH of 7.2. The experiment was conducted in Factorial randomized block design (FRBD), with treatment combination of mulch@ 5 tonnes/ha and without mulch and having five sub treatments with three replications. The five sub treatments consisted of different antitranspirants Mg CO_3 @ 5 per cent, Glycerol @ 5 per cent, Na_2CO_3 @ 2 per cent, KNO_3 @ 1 per cent and control (water spray). Wheat straw was used as mulch material and spraying of antitranspirants was done after 60 days of sowing. Soybean variety PS-1347 was inoculated with *Bradyrhizobium japonicum* culture before sowing. The observations on yield attributes were taken on randomly selected five plants from each treatments. The data collected for different parameters were statistically analysed using the F-test as per procedure given by Gomez and Gomez (1984) for factorial randomized block design. The results are presented at 5 percent level of significance (P=0.05) for making comparison between treatments.

RESULTS

Application of mulch did not differ significantly with respect to pods per plant and seed index, while seed yield, straw yield and harvest index were significantly influenced by application of mulch. Mulch application resulted in 16.8 per cent higher seed yield as compared to control treatment, this could be due to moisture conservation by mulch, similar findings were also reported by Patil *et al.*, 2010. Application of mulch also resulted in significantly higher harvest index over control treatment.

Different antitranspirant treatments did not differ significantly among themselves with respect to pods per plant, but treatments Mg CO_3 @ 5 per cent and Glycerol @ 5 per cent recorded significantly lower number of pods plant when compared to control treatment. Application of antitranspirant did not significantly influenced seed index. Treatment Mg CO_3 @ 5 per cent being at par with control recorded significantly higher seed yield over other antitranspirant treatments, viz. Glycerol @ 5 per cent -2, Na_2CO_3 @ 2 per cent, KNO_3 @ 1 per cent and control (water spray). Significantly lowest seed yield was recorded due to Glycerol @ 5 per cent treatment when compared to all other treatments. Highest straw yield was recorded with Glycerol @ 5 per cent treatment and it being at par with Mg CO_3 @ 5 per cent recorded significantly higher straw yield over other treatments. Highest harvest index was recorded with Na_2CO_3 @ 2 per cent treatment and it being at par with Mg CO_3 @ 5 per cent and control (water spray) treatments recorded significantly higher harvest

Table 1. Influence of mulch and different antitranspirant treatments on yield attributing characters yield and B:C ratio of soybean

Treatments	Pods/plant	Seed index (g/100 seeds)	Seed yield (kg/ha)	Straw yield (kg/ha)	Harvest index (%)	B:C ratio
Mulch						
Mulch @ 5 t/ha	21.34	9.56	1511	3779	28.5	1.17
Control	20.10	9.41	1293	3569	26.6	1.07
SEm	0.646	0.12	32.1	66.8	0.41	-
CD (P=0.05)	NS	NS	92.6	95.6	1.29	-
Anti-transpirants						
Mg CO_3 @ 5 per cent	20.0	9.09	1555	3822	28.9	1.31
Glycerol @ 5 per cent	19.0	9.96	1172	3834	23.4	0.90
Na_2CO_3 @ 2 per cent	21.2	9.40	1407	3222	30.4	1.22
KNO_3 @ 1 per cent	21.2	9.30	1395	3555	28.2	1.18
Control (water spray)	23.7	10.06	1479	3464	29.9	1.34
SEm	1.02	0.42	46.4	63.7	0.63	–
CD (P=0.05)	3.13	NS	141.7	163.6	1.91	–

index over remaining antitranspirant treatments. Highest benefit: cost (B: C) ratio was recorded with control treatment and lowest B:C ratio was recorded in Glycerol @ 5 per cent treatment.

CONCLUSION

Application of mulch helped in moisture conservation leading to higher seed yield. Among antitranspirant application of 5 per cent $MgCO_3$ at 60 days after planting stage resulted in higher seed yield over other antitranspirant treatments.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Impact of hydrogel in wheat 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. 400–1,500 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 and 2014–15 at 15 sites on hydrogel was conducted at the farmers' fields of sandy soils of district Bhiwani (Haryana) where pearlmillet–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 4,980 kg/ha and net return of ₹ 39,995 than normal irrigations (4,730 kg/ha and ₹ 36,680) and was followed by limited irrigations (Four) (4,530 kg/ha and ₹ 32,600) 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.

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

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

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

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.

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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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Quantification of soil enzymes under different irrigation schedules and nutrient managements in different wheat varieties

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Wheat is one of the most important cereal crops grown in the Indo-Gangetic plains and central India. India, today is, the second largest wheat-producing country in the world. The continuing plateau of wheat production since it reached as high as 93.51 million tonnes in 2012–13. Agricultural practices that improve soil quality and agricultural sustainability have been receiving more attention from researchers and farmers researchers and farmers. Microorganisms are the main source of enzymes in soils (Tabatabai, 1994), and thus the composition of the soil microbial communities strongly affects the potential of a soil for enzyme-mediated substrate catalysis. Soil enzymes (intracellular and extracellular) are the mediators and catalysts of biochemical processes important in soil functioning such as nutrient mineralization and cycling, decomposition and formation of soil organic matter and decomposition of xenobiotics (i.e. pesticides). Keeping, above fact the research was taken in this area.

METHODOLOGY

A field experiments was conducted during the winter seasons (*rabi*) of 2011–12 and 2012–13 at the Research Farm, Division of Agronomy, Indian Agricultural Research Institute, New Delhi. The experiment was laid out in split-plot design with 3 replications. Main plot consisted of 2 nutrient levels, viz. 100% recommended dose of fertilizer (RDF) and 50% RDF + 50% recommended dose of nitrogen (RDN) through FYM, and 3 levels of irrigation, viz. 1 irrigation at crown root imitation (CRI), 2 irrigation at CRI and flowering and irrigation at all critical stages of crop (CRI, tillering, jointing, flowering and grain filling stage). Sub-plot treatments consisted of 4 varieties, viz. 'HD 2967', 'WR 544', 'HD 2987' and 'HD 2329'. The recommended doses of fertilizers, i.e. 120 : 60 : 40 N, P_2O_5 and K_2O kg/ha was applied to wheat as per the treatment. Dehydrogenase enzyme was estimated by method of Klein *et al*. (1971), acid phosphatase and alkaline phosphatase activity were determined calorimetrically by a visible spectrophotometer using the method as outlined by Tabatabai and Bremner (1969) and Soil microbial biomass C was determined by a chloroform fumigation–extraction method (Vance *et al*., 1987). The farmyard manure (FYM) was applied a week before sowing as per treatment. The FYM contains 0.5% N, 0.2% available P_2O_5 and 0.5% of available K_2O. The N, P and K doses adjusted by subtracting nutrient supply by FYM and remaining N, P and K were compensated in the form of urea, diammonium phosphate and muriate of potash respectively.

RESULTS

Significantly higher dehydrogenase, acid phosphatase, alkaline phosphatase and microbial biomass carbon activities were recorded from one irrigation at CRI stage than other irrigation schedules during both the years due to higher root length and volume that favours higher rhizoplane for the growth of microorganism. Similarly, Mavrodi *et al.* (2012) has reported the abundant Phz-*Pseudomonas* spp. under non-irrigated areas adjacent to the sampled dry land wheat fields. Freeman *et al.* (1996) reported that microbial activity and enzymatic decomposition processes increased when water table drawdown. Among nutrient levels, 50% RDF+50% RDN through FYM gave significantly higher dehydrogenase, acid phosphatase, alkaline phosphatase and microbial biomass carbon than 100% RDF during both years, It might be due to priming effect of FYM that increases the higher organic carbon in soil that facilitate the growth of microorganism in soil. Organic carbon acts as source of energy for the bacterial growth. The increased microbial biomass and activity due to organic manure fertilization may be derived from the increased root biomass which provided organic matter for microorganisms. The organic manure itself could provide abounding organic matter for the growth of microorganisms (Timmusk and Behera, 2012). Significantly higher dehydrogenase, acid phosphatase, alkaline phosphatase and microbial biomass carbon activity was recorded from HD 2987 than other varieties during both years. This variety having ability to resist adverse conditions by altering the root: shoot ratio might be a reason for providing high root surface area for growth and development of microorganism. The bacteria may secrete some volatile compound and enzymes under adverse conditions might be a reason for higher soil enzymes (Kim *et. al.* 2003)

Among different combinations of irrigation schedules and varieties significantly higher dehydrogenase, acid phosphatase, alkaline phosphatase and microbial biomass carbon activity was recorded from 'HD 2967' and applied with one irrigation at CRI stages than other combinations during first year. Significantly higher dehydrogenase, acid phosphatase, alkaline phosphatase and microbial biomass carbon activity was recorded when HD 2987 irrigated twice at CRI and at flowering stage or irrigated once at CRI stage during second year this might be due to higher root length, volume and dry weight of HD 2967 during first year and variety HD 2987 during second leads higher enzymes due to their larger rhizoplane and root surface area.

CONCLUSION

On the basis of this experiment we can conclude that the single applied irrigation at CRI stage shown highest amount of soil enzymes. Application of FYM as integrated nutrient approach, 50% RDF+50% RDN through FYM applied are able to maintain high soil enzymes as compared to 100% RDF.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

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 levels 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 (1,122, 1,152 and 1,137 kg/ha, respectively) and stover (1,960, 1,838 and 1,899 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

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		

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 ₹ 41,513/ha with BCR of 2.24 and lowest net realization of ₹ 35,442/ha with BCR of 1.94 was obtained under flatbed sowing treatment. The data further revealed that the maximum net realization of ₹ 41,725/ha with BCR of 2.21 were obtained in treatment two irrigations at branching and pod development stages.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Root architecture of groundnut 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 : 75 kg NPK/ha was applied to crop and crop was sown at row spacing of 30 cm × 10 cm. 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 (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 60 days 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).

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)	
	60DAS	At harvest	60DAS	At harvest	60DAS	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.

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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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Performance of partial root zone drying (PRD) irrigation in Kinnow mandarin under a semi arid region

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Citrus is the third important fruit crop, after mango and banana in India. As an evergreen perennial fruit crop, citrus require sufficient soil moisture throughout the crop growing season. Kinnow is a leading commercial citrus cultivar grown in Northern India. The productivity of Kinnow (14.4 t/ha) is far below than its potential yield in this region. Scarcity of irrigation water in critical growth stages of the crop is one of the major causes of low productivity and decline of Kinnow orchards. Drip irrigation is found as a potential water saving technique over traditional surface irrigation methods in Kinnow (Hasan and Sirohi, 2006). However, irrigation scheduling is vital to enhance the efficiency of any irrigation system. Partial root zone drying (PRD) is a recently proposed water saving technique in irrigated agriculture. The present study was planned with a hypothesis that the drip irrigation scheduling with partial root zone drying technique could save a substantial amount of water over full irrigation, besides improving the fruit yield and quality of Kinnow trees.

METHODOLOGY

The experiment was conducted for 2 seasons during 2010 and 2011, with 10-year-old Kinnow mandarin (*Citrus reticulata* Blanco) plants budded on Jatti Khatti (*Citrus Jambhiri* Lush) rootstock at Indian Agricultural Research Institute, New Delhi. The soil of the experimental site is sandy loam with bulk density of 1.57 g/cm^3. The field capacity (0.33 kPa) and permanent wilting point (–15.0 kPa) of the soil were 20.8% and 7.2%, respectively, in volume basis. The pH of soil was 7.2 and EC was 0.16 dS/m. The daily pan evaporation rate varies from 1.6 mm in January to 10.7 mm in June. The treatments: deficit irrigation (DI) at 50% ETc (DI_{50}), DI at 75% ETc (DI_{75}), PRD at 50% ETc (PRD_{50}), PRD at 75% ETc (PRD_{75}) and full irrigation at 100% ETc (FI) were imposed following randomized complete block design, with four replicates per treatment and two trees per replication. Water was applied in each alternate day using 6 on-line 8 l/h pressure compensated drip emitters per tree fixed on two 16 mm diameter lateral pipes. Under PRD, irrigation was switched over from one side to another side of the plant basin once in 7 days. The water quantity was calculated considering 100% class-A pan evaporation rate as FI (Hasan and Sirohi, 2006) and water meter was used to measure the water applied under different treatments.

Leaf nutrient (N, P, K, Fe, Mn, Cu and Zn) contents were determined following the standard methods suggested by Tandon (2009). The measurement of net photosynthesis rate (P_n), stomatal conductance (g_s), and transpiration rate (T_r) of leaves was performed fortnightly from 9 AM to 3 PM by portable photosynthesis meter (LI COR-6400, USA). Leaf water use efficiency (LWUE) was worked out as the ratio of P_n to T_r of leaves as suggested by García-Sánchez *et al.* (2007). The vegetative growth and fruit yield of plants under different treatments were recorded and five fruits per plant were taken randomly to determine their quality (juice percent, acidity and total soluble solids). Irrigation water use efficiency (IWUE) was worked out as fruit yield per unit quantity of irrigation water applied.

RESULTS

The maximum net photosynthesis rate, stomatal conductance, and transpiration rate of leaves was registered with fully-irrigated trees, followed by the trees under PRD_{75} (Table 1). The highest values of g_s and T_r with FI attributed to higher soil water content in root zone of the trees under this treatment. Moreover, higher photosynthesis rate was probably caused by wider opening of stomata with higher stomatal conductance of fully-irrigated trees. However, the highest LWUE was observed in PRD_{50} (2.02) treatment, whereas the lowest LWUE was observed in DI_{75} treatment (1.58). The vegetative growth parameters (plant height, scion girth diameter, canopy diameter, and canopy volume) were observed to be significantly affected by irrigation treatments (Table 1). The highest growth of the plants was observed with FI, followed by DI_{75}. The higher vegetative growth under higher irrigation regime was probably due to higher photosynthesis rate and its proportionate partitioning towards vegetative growth under this treatment.

The leaf nutrients content followed the same trend of vegetative growth under different treatments. FI produced the highest N (2.69%), P (0.20%), and K (1.64%) in leaves,

Table 1. Leaf photosynthesis rate (Pn, mmol/m^2/s), stomatal conductance (gs, mmol/m^2/s), transpiration rate (Tr, mmol/m^2/s), leaf water use efficiency (LWUE) and annual incremental vegetative growth parameters of Kinnow plants (pooled data for 2010 and 2011)

Treatments	Leaf physiological parameters				Vegetative growth parameters			
	Pn	gs	Tr	LWUE	Plant height (cm)	Scion diameter (cm)	Canopy diameter (cm)	Canopy volume (m^3)
DI_{50}	2.89	21.07	1.66	1.74	33.4	2.04	25.8	0.811
DI_{75}	2.92	24.80	1.84	1.58	36.2	2.25	31.3	0.835
PRD_{50}	2.90	20.13	1.43	2.02	32.5	1.97	25.3	0.792
PRD_{75}	2.95	23.13	1.79	1.65	35.9	2.20	30.9	0.803
FI_{100}	3.88	37.78	2.08	1.86	40.7	2.62	48.7	0.868
$CD_{0.05}$	0.42	4.71	0.53	0.33	4.70	0.38	6.73	0.16

Table 2. Fruit yield, irrigation water applied (IW), irrigation water use efficiency (IWUE) and fruit quality of Kinnow plants as affected by irrigation treatments (pooled data for 2010 and 2011)

Treatment	Yield parameters			IW (mm)	IWUE (t/ha/mm)	Quality parameter		
	No. fruits harvested/ plant	Average fruit weight (g)	Fruit yield (t/ha)			Juice content (%)	TSS (°Brix)	Acidity (%)
DI_{50}	671	152.7	51.23	474	0.108	43.7a	11.4	1.02
DI_{75}	718	161.6	58.01	710	0.081	46.7b	10.9	0.82
PRD_{50}	703	160.7	56.48	474	0.119	45.5b	11.2	0.84
PRD_{75}	755	163.0	58.73	710	0.082	48.2b	10.8	0.82
FI_{100}	763	162.3	61.91	947	0.065	49.6c	10.8	0.81
$CD_{0.05}$	21.0	8.33	4.56	45.0	0.006	3.81	0.39	0.03

followed by PRD_{75} (N, 2.47; P, 0.19%; K, 1.59%), whereas Fe, Mn, Cu, and Zn concentration in leaves did not show any significant difference among the treatments. Table 2 shows that the maximum number of fruits was harvested under FI (763/plant), followed by PRD_{75} (755/plant). However, the heavier fruits were recorded under PRD_{75} (163 g/fruit). Likewise, the highest fruit yield was recorded in FI (61.91 t/ha) treatment, which was statistically at par ($P < 0.05$) with that under PRD_{75} (58.73 t/ha). The maximum IWUE was observed with PRD_{50} followed by PRD_{75}.

CONCLUSION

Overall, these results reveal that partial root zone drying under drip irrigation scheduled at 75% ETc is a productive and potential water saving technique in Kinnow mandarin cultivation in Northern India. The adoption of such technique could bring more area under irrigation, resulting in higher production of quality citrus fruits.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Runoff harvesting and recycling for production and profit enhancement through land modification and crop management practices

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In recent years, India has seen tremendous rise in population and it has reached to an alarming figure of 131 crores. To fulfill their requirements, agricultural lands are being diverted continuously for non-agricultural purposes. As a result, the per capita availability of land has reduced to 0.3 ha per person and will reduce further (Anonymous, 2012). In this context, it would be extremely difficult to ensure food as well as nutritional security from diminishing per capita land. So the other way round way is to increase production per unit area per unit time per unit space, i.e. production enhancement in time and space dimension from the same piece of land. Creation of more surface area through land modification is another dimension for increasing production and productivity of the land (Hellin and Schrader, 2003; Cau and Panicon 2007; Lasanta *et al.,* 2006). In India, sizeable amount of land remains as fallow in *rabi* including Rice-fallow (11.65 million hectares) due to unavailability of water. Even during *kharif*, intermittent long dry spell reduces rice yield severely. Moreover, in case of heavy down pour, sizeable amount of water goes as run-off due to lack water harvesting structures. We have, 67% marginal farm holdings having land area less than 1 hectare. Low and uncertain income from these holdings forces the farmers to leave agriculture and migrate to urban areas. Providing regular income to the farmer and enhancing farm income through combination of cereal, pulse, oilseed, fruit, vegetable, milk and fish from small holdings is a challenging task. Arranging quality green fodder for livestock during *kharif* also becomes difficult for the farmer. Thus a modified land system was designed and evaluated to meet the needs of the farmer by harvesting and recycling excess runoff.

METHODOLOGY

Approximately, 1 hectare area (9,700 m^2) land was selected. After analyzing long term climatic and hydrologic parameters, the size of water harvesting structure was decided. The excavated soil was put around the water harvesting structure to make embankment. Excavated soil was also heaped in regular interval at a distance of 7.5 m (for tractor operation and 6.5 m for power tiller operation) with a dimension of paraboloid shape with a radius of 2 m and height 1 m having gradual slope at both the sides. On the embankment of water harvesting structure, papaya variety Red Lady was grown. On the top of the heap, acid lime variety Sai Sarbati was planted. In the inter spaces, paddy was transplanted. On the outer side of heap, cowpea was sown. In the water harvesting structure, rohu and bhakur (IMC) were released. In the winter season, using harvested water with the help of water saving technologies crops such as broccoli, mustard, greengram and blackgram were grown. Recommended package of practices were followed for all crops.

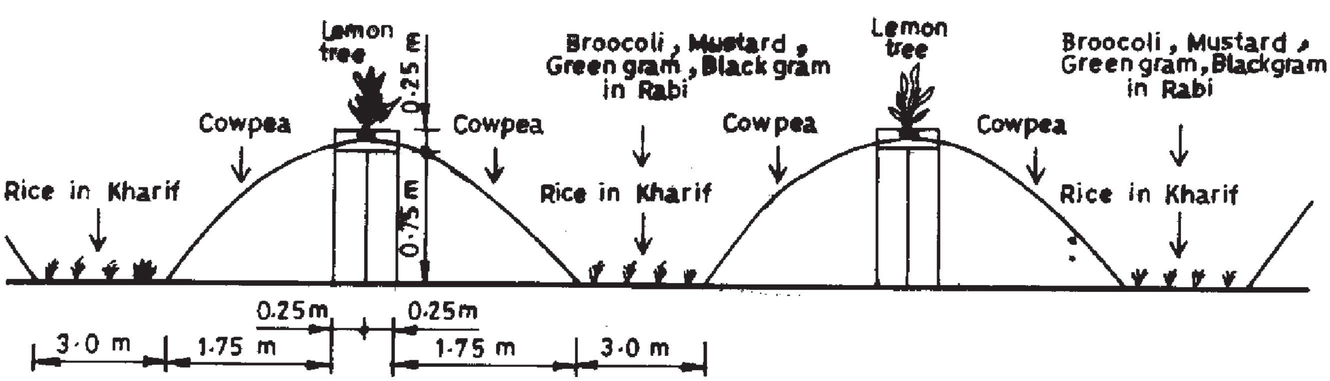

Fig. 1. Individual design of modified land

Fig. 2. Papaya variety Red Lady on embankment

Fig. 3. Rice+Cowpea+ Acid lime

RESULTS

During *kharif* season rice was grown in inter spaces and grain yield of 4 t/ha was obtained from the variety Lalat along with a harvest of 34.85% (5,071 m^3) rain in the water harvesting structure. Cowpea was sown in the side slope of the modified land system and a green fodder yield of 2.4 t/ha was recorded. During *rabi* season using harvested water, vegetable (broccoli), mustard, black gram and green gram were grown. Maximum seed yield of 0.11 t/ha was obtained from mustard variety NRCBH-101. Brocolli variety CHB-1 produced a head yield of 1.10 t/ha. Black gram variety Prasad recoded a seed yield of 0.11 t/ha. Average fruit yield of 35.1 kg/plant was harvested from papaya variety Red Lady. Fish growth was recorded to be 417 g/fingerlings in the water harvesting structure. By the land modification process, extra surface area of 390 m^2 for cultivationwas created which constitutes 32.5% of the total pond area. With this technology, net income (₹ 180,000) was increased up to 4.5 and 7 times compared to exiting rice–pulse (paira cropping-₹ 40,000) and rice-fallow cropping system, respectively.

CONCLUSION

By this technology income of the farmer can be increased by more than four times (₹ 180,000) compared to conventional practice of rice- pulse paira cropping (₹ 40,000) with regular cash flow without damaging the ground water and *rabi* fallow can be brought under cultivation using harvested runoff.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Effect of irrigation and plant geometry on quality attributes and economics of pigeonpea (*Cajanus cajan*)

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Pigeonpea (*Cajanus cajan* (L.) Mill sp, 2n = 22) commonly known as redgram or *arhar* or *tur* in India originated in South Africa in the areas of Angola and Nile river. The ability of pigeonpea to produce economic yield in soil characterized by moisture deficit makes it an important crop of dryland agriculture. 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. 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. 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 × 45 cm, 60–120 × 60 cm, 75–150 × 45 cm and 90–180 × 45 cm. Seeds of pigeonpea variety (BSMR-736) released by Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani were used for experimental purpose. 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.

RESULTS

Three irrigations given at bud initiation, flowering and pod development stage recorded significantly higher grain yield, gross monetary returns, net monetary returns and benefit cost ratio over two irrigation treatment given at bud initiation and pod development stage (Table 1). Rainfed treatment recorded significantly lower values during both the year and in pooled results. The comparative economic analysis revealed that irrigation to pigeonpea was found economically viable with higher net returns and benefit cost ratio than rainfed condition. It might be attributed to maximum seed yield and straw yield in irrigated pigeonpea finally reflected in higher net returns and benefit cost ratio

Table 1. Seed yield and economics of pigeonpea as influenced by different treatments (2 year pooled)

Treatment	Seed yield (kg/ha)	Gross monetary returns (₹/ha)	Net monetary returns (₹/ha)	B:C ratio
Irrigation (I)				
I_0- Rainfed	1048	44,020	23,202	1.10
I_1- Two irrigations	1566	65,212	40,748	1.66
I_2- Three irrigations	1907	78,987	52,104	1.94
SEm±	15	245.23	519.86	0.06
CD (P=0.05)	47	762.14	1,615.6	0.20
Plant geometries (S)				
S_1 - (120 × 45) cm	1466	61,110	37,218	1.51
S_2 - (60–120 × 60) cm	1338	55,877	32,238	1.33
S_3 - (75–150 × 45) cm	1701	70,765	46,288	1.86
S_4 - (90–180 × 45) cm	1523	63,206	38,996	1.58
SEm±	45	263.74	395.16	0.03
CD (P=0.05)	141	819.66	1,228.1	0.11
Interaction (I × S)				
SEm±	78	456.81	684.44	0.07
CD (P=0.05)	NS	NS	NS	NS

compared to rainfed pigeonpea. In this context, increased net returns and benefit cost ratio due to irrigation in pigeonpea were reported by Reddy *et al.* (2008). Experimental findings regarding effect of plant geometries on growth, yield attributes, yield, quality parameters and economic studies have been discussed under different heads. The trend of increased seed yield in plant geometry of 75–150 × 45 cm was also observed in gross monetary returns, net monetary returns and benefit cost ratio. The seed yield, gross monetary returns, net monetary returns and benefit cost ratio were significantly higher in plant geometry of 75–150 × 45 cm compared to other plant geometries in pooled analysis, respectively. Lowest values for GMR, NMR and benefit cost ratio were recorded by 60–120 × 60 cm plant geometry during both the year and in pooled analysis. Similar results were reported by Meena *et al*. (2013) and Ravikumar *et al*. (2013).

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Water productivity and profitability enhancement of wheat through improved water management practices in south eastern Rajasthan

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Wheat (*Triticum aestivum* L.) 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 systemof several nations.Yield of wheat crop is influenced by improved production technology and water management practices (Sharma *et al.*, 2007).The 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 6 cm depth by border strip method (6 m × 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

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 (₹ × 1,000)		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.

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 ₹ 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 were 8.24 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 ₹ 67,032/ha in 2012–13, ₹ 73,055/ha in 2013–14 and ₹ 76,744/ha in 2014–15 which were 9.6, 10.7 and 11.6% higherhaving 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[1] /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 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 6cm depth, by border strip method (6 m × 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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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

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 differs 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

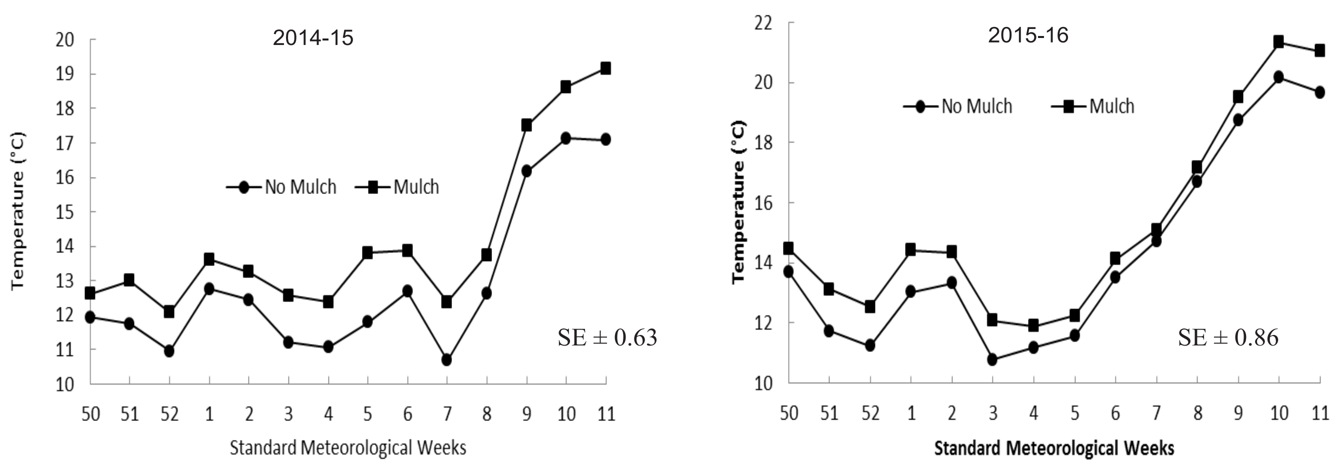

Fig. 1. Soil temperature under mulch and no mulch treatments

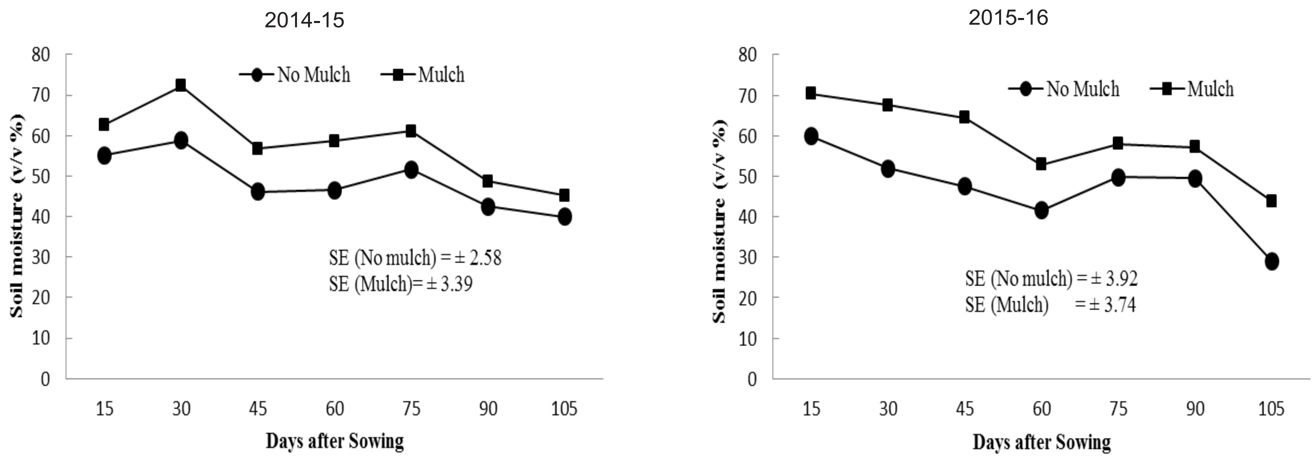

Fig. 2. Soil Moisture (v/v%) under mulch and no mulch treatments.

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 analysis
	2014–15	2015–16	
No mulch	4.09	3.93	4.01
Mulch	4.30	4.23	4.26
CD (p=0.05)	0.158	0.22	0.13

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. 2). Application of mulch significantly influences the grain yield of wheat. Wheat yield recoded was 4.30 t/ha and 4.23 t/ha higher in mulched conditions as compared to 4.09 t/ha and 3.93 t/ha non mulched conditions during 2014–15 and 2015–16 respectively (Table 1).

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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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Effect of irrigation and plant geometry on quality attributes and economics of pigeonpea

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A field experiment was conducted at Agronomy Farm, College of Agriculture, Parbhani during *kharif* season 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 × 45 cm, 60–120 × 60 cm, 75–150 × 45 cm and 90–180 × 45 cm. Gross monetary returns (₹/ha), net monetary returns (₹/ha) and benefit to cost ratio were significantly higher with application of three irrigation (I_2) treatment than two irrigation (I_1) and rainfed pigeonpea (I_0). Gross monetary returns (₹/ha), net monetary returns (₹/ha) and benefit to cost ratio were higher with plant geometry of 75–150 × 45 cm than any other due to higher plant population/ha. Different plant geometries did not show any significant impact on quality parameters like protein content (%) and test weight (g) during both the years of experimentation. Treatment combination of three irrigations (I_2) with 75–150 × 45 cm plant geometry recorded significantly higher net monetary returns (₹/ha) and benefit to cost ratio during both the years.

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Role of farm ponds in enhancing the livelihoods of rainfed farmers- A case study

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Castor (*Ricinus communis* L.) is the premier non-edible oilseed crop grown throughout the world owing to its high oil content (45–55%). India is the world leader having maximum area (59%), production (64%) and productivity (1,512 kg/ha) of castor and meets 90% of the world's requirement of castor oil, earning about ₹ 2,500 crores of foreign exchange annually (DOR, 2011–12). Though the state of Andhra Pradesh stands second in area (1.86 l ha) and third in production (1.20 l t), the productivity levels of castor are very low (645 kg/ha) as compared to Gujarat (1,978 kg/ha), Haryana (1,600 kg/ha) and Rajasthan (1,417 kg/ha). The major reasons being growing castor under rainfed conditions in marginal and sub-marginal soils with low input management, occurrence of prolonged dry spell during mid/terminal stages and incidence of botrytis grey rot (BGR) at flowering/capsule development stage during *kharif* season. Further, neither efficient botrytis management strategies nor effective drought proofing mechanisms are available. Consequently, the realized productivity is only 25 to 30% of actual potential yield. Thus, castor cultivation during *kharif* season has become non-remunerative. Castor productivity can be enhanced by growing it during *rabi* season. However, in view of ever increasing water scarcity and electricity shortage, there is a need to adopt modern and efficient methods of irrigation and nutrient application, viz. drip fertigation which can help to produce more with little water and efficient utilisation of nutrients. A project was implemented with financial assistance from NABARD under Farm Innovation Promotion Fund (FIPF) in order to develop irrigation and fertigation scheduling to enhance productivity, water use efficiency and returns from *rabi* castor in Andhra Pradesh.

METHODOLOGY

A field investigation was executed during *rabi* 2010–11 at Regional Agricultural Research Station (Achaya N.G. Ranga Agricultural University), Palem, Mahabubnagar district of Andhra Pradesh to study the effect of drip irrigation and fertigation on bean yield, water use efficiency and economics of *rabi* castor. The soil of experimental site was red chalka with pH 7.6, low in available N (217 kg N/ha), medium in available P (32.2 kg P_2O_5/ha), available K (476 kg K_2O/ha), bulk density of 1.32 g/cc and available soil moisture of 3.65 mm (0–30 cm depth). The experiment was laid out in a split plot design with four irrigation levels as main plots (I_1: Irrigation at 0.3 Pan evaporation, I_2: Irrigation at 0.6 Pan evaporation, I_3: Irrigation at 0.9 Pan evaporation through drip and I_4: Irrigation at 75 mm CPE through check basin method) and four N levels as subplots (N_1: 40 kg N/ha through fertigation, N_2: 80 kg N/ha through fertigation, N_3: 120 kg N/ha through fertigation and N_4: 80 kg N/ha through pocketing). A uniform dose of 40 kg P_2O_5 and 30 kg K_2O/ha was applied as basal in all the treatments in the form of SSP and MOP, respectively. Castor hybrid PCH-111 was used as test hybrid and was sown at a spacing of 120 × 60 cm spacing.

Table 1. Yield and water use efficiency of *rabi* castor as affected by drip irrigation and fertigation (*rabi* 2010–11)

Treatment	Seed yield (t/ha)	WUE (kg/ha /mm)	Oil yield (t/ha)	N uptake (kg/ha)	Net returns (₹/ha)	B:C ratio
Irrigation						
I_1	2.22	8.33	1.14	105.8	54,569	2.59
I_2	2.94	6.54	1.51	164.2	82,539	3.35
I_3	3.26	5.14	1.67	192.1	94,329	3.63
SEm±	0.14		0.74	5.3	5,490	0.15
CD (0.05)	0.54		2.89	21.0	21,549	0.60
Fertigation						
N_1	2.13	4.73	1.09	132.1	50,578	2.45
N_2	3.02	6.71	1.55	166.5	86,071	3.48
N_3	3.34	7.42	1.70	162.8	98,799	3.82
N_4	2.74	6.09	1.41	154.6	73,136	3.00
SEm±	0.13	–	0.62	8.5	4,984	0.13
CD (P=0.05)	0.37	–	1.85	25.1	14,806	0.42

I_1- 0.3 Pan evaporation (PE); I_2- 0.6 PE; I_3- 0.9 PE; I_4- 75 mm CPE; N_1- 40 kg N/ha through fertigation; N_2- 80 kg N/ha through fertigation; N_3- 120 kg N/ha through fertigation; N_4- 40 kg N/ha through pocketing; B : C ratio-benefit:cost ratio; Market price ₹ 4,000/tonnes

Lateral distance of 120 cm and dripper distance of 40 cm with dripper discharge of 2 lph was maintained throughout the experiment. Irrigation through drip was scheduled based on pan evaporation at three days interval and fertigation was given once in 6 days through ventury. While irrigation by check basin method was given based on cumulative pan evaporation. The data on bean and oil yield were analysed in a split plot design in order to know the main and sub plot effects, while, RBD (randomized block design) analysis was carried out to compare the drip irrigation and fertigation treatments vis-à-vis control.

RESULTS

The bean and oil yield of castor was significantly influenced by irrigation and fertigation treatments (Table 1). Significantly higher castor bean yield was recorded when the crop received irrigation at 0.9 PE (I_3: 3.3 t/ha). However, it was at par with that of 0.6% PE (I_2: 2.94 t/ha) and both were significantly superior to 0.3 PE (I_1: 2.22 t/ha). Castor seed yield obtained in I_3 and I_2 treatments was higher by 46.6 and 32.5%, respectively over I_1. The main reason for getting higher yield in I_2 and I_3 as well as N_3 and N_2 treatments is due to production of significantly lengthy spikes and more no. of total and effective spikes/plant. Fertigation @ 120 kg N/ha (N_3) resulted in significantly higher castor bean yield (3.34 t/ha). The enhancement in bean yield due to N3 was to the extent of 10.7, 21.9 and 57.0% over N_2 (80 kg N/ha through fertigation), N_4 (80 kg N/ha through pocketing) and N_1 (40 kg N/ha through fertigation). However, N_3 was

Table 2. Yield and water use efficiency of *rabi* castor as affected by drip irrigation and fertigation (*rabi* 2010–11)

Treatment	Seed yield (t/ha)	WUE (kg/ha /mm)	Oil yield (t/ha)	N uptake (kg/ha)	Net returns (₹/ha)	B:C ratio
I_1N_1	1.70	5.98	0.82	92.3	30,172	1.90
I_1N_2	2.35	8.80	1.20	117.1	59,998	2.77
I_1N_3	2.65	9.92	1.34	109.1	71,717	3.10
I_1N_4	2.30	8.64	1.19	104.7	56,388	2.58
I_2N_1	2.12	4.71	1.08	123.3	49,835	2.43
I_2N_2	3.37	7.50	1.73	181.1	100,283	3.89
I_2N_3	3.55	7.89	1.83	176.9	107,074	4.07
I_2N_4	2.74	6.08	1.39	175.5	72,963	3.00
I_3N_1	2.68	4.22	1.37	180.8	71,725	3.04
I_3N_2	3.34	5.27	1.72	201.4	97,929	3.76
I_3N_3	3.83	6.05	1.94	202.4	117,605	4.30
I_3N_4	3.18	5.03	1.65	183.5	90,057	3.41
I_4N_4	2.08	3.28	1.07	96.0	55,502	3.02
SEm±	1.56	–	0.08	9.8	6,254	0.18
CD (P=0.05)	4.56	–	0.23	28.5	18,255	0.52

I_1- 0.3 Pan evaporation (PE); I_2- 0.6 PE; I_3- 0.9 PE; I_4- 75 mm CPE; N_1- 40 kg N/ha through fertigation; N_2- 80 kg N/ha through fertigation; N_3- 120 kg N/ha through fertigation; N_4- 40 kg N/ha through pocketing; B : C ratio- benefit : cost ratio; Market price ₹4,000/tonne found to be statistically at par with that of N_2 (3.02 t/ha) and both were significantly superior to N_1. It was owing to more total and effective spike length.

Castor crop gave only 2.08 t/ha seed yield when it received irrigation at 75 mm CPE and 80 kg N/ha through pocketing (Control: I_4N_4). It was far lower than that of drip irrigation and fertigation treatments except I_1N_1 (1,595 kg/ha) (Table 2). Significantly higher seed yield of castor (3.83 t ha) was obtained when drip irrigation was scheduled at 0.9 PE and fertigation was done @ 120 kg N/ha (I3N3). However, it was at par with that of I_2N_3 (0.6 PE and 120 kg N/ha). Yield enhancement due to drip irrigation and fertigation vis-à-vis control was to the tune of 71.1%. The better performance of I_2N_3 and I_3N_3 was mainly because of significantly more total and effective spike length thus higher dry matter. Water use efficiency (WUE) was found to be higher when drip irrigation was scheduled at under dry regime (0.3 PE: 8.33 kg/ha/mm) than wet regime (6.54 and 5.14 kg/ha/mm). Among fertigation treatments, higher WUE was recorded at higher levels of fertigation (N_3: 7.42 kg/ha/mm) than other levels of fertigation. A perusal of data in Table 2 revealed that WUE was found to be higher in I_1N_3 (9.92 kg/ha/mm) followed by I_1N_2 (8.80 kg/ha/mm) and was two and half to three times higher than that of control treatment (3.28 kg/ha/mm). All the drip irrigation and fertigation treatment combinations have produced more bean yield per unit of water utilized as compared to control plot (I_4N_4). Oil yield followed the similar trend set by bean yield of castor (I_3N_3: 1.94 t/ha and I_2N_3: 1.8 t/ha). Water saving due to drip irrigation was to the tune of 29.0%. These results are in accordance with that of Patel *et al*. (1997) who reported that irrigation scheduling for castor at 0.8 fraction of pan evaporation through drip increased seed yield by 36% with water saving of 25%. Patel *et al*., (2010) from Anand concluded that irrigation at 0.6 to 0.8% PE was better with respect to higher castor bean yield, dry matter production and N uptake by seed and stalk. Maximum castor bean yield, net returns and nitrogen use efficiency were observed when 100% N was applied through drip and was closely followed by 80% N through drip (Patel *et al*., 2006). Castor crop removed significantly higher amount of N (192.1 kg N/ha) from soil when it was irrigated at 0.9 PE (I_3) and was significantly superior to I_1 (0.3 PE: 105.8 kg/ha) and 0.6 PE (164.2 kg/ha). N mining was significantly greater when fertigation was done @ 120 kg N/ha (N_3). Crop grown with drip irrigation @ 0.9 PE and 120 kg N/ha applied through fertigation (I_3N_3) removed significantly higher amount of N (202.4 kg/ha) than other treatment combinations, however, it was found to be on par with I_3N_2 (201.4 kg/ha), I_2N_2 (181.1 kg/ha) and I_3N_1 (180.8 kg/ha). Higher amount of net returns and B : C ratio were accrued in the treatments, viz. I_3N_3 (₹ 117,605/ha, 4.3), I_2N_3 (₹ 107,074/ha, 4.07) and I_2N_2 (₹ 100,283/ha, 3.89).

CONCLUSION

From the foregoing discussion, scheduling of irrigation @ 0.6 PE and fertigation @ 120 kg/N ha can be advocated for *rabi* castor in Andhra Pradesh for higher productivity, water use efficiency and economic returns.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Drip irrigation levels influence on yield attributes, yield and water productivity of *rabi* sorghum (*Sorghum bicolor* (L.) Moench)

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Sorghum (*Sorghum bicolor* (L.) Moench) is the fifth most important cereal crop, used for food, fodder, production of alcoholic beverages and biofuels and is the dietary staple for more than 500 million people in 30 countries with an area of 40 million ha. The area of post rainy (*rabi*) season sorghum in India is 3.78 out of 6.10 million ha (2012–13). Water is increasingly becoming scarce because of erratic distribution of monsoons and uncontrolled exploitation of ground water. The global challenge for the coming decades is to increase the food, fodder and fiber production, with less utilization of water and as water is a limiting input in near future. The present experiment initiated to maximize yield attributes, yield and water productivity of *rabi* sorghum with less water under drip irrigation.

METHODOLOGY

Field experiment was conducted during *rabi,* 2014–15 and 2015–16 (October) with CSH-16 hybrid (at 0.40 m × 0.15 m with population of 166,666 plants/ha) at Water Technology Center, College farm, College of Agriculture, Rajendranagar, Professor Jayashankar Telangana State Agricultural University, Hyderabad in a randomized block design with ten treatments of drip irrigation schedules at estimated ETc of 0.6, 0.8, 1.0, 1.2 throughout the life and combinations of up to flowering and later on in comparison to surface furrow irrigation at 0.8 IW/CPE ratio and replicated thrice as detailed in Table 1 on a sandy clay loam soil of alkaline in reaction, low in available nitrogen, high in available phosphorous and potassium, medium in organic carbon content having field capacity and Permanent wilting point of 21.7 and 9.60 per cent, respectively with available soil moisture of 76.50 mm in 0-45 cm depth. The recommended dose of fertilizer was 100-60-40 kg N : P_2O_5 : K_2O/ha (entire dose of P and K was applied as basal before sowing and N applied as fertigation in 6 splits of equal doses at 10 days interval from 15 days after sowing). Irrigation was scheduled based on USWB class a pan evaporation rates by estimating ETc by adopting suitable pan coefficient based on wind speed and relative humidity and crop coefficient as per crop stage.

RESULTS

Ear head length, ear head weight and grains/ panicle of *rabi* sorghum was significantly higher with drip irrigation scheduled at estimated ETc of 0.8 up to flowering and 1.2 ETc later on and was on par with 1.2 ETc throughout life, 0.6 ETc up to flowering and 1.2 ETc later on or 0.8 ETc up to flowering and 1.0 ETc later on (Table 1). Significantly lower yield attributes recorded with drip irrigation scheduled at estimated ETc of 0.6 throughout life. Surface furrow irrigation at 0.8 IW/CPE ratio recorded on par ear head length and weight and grains/ panicle with drip irrigation at estimated 0.6 ETc up to flowering and 0.8 or 1.0ETc later on. Test weight of *rabi* sorghum recorded with drip irrigation scheduled at 1.2 ETc though was higher, there was no significant difference among the treatments. Sorghum grain yield realized during *rabi* with drip irrigation scheduled at estimated ETc of 0.8 up to flowering and 1.2 ETc later on (6,894 kg/ha) and was on par with 0.8 or 1.0 or 1.2 Etc throughout life, 0.8 ETc up to flowering and 1.0 ETc later on or 0.6 ETc up to flowering and 1.2 ETc later on (Table1). There was an increase of 50.6 per cent in yield with drip irrigation scheduled at estimated ETc of 0.8 up to flowering and 1.2 ETc later on compared to drip irrigation at 0.6 ETc throughout the life. Significantly lower grain yield was observed with deficit drip irrigation scheduled at 0.6 Etc throughout the life (4,577 kg/ha) over rest of the treatments (except 0.6 ETc up to flowering and 0.8 ETc later on). Whereas the sorghum grain yield obtained under surface furrow irrigation at 0.8 IW/CPE ratio was on par with drip irrigation at 0.6 ETc up to flowering and 0.8 or 1.0 ETc later on and was significantly lower than rest of the drip irrigation treatments though significantly higher than 0.6 ETc throughout the life. It might be due to moisture fluctuation from field capacity to permanent wilting point in surface furrow irrigation while in drip irrigation moisture was maintained at field capacity level. Water productivity of *rabi* sorghum recorded with drip irrigation scheduled at estimated 0.8 ETc throughout the life (2.97 kg m^3) was on par with 0.8

Table 1. Yield attributes, yield and water productivity (WP) of *rabi* sorghum as influenced by different drip irrigation treatments (mean 2 years)

Treatment	Ear head length (cm)	Ear head weight (g/plant)	No. of grains/ plant	Test weight (g)	Grain yield (kg/ha)	Total water applied (mm)	WP (kg/m^3)
Drip Irrigation at estimated 0.6 ETc throughout the life	57.3	86.8	4,549	29.8	4,577	173.3	2.64
Drip Irrigation at estimated 0.8 ETc throughout the life	66.6	98.9	5,849	32.2	6,360	213.9	2.97
IDrip Irrigation at estimated 1.0 ETc throughout the life	67.9	107.0	6,401	32.9	6,378	254.6	2.50
Drip Irrigation at estimated 1.2 ETc throughout the life	71.7	119.3	7,080	34.8	6,677	295.6	2.26
Drip Irrigation at estimated 0.6 ETc up to flowering and 0.8 ETc later on	57.5	89.8	5,471	32.3	4,877	195.4	2.50
Drip Irrigation at estimated 0.6 ETc up to flowering and 1.0 ETc later on	62.0	102.2	6,113	33.0	5,538	217.6	2.55
Drip Irrigation at estimated 0.6 ETc up to flowering and 1.2 ETc later on	69.5	108.3	6,808	34.1	6,453	239.7	2.69
Drip Irrigation at estimated 0.8 ETc up to flowering and 1.0 ETc later on	68.5	110.5	6577	34.2	6,490	236.0	2.75
Drip Irrigation at estimated 0.8 ETc up to flowering and 1.2 ETc later on	72.1	119.2	7084	34.9	6,894	258.2	2.67
Surface furrow irrigation at 0.8 IW/CPE ratio with irrigation water of 50 mm	60.2	96.9	5,642	32.3	5,418	351.4	1.54
CD (P= 0.05)	4.0	8.4	713	NS	580	–	0.24

up to flowering and 1.0 later on (2.75 kg m^3) and significantly superior over rest of the drip irrigation and surface irrigation treatments (Table1). Surface furrow irrigation at 0.8 IW/CPE ratio recorded significantly lower productivity (1. 54 kg m^3) compared to rest of drip irrigation treatments.

CONCLUSION

Drip irrigation scheduled at estimated ETc of 0.8 up to flowering and 1.2 ETc later on and recorded higher yield attributes and yield of *rabi*sorghum compared to other drip irrigation treatments and surface furrow irrigation at 0.8 IW/CPE ratio with irrigation of 50 mm and Water productivity recorded with drip irrigation scheduled at estimated 0.8 ETc throughout the life (2.97 kg m^3) was on par with 0.8 up to flowering and 1.0 later on (2.75 kg m^3) and was significantly superior over rest of the treatments.

Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

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.

MATERIAL AND METHODS

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 AND DISCUSSION

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 141 t/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 (5.37×10^4 cfu/g) and heterotrophs

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

(8.43×10^5 cfu/g) on okra fruits were also the highest when the crop was irrigated with untreated sewage in comparison to the mean value of coliform counts 2.09×10^3 cfu/g and 4.67×10^4 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 groundwater 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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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Energy synthesis in crop production

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Energy parameters such as, net energy return, energy ratio and energy productivity are now-a-days meaningful and common indicators for assessing or comparing the efficiency of production systems (Singh *et al.,* 2016b). However, energy consumption and output differ widely among crops, production systems, and management intensity. Indeed, studies on energy use are strongly influenced by experimental plot data, upon which the computations are based, system boundaries and methodologies. Therefore, agro-ecosystem productivity evaluation of any crop production system using emergy synthesis is more important and interesting over energy budgeting. One of the arguments behind this opinion is that energy budgeting does not consider soil erosion results from energy transmitted from rainfall drops which hit exposed soil with an explosive effect, launching soil particles into air and run-off itself has kinetic energy. Erosion also affects other ecosystem services like carbon emission, eutrophication, sedimentation of reservoirs etc. and finally affects national economy of the country. All of these inputs never considered in the energy budgeting. Without quantifying the intrinsic value of these services in the context of the resource basis of the economy, decision makers have no way to evaluate problem severity, nor any quantitative rationale to justify diverting sufficient resources to attenuate it. In contrast to energy budgeting, emergy evaluation takes into account all the inputs (precipitation, global radiation, wind, soil loss etc.) involved in a production system (*i.e*. renewable and non-renewable, local and imported) and transforms them into a common measure of direct and indirect solar energy requirement by means of a conversion factor called transformity (Singh *et al.,* 2016a). In this way, all the flows get the same common unit for the analysis. Information on the emergy synthesis is very limited in India as well as on global level.

METHODOLOGY

Emergy is defined as the quantity of solar energy directly or indirectly necessary to support a given system. Since solar energy is the primary source of all kinds of energy on earth, the emergy of all inputs to a system can be expressed on a common basis solar emergy, which can be calculated by multiplying the energy in Joules (or directly from its mass) by suitable conversion factors called transformities (sej/J). Transformity is a quality factor and gives a measure of the concentration of solar emergy through a hierarchy of process. The first step of emergy analysis is drawing a diagram of the system to identify all the components, their relationships and categories. In this step, available input resources will be developed and allocated to outputs, then all the inputs will be categorized as renewable, non-renewable, and purchased. The second step is transforming all the components of a system into emergy by multiplying transformity, which in this study are derived from previous research that has been used to evaluate the energy flows and conversion efficiencies

Table 1. Emergy indicators

Indicator	Expression	Meaning
Solar transformity (Tr)	Y/E	The ratio of the emergy of the output (Y) divided by the energy (E) of the products. The higher the transformity of a product the more resources used to produce it. Therefore, high transformity means high production cost.
Renewability (% R)	100 × (R + Mr + Sr)/Y	The ratio of the renewable inputs divided by the total emergy (Y) of the system. In the long run, a system with a high percentage of renewable resources is more sustainable. It has a larger capability to adapt to environmental pressure and shows greater competitive advantage in comparison with the system using a high percentage of non-renewable resources.
Emergy yield ratio (EYR)	Y/F	The ratio of total emergy (Y) used divided by the emergy of non-renewable inputs (F) from the economy. In this study, Y = F + I, EYR can be expressed as: EYR = (F + I)/F = 1 + I/F, where F is the purchased inputs and I is the natural resources. So EYR is also an indicator to measure the ability of the production process to exploit local nature resources.
Emergy investment ratio (EIR)	(Mn +Sn)/(R + Mr + Sr + N)	The ratio of the emergy of non-renewable economic inputs divided by the emergy of nature investment. It is an indicator to measure whether a productive process is a good user of the invested emergy. This is not an independent index; it is linked to EYR and an additional explanation to EYR. A system with low EIR means its productive process uses the invested emergy efficiently.
Environmental loading ratio (ELR)	(N + Mn + Sn)/(R + Mr + Sr)	The ratio of non-renewable emergy and renewable inputs indicates the sustainability of the system. It is an indicator to measure the pressure of the ecosystem.
Emergy Sustainability Index (ESI)	EYR/ELR	High ESI is provided by a high EYR and a low ELR, so a system with high ESI has good performance both in yield and developmental sustainability.

of natural resources, products or service inputs. After all the components of a system are transformed into emergy, some emergy indicators are calculated to assess the system. Hence, solar emergy and transformity, together with other indicators and ratios, are the key elements of emergy analysis, which can be used to evaluate the efficiency and environmental impact of an assessed system, and to make policy recommendations for long-term sustainability. All the inputs and outputs to the system are expressed in an emergy form through their transformities. Since the calculation function of all renewable natural resources are coupled with each other, counting each as a separate cost would "double-count" the emergy required for the productive process. The value of total renewable natural resources is equal to its maximum value. Based on these data, emergy indicators of transformity, renewability, emergy yield ratio, emergy investment ratio, environment loading ratio and environment sustainability ratio can be calculated to evaluate system performance (Table 1).

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Mitigation of point source pollution of water: steps towards addressing water security

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To analyze the degradation potential of the different soil/biochar/digestate biomixtures on herbicide a degradation study was performed. The results from the ^{14}C labelled herbicide study indicated that a mixture of digestate (5%) and biochar (5%) well balanced the mineralization (~20%) and sorption process (>85% non-extractable residues) resulting in favorable dissipation process. To investigate the sorption-desorption potential of the above herbicide a batch equilibrium study was carried out with selected biomixtures. A higher K_d (>1500 L/kg), k_f (>400 $\mu M^{1-1/nf}$ $L^{1/nf}$/kg) and K_L (>40 L/kg) was obtained for the soil/digestate/biochar mixtures, which had a higher organic matter content. This mixture found to be the most promising substrate amongst the tested ones for the retention of bentazone. Unsustainable management of herbicides can cause high concentrations in soils, groundand surface waters. In general, sources of pollution are categorized into diffuse and point sources. Diffuse contamination via leaching, runoff, surface drainage, and drift usually contributes only to a smaller part of pollution of groundand surface water. Point source pollution can be avoided or significantly reduced by applying best management practices in the area of daily routines (e.g. sprayer washing). A possible approach to safely dispose remnants of crop protection products is the use of biobeds or biofilters (biopurification systems). To mimic a realistic pesticide application doses for the biobeds, pesticide loads are calculated from recommended field application (960 g/ha for bentazone) assuming a depth of incorporation into the top 5 cm soil and soil bulk density of 1.5 g/cm^3. To account for higher concentrations which will be applied to the biobed containers with a surface area of 1 m^2, ten times the field application was assumed resulting in pesticide concentrations of 0.0128 mg/g soil for bentazone. Overall six different biomixtures plus a control soil were analyzed with respect to their pesticide mineralization capabilities. Fig. 1 shows the mineralization of ^{14}C bentazone in percent of applied pesticide for all biomixtures and the control soil. In general, mineralization increases over the entire period of incubation (135 days) and mineralization seems not to be complete for all treatments, indicated by still ongoing evolution of ^{14}C carbon dioxide at the last sampling dates. Nevertheless, a clear trend in the mineralization pattern between the mixtures is detectable with significant lower mineralization rates (and total mineralization at t =135 days) for the biochar/soil

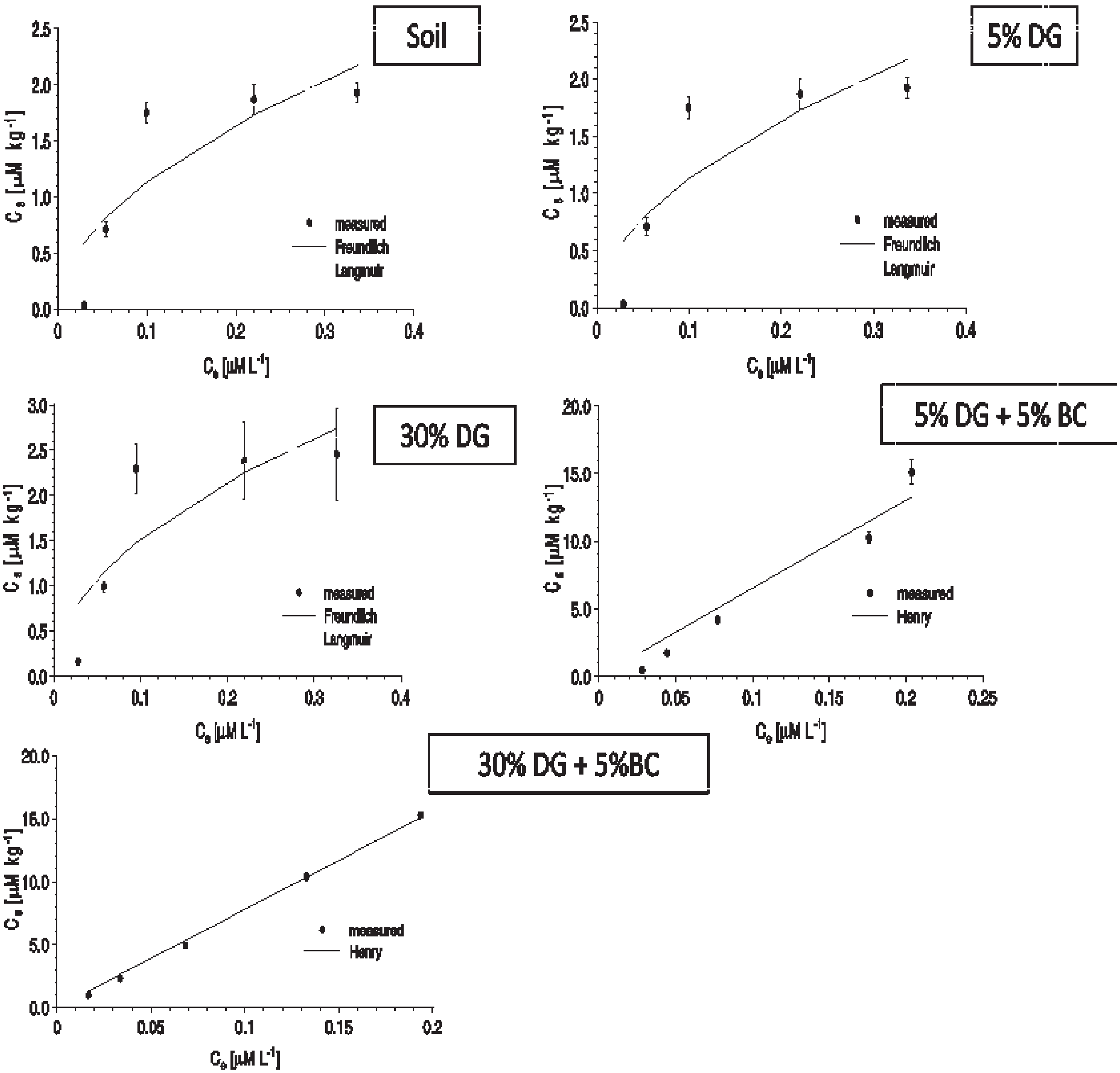

Fig. 1. Mineralization of ^{14}C-bentazone in% of initial concentration for the different soil-biomaterial mixtures. Error bar represents standard deviation (n = 3). Control = Kaldenkirchen soil (loamy sand), LTB = low temperature biochar, and DG = digestate. The percentage indicates the mass ratios in the mixtures. Bentazone sorption could not be described by one model for all mixtures, which makes the interpretation much more difficult but the general sorption can be described as less strong (see Fig. 2) with K_d (K_{OC}) values. For the most sorbing biochar + digestate mixtures, 65 (966) and 78 (470) values of K_d (K_{OC}) can be estimated for the lower and higher digestate loads (Mukherjee *et al.,* 2016 a and b).

mixtures compared with the control soil. For the 1% BC addition reduction in mineralization is 30% and for the addition of 5% LTB even larger with ca. 40%. Digestate alone increased the mineralization of bentazone significantly compared to the native soil. For the addition of 5% digestate mineralization already increased by 18% and for the 30% digestate even by 63% indicating that is a good source of ligno-cellulosic compounds, which may be utilized by white-rot fungi for co-metabolic degradation of pesticides by ligno-cellulosic extracellular enzymes as already observed for straw in biobed systems by Coppola *et al.* (2010).

CONCLUSION

We conclude that a blended mixture of biochar and

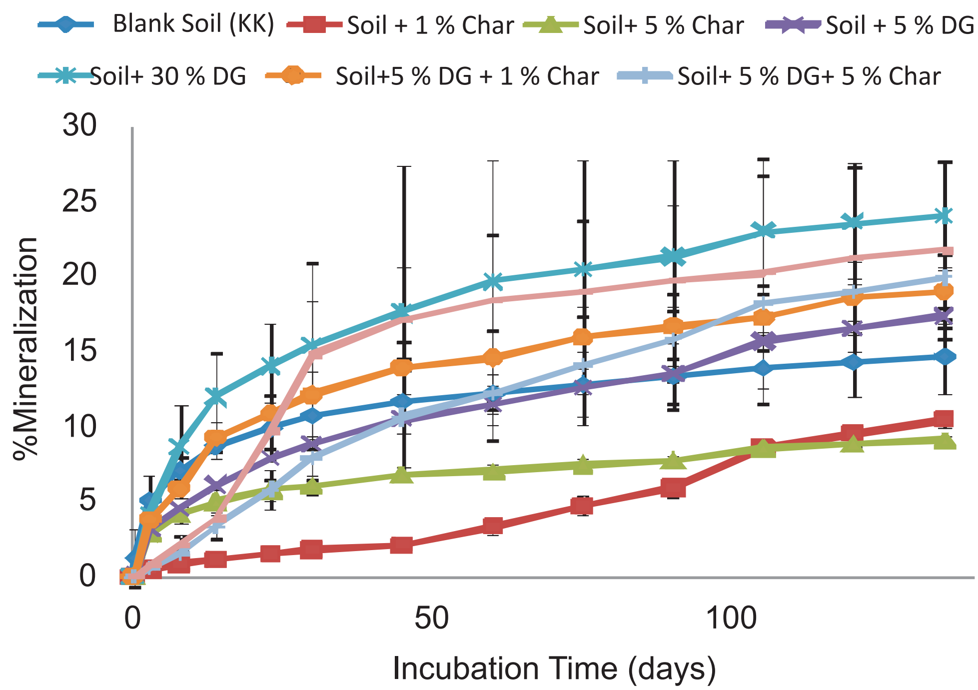

Fig. 2. Adsorption isotherms of bentazone for the different soil/amendment mixtures. Data points represent means and error bars indicate standard errors of triplicate samples (symbols in part cover smaller error bars). C_s denotes sorbed amount and C_e indicates equilibrium water phase concentration. Soil = loamy sand, BC = low temperature biochar, and DG digestate. The percentage indicates the mass ratios in the mixtures. For bentazone, the Langmuir model was not applicable for describing sorption on blended mixture of digestate and biochar, as negative values for Langmuir constants C_{smax} and K_L were obtained, which is improbable (De Wilde *et al.,* 2009). This may indicate that monolayer adsorption, assumed in this model, was not valid for these specific experiments. In the study presented incubation experiments with different soil amendments, namely biochar and digestate, were preformed over the course of 135 days. Hereby not only the amendments were used in different application ratios but the amendments were also mixed together with the soil to analyze their interactions. Additionally, two contrasting soil types (loamy sand and silt loam soil) were used. The results of the incubation experiment nicely showed that the mineralization rate of biochar /soil mixtures is slower compared to the turnover of digestate based mixtures (even if the same amount of biochar and digestate was used), which reflects the recalcitrant nature of the biochar. On the other hand CO_2 evolution from bare soil (without amendment) and biochar (soil with amendment) did not show much difference irrespectively of the larger carbon content of the biochar mixtures. From sorption experiment it is clear that, bentazone showed highest adsorption by blended mixture of digestate and biochar followed by digestate based mixture. 5 and 30% digestate combinations showed almost similar sorption capacity for bentazone.

digestate significantly increases the adsorption and decreases the desorption potential of pesticides compared to bare soil. Therefore, with respect to the use of digestate / biochar mixtures for bio-purification systems more fundamental research will be needed. From the results presented here a mixture of digestate and biochar might be most suitable, balancing between microbial activity and long terms stability of the organic amendment mixture.

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Symposium 7
Precision Nutrient Management

Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Assessing leaf-nitrogen content in wheat using optical plant sensors

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Precision farming has been shown to address the triple challenges of higher crop productivity, greater resource-use efficiency and environmental safety by applying agro-inputs as per the spatial, temporal and in-season variability, particularly in the developed countries. In developing countries also precision framing research is being greatly emphasised, mostly with respect fertilizer and water applications. Nitrogen (N) is the most important plant nutrient, often, applied in heavy amounts in inequity to other plant nutrients in cereal crops that leads to low N-use efficiency and environmental pollution including N_2O emissions. Precise N management can offer effective solution to this issue and national and international level. Assessing plants' nitrogen (N) status timely and quickly is the pre-requisite for real-time precision N management addressing its spatial and in-season variability. Unlike costly, time consuming and labour intensive conventional approaches plant chemical analysis, the optical sensors technology enables real time measurements on crop's N content and facilitates variable rate application of N. Several research workers have found a significant correlation between leaf N-content and sensor values (Xiong *et al*., 2015, Stroppiana *et al*., 2009 and Li *et al*., 2008). However, before practically deploying on a large scale, plant sensors need to be field evaluated and standardized. Hence the current field investigation was carried out to evaluate the hand held plant sensors for assessing plant N status world's most important crop, wheat.

METHODOLOGY

A field experiment was experiment was carried out at Research Farm of Division of Agronomy, ICAR-IARI, New Delhi during winter season of 2014–15 to evaluate sensors, viz. GreenSeeker, Chlorophyll meter, Leaf Colour Chart (LCC) and radio-spectrometer on wheat crop treated with variable N rates (0, 30, 60, 90, 120, 150, 180, 240 kg N/ha). The experimental field soil was sandy loam in texture, medium in organic C, available N and medium in available P and high in available K. The experiment was laid-out in a RBD replicated three times. Leaf N-content and different sensor measurements on crop leaf/canopy were taken at four different times during crop period. Relationships between leaf-N content and different sensor indices were developed.

RESULTS

At low rate or no N application, SPAD values (Chlorophyll meter) and NDVI (GreenSeeker) decreased with progression in crop growth, while at higher N rates (>150 kg N/ha) these sensor indices values increased up to ear emergence. The Indices values peaked at 150 kg N/ha, beyond which the values either did not increase or increased marginally. Correlation analysis of different sensor (Chlorophyll meter, GreenSeeker, LCC) indices with leaf N content was positive (Table 1) and significant (R^2=0.86–0.95). Nitrogen stress could also be potentially monitored using the spectral signatures of wheat crop recorded using radio-spectrometer. Different spectral derived indices were evaluated for plant N-content estimation which, in turn, indicates plant N stress. The indices gave good prediction of plant N status as indicated by R^2 value of 0.71.

Table 1. Correlation of different sensor indices with leaf N content in wheat

Indices	Observation date		
	17.01.2015	9.02.2015	17.03.2015
SPAD	0.871**	0.862**	0.946**
NDVI	0.942**	0.891**	0.971**
LCC	0.955**	0.895**	0.804*

**significant at P≤0.01, *significant at P≤0.05

CONCLUSION

All sensors were found suitable in determining leaf-N content in wheat. LCC and GreenSeeker showed better correlation with leaf N content and could be considered better leaf N content estimators for wheat crop.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Effect of alley cropping with subabool and fertilizer application on yield of *rabi* crops

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A field experiment was conducted during *rabi* 2011–12 and 2012–13 to investigate the effect of alley cropping with Subabool (*Leucaena Leucocephala*) and fertilizer application on yield of different field crops in sandy loam soils in Jharkhand in randomized block design at Zonal Research Station Chianki, Palamau for the suitability for western plateau region of Jharkhand. Five field crops, viz. chickpea, mustard, linseed, safflower and sesame were grown in five meter wide established alley of Subabool hedgerow with 50% N and 100% P and K RDF as mineral fertilizer in respective crops. *Leucaena* pruning yielded large biomass and nutrients in both the years. Yield of five different crops responded more to 50% N and 100% P and K as RDF respective crops than the control than to alley cropped with Subabool leaves incorporated plots. As the chickpea is the main *rabi* crops of this area therefore chickpea equivalent yield was calculated. Significantly maximum equivalent yield was observed in safflower followed by chickpea and lentil. After two years of experimentation, soils were analyzed and N content was found on higher side where as P and K content observed averagely. Besides this wood biomass was obtained by cuttings before *rabi* season.

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Effect of sequential application of herbicides on grain yield of transplanted basmati rice and associated weeds in sub-tropical belt of Jammu region

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Rice (*Oryza sativa* L.) is important staple food crop grown extensively in India. Transplanted rice faces diverse type of weed flora, consisting of grasses, broad-leaved weeds and sedges. Competition offered by weeds reduces the grain yield up to the extent of 15–45% (Bali *et al*., 2006). Hand weeding is the most effective method, however, high labour wages

Table 1. Effect of different weed management practices on plant height, plant dry matter, weed density, weed biomass and grain yield of basmati rice

S. No.	Treatments	Plant height (cm)	Plant dry weight (g/m^2)	Weed density ($No./m^2$)	Weed biomass (g/m^2)	Grain yield (t/ha)
1.	Butachlor 1.5 kg/ha fb bispyribac 25 g/ha	98.35	208.95	4.18 (16.50)	4.10 (16.01)	2.99
2.	Pretilachlor 0.75 kg/ha fb bispyribac 25 g/ha	92.80	210.10	4.27 (17.25)	4.27 (17.26)	2.92
3.	Anilofos 0.4 kg/ha fb bispyribac 25 g/ha (c)	94.95	219.45	4.05 (15.50)	4.06 (15.57)	3.06
4.	Butachlor 1.5 kg/ha fb Chlorimuron+metsulfuron 4 g/ha	95.70	211.20	4.24 (17.00)	4.35 (17.97)	2.90
5.	Pretilachlor 0.75 kg/ha fb Chlorimuron+metsulfuron 4 g/ha	95.30	206.45	4.36 (18.00)	4.53 (19.57)	2.79
6.	Anilofos 0.4 kg/ha fb Chlorimuron+metsulfuron 4 g/ha	96.80	216.40	4.27 (17.25)	4.41 (18.52)	2.84
7.	Weedy check	89.85	181.25	9.15 (82.75)	10.04 (99.83)	2.18
	SEm±	3.63	7.20	0.11	0.17	0.12
	(P=0.05)	NS	21.19	0.32	0.51	0.35

and non availability of labour during peak periods of agricultural operations, timely weeding is not possible. Most of the pre-emergence herbicides, viz. butachlor, pretilachlor and thiobencarb were applied for weed management in transplanted rice and effective very effective for controlling weeds up to 20 DAT (Kiran *et al*., 2010). Application of sequential application of pre-emergence followed by post emergence herbicides may be useful for broad-spectrum control of weeds in rice. Hence, the present investigation was carried out to evaluate the relative efficacy of some sequential combinations of pre- and post-emergence herbicides for control of weeds in transplanted rice.

METHODOLOGY

A field experiment in basmati rice was conducted in *kharif* 2015 at Research Farm, AICRP on weed management, SKUAST-Jammu. The experiment was conducted in randomized block design with four replication. All the herbicides were applied by using a Knapsack sprayer fitted with flat-fan nozzle with spray volume of 500 litres water/ha. Butachlor, pretilachlor and anilophos were applied 3 days after transplanting in standing water of 5 cm and water level was maintained up to two weeks after herbicide application. Bispyribac-sodium and chlorimuron + metsulfuron were applied at 30 days after transplanting after draining water. Data on weed density and biomass of weeds were recorded at 60 days after transplanting of rice crop by using 1 m × 1 m quadrate and the data were subjected to square root transformation by adding 1 to original values prior to statistical analysis.

RESULTS

The most dominant weed species found in experimental field during crop growth period were mainly *Echinochloa* spp. and *Cynodon dactylon* amongst grassy weeds, *Alternanthera philoxeroides*, *Ammania baccifera, Commelina benghalensis, Caesulia axillaries* amongst broad leaved weeds, *Cyperus* spp. amongst sedges and *Eclipta alba, Marsilea quardifolia, Ludwigia* spp. and *Sphenoclea zeylanica* amongst other weeds. All the herbicidal treatments significantly reduced the density and biomass of weeds in comparison to weedy cheek. However, anilofos 0.4 kg/ha fb bispyribac 25 g/ha recorded the lowest density and biomass of total weeds whereas, the highest total weed density and biomass were recorded in pretilachlor 0.75 kg/ha fb chlorimuron + metsulfuron @ 4 g/ha. Different weed management treatments had non-significant effect on plant height of rice. All herbicidal treatments recorded significantly higher crop dry matter and rice grain yield (2.79–3.06 t/ha) as compared to that recorded in weedy check. Pre-emergence application of herbicides effectively controls the weeds at early stages of crop growth followed by post-emergence application of herbicides controls the late coming weeds. The findings of the present study are in accordance with those of Kiran *et al*. (2010). However, anilofos 0.4 kg/ha fb bispyribac 25 g/ha recorded the highest grain yield whereas, the lowest grain yield was recorded in pretilachlor 0.75 kg/ha fb chlorimuron + metsulfuron 4 g/ha.

CONCLUSION

On the basis of one year it may be concluded that butachlor 1.5 kg/ha or pretilachlor 0.75 kg/ha or anilophos 0.4 kg/ha as pre-emergence followed by bispyribac 25 g/ha or chlorimuron + metsulfuron 4 g/ha as post emergence may be used for weed control in transplanted basmati rice for higher grain yield.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Nutrient uptake study of potato preceding by green manuring crops

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A field experiment was conducted for two consecutive years at Post Graduate Institute Research Farm of Mahatma Phule Krishi Vidyapeeth Rahuri during 2013–14 and 2014–15 to study the performance of nutrient management, nutrient uptake pattern of potato preceding by green manuring crops. The experimental results showed that, under residual effect (green manuring crop as dhaincha)–potato crop recorded significantly higher uptake of nitrogen, phosphorus and potassium whereas under nutrient management treatments, 100% GRDF recorded significantly higher uptake of nitrogen, phosphorus and potassium by potato crop (tuber as well as haulm) after harvest of potato than rest of other treatments during both the years, however it was at par with the treatment of 100% RDF during both the years. Incorporation of dhaincha at 50% flowering stage as a green manuring crop in *kharif* season followed by growing of potato in *rabi* season with 100% general recommended dose of fertilizers (GRDF-120 : 60 : 120 N, P_2O_5, K_2O kg/ha + 20 tons of farmyard manure/ha) found superior for recording higher potato yield.

Green manure legumes can play an important role in the soil fertility improvement, when incorporated into the soil, improves soil organic matter, moisture retention capacity and soil workability (Kiiya *et al.*, 2010). Green manuring being a low cost practice, is an alternate way to improve soil fertility status. Potato (*Solanum tubersum* L.) is one of the most important vegetable crop after wheat, maize and rice, contributing to food and nutritional security in the world. In India potato is cultivated on an area of 20.32 lakh ha, production 46.61 million MT with an average productivity of 22.9 MT/ha during the year 2013–14. Fertilization and manuring plays a crucial role in potato production. Combined use of fertilizer with organic with inorganic sources improves the productivity and giving higher returns per unit area per unit time (Chettri *et al.*, 2002). Potato producers are using green manures to produce better crops by improving the quality of their soils. The nutrient uptake pattern of crops, physical, biological, and some chemical characteristics of soil may be improved by green manures.

METHODOLOGY

The field experiment was conducted for two consecutive years at Post Graduate Institute Research Farm of Mahatma Phule Krishi Vidyapeeth Rahuri during 2013–14 and 2014–15. The tract is in the shadow area, lying on eastern side of western ghat. The experiment was carried out in split-plot design with three replication. The net plot size was 2.40 m × 3.60 m (8.64 m^2). The green manuring crops were kept in main plots (*kharif* season) and nutrient management levels kept in sub plots (*rabi* season). The main plot treatments (*kharif* season) comprised of four green manuring crop, viz. G_1 : sannhemp, G_2 : dhaincha, G_3 : cowpea, G_4 : greengram while the sub-plot treatments (*rabi s*eason) consisted of four nutrient management levels, viz. F_1 : 100% GRDF (120 : 60 : 120 N, P_2O_5, K_2O kg/ha + 20 t/ha of FYM, F_2 : 100% RDF (120 : 60 : 120 N, P_2O_5, K_2O kg/ha), F_3 : 75% RDF (90 : 45 : 90 N, P_2O_5, K_2O kg/ha), F_4: 50% RDF (60 : 30 : 60 N, P_2O_5, K_2O kg/ha). A common seed treatment with *Azotobactor* + PSB) given to all treatments of potato. The recommended packages of practices were followed to potato crop. The potato was planted after incorporation of green manuring crops. The plant uptake nitrogen was analysed by Microkjeldhal's method, phosphorus by Vanado-phosphomolybdate yellow colure in nitric acid and potassium by Flame photometer method. The total green biomass of green manuring crops will be recorded by using one m^2 quadrate. For economic evaluation, the cost of cultivation, gross monetary returns (GMR), net monetary returns (NMR) and benefit: cost ratio (B : C) of 2013–14 and 2014–15 and pooled were computed treatment wise.

RESULTS

Residual effect of dhaincha recorded significantly maximum total potato yield (t/ha), i.e. 29.07, 31.81 and 30.44 (t/ha) during first year, second year and on pooled mean, respectively. Whereas, nutrient management treatment like 100% GRDF recorded significantly higher total potato yield 32.01, 31.52 and 28.52 (t/ha) during first year, second year and on pooled mean, respectively (Table 1). Same trend was recorded in case of dry haulm yield of potato. The interaction effect found significant in case of potato as well as dry haulm yield. This might be because of beneficial residual effect of *kharif* dhaincha as a green manuring crop by fixing atmospheric nitrogen through biological means and which may be available to mineralization of plant residues thereby increases the growth and yield of succeeding crop. These results are in agreement with those reported by Khan *et al.* (2010) and Tanveer *et al.* (2013).

Residual effect of green manuring crop as dhaincha recorded significantly higher uptake of nitrogen, phosphorus and potassium by potato tuber as well as haulm after harvest of potato over rest of treatments during both the years, however it was at par with treatment residual effect of sunhemp during both the years except phosphorus uptake by tuber during first year. Nutrient uptake after harvest of potato crop was influenced significantly due to different

Table 1. Total potato yield (t/ha) and dry haulm yield (q/ha) as influenced by different treatments

Treatment	Total potato yield (t/ha)			Dry haulm yield (q/ha)		
	2013–14	2014–15	Pooled mean	2013–14	2014–15	Pooled mean
A. Green manuring crops						
G_1- Sunnhemp	27.88	29.16	28.52	17.59	17.72	17.65
G_2- Dhaincha	29.07	31.81	30.44	18.52	18.55	18.53
G_3- Cowpea	26.88	26.72	26.80	15.78	15.80	15.79
G_4- Greengram	26.79	28.17	27.48	18.68	18.71	18.70
S.Em ±	0.24	0.87	0.56	0.15	0.13	0.14
C.D. at 5%	0.85	3.02	1.94	0.51	0.44	0.48
B. Nutrient management levels						
F_1- 100% GRDF	32.01	31.52	31.77	20.98	21.01	21.00
F_2- 100% RDF	29.41	30.47	29.94	18.65	18.79	18.72
F_3- 75% of RDF	24.91	27.72	26.31	16.22	16.25	16.24
F_4- 50% of RDF	24.29	26.16	25.22	14.71	14.73	14.72
S.Em ±	0.21	0.56	0.39	0.24	0.23	0.24
CD at 5%	0.62	1.63	1.13	0.70	0.67	0.69
C. Interaction (A × B)	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
General mean	27.65	28.97	28.31	17.64	17.7	17.67

Table 2. Nutrient uptake of potato as influenced by different treatments after harvest of potato (2013–14)

Treatment	Nutrient uptake (kg/ha)					
	Nitrogen		Phosphorus		Potassium	
	Tuber	Haulm	Tuber	Haulm	Tuber	Haulm
A. Green manuring crops						
G_1- Sunnhemp	269.76	2.78	30.99	1.10	263.31	5.55
G_2- Dhaincha	273.24	2.84	33.99	1.17	272.36	5.59
G_3- Cowpea	252.38	2.51	30.19	0.96	241.01	4.51
G_4- Greengram	241.37	2.40	29.91	1.08	240.29	4.44
S.Em ±	4.42	0.04	0.29	0.02	3.76	0.22
CD. at 5%	15.31	0.13	1.01	0.08	13.01	0.77
B. Nutrient management levels						
F_1- 100% GRDF	277.36	2.75	34.71	1.22	263.71	5.81
F_2- 100% RDF	265.63	2.61	33.71	1.16	256.14	5.47
F_3- 75% of RDF	248.15	2.65	26.50	1.05	247.22	5.30
F_4- 50% of RDF	235.61	2.52	30.15	0.99	249.90	4.61
S.Em ±	9.56	0.04	0.67	0.03	3.92	0.26
CD. at 5%	27.90	0.12	1.94	0.08	11.43	0.77
C. Interaction (A×B)	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
General mean	257.19	2.63	31.27	1.08	254.24	5.30

Table 3. Nutrient uptake of potato as influenced by different treatments after harvest of potato (2014–15)

Treatment	Nutrient uptake (kg/ha)					
	Nitrogen		Phosphorus		Potassium	
	Tuber	Haulm	Tuber	Haulm	Tuber	Haulm
A. Green manuring crops						
G_1- Sunnhemp	294.30	3.70	47.70	2.07	382.79	7.78
G_2- Dhaincha	297.85	3.77	48.71	2.17	394.89	7.96
G_3- Cowpea	276.61	3.37	43.63	1.91	352.98	6.94
G_4- Greengram	265.39	3.24	43.25	2.04	352.02	6.43
S.Em ±	4.51	0.05	0.39	0.03	5.02	0.27
CD at 5%	15.59	0.16	1.34	0.10	17.39	0.95
B. Nutrient management levels						
F_1- 100% GRDF	302.05	3.67	49.67	2.23	383.33	8.11
F_2- 100% RDF	290.10	3.54	48.33	2.14	368.87	7.69
F_3- 75% of RDF	272.48	3.50	38.70	2.02	361.28	7.08
F_4- 50% of RDF	259.52	3.38	43.57	1.95	363.21	6.63
S.Em ±	9.74	0.05	0.89	0.03	5.24	0.32
CD at 5%	28.42	0.15	2.60	0.10	15.28	0.95
C. Interaction (A×B)	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
General mean	282.54	3.52	45.07	2.05	370.67	7.48

nutrient management treatments during both the years of experimentation. Treatment 100% GRDF recorded significantly higher uptake of nitrogen, phosphorus and potassium by potato tuber as well as haulm after harvest of potato than rest of other treatments during both the years, however it was at par with the treatment 100% RDF during both the years. This might be due to combine residual effect of dhaincha as a green manuring crop along and higher level of fertilizer to the succeeding crops increase the availability of nutrients in the root rhizosphere, leads increase uptake of nutrients through the crop growth period. As the nutrient uptake depends upon the soil pH, oxidation potential, rhizoposition, nutrient concentration and root exudates. Also the chemical changes in the root rhizosphere were significantly influenced on nutrient solubility and uptake by plants. This result was in accordance with findings of Chauhan *et al.* (2014).

CONCLUSION

It may be concluded from the finding of this study based on the two years experimentation incorporation of dhaincha at 50% of flowering stage as a green manuring crop in *kharif* season and application of 100% general recommended dose of fertilizers (RDF-120 : 60 : 120 N P_2O_5 K_2O kg/ha + 20 tonnes of farm yard manure/ha) to potato crop in *rabi* season found beneficial in terms of total biomass of green mannuring crops, potato yield and monetary returns.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Yield sustainability and phosphorus utilization efficiency as affected by different source of phosphorus in soybean–wheat cropping system

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Soybean–wheat crop rotation is a most profitable agricultural production system in the Indian Himalayas. Soybean and wheat crops remove about 28 and 20 kg P/ha respectively from soil (Stauffer and Sulewski, 2001). Sustained high yields require replacement of harvested nutrients, particularly on low- to medium-fertility soils. Phosphorus is one of the major nutrients needed to sustain life, which plays a central role in the functioning of biological systems. The importance of water soluble source of phosphorus (DAP and SSP)) is well established as efficient P fertilizer but they are very expensive and need to be imported. Therefore, it is the need of the hour to look for alternative source of water soluble phosphorus for small and marginal farmers. In India, about 160 mt of rock phosphate deposits are available, mostly of low-grade containing less than 20% P_2O_5 that are considered unsuitable for manufacturing commercial phosphatic fertilizers. Huge quantities of crop residues can also be a good source of plant nutrients if it is effectively recycled to agriculture by converting them into good quality manure. In this context, phosphorous enriched composting would reduce dependence on costly inorganic P fertilizers and save precious foreign exchange, besides providing an environmentally sound and economically feasible solution to problems of waste management. Keeping above facts, an experiment was conducted to study the comparative performance of different P sources on yield, sustainability and P utilization efficiency of the soybean-wheat cropping system in the NW Himalayas.

METHODOLOGY

A field experiment with soybean-wheat cropping sequence was carried out during 2008–09 to 2011–12 at ICAR-Vivekananda Parvatiya Krishi Anusandhan Sansthan, Almora- Uttrakhand. The soil of experimental field was silty clay loam with pH 4.7 organic carbon 0.55%, available N, P and K 352.4, 12.9 and 208 kg/ha, respectively, in upper 0–15 cm soil depth. The experiment was laid out in randomized block design with four replications. The experiment consisting of 5 treatments, viz. T_1- Control, T_2- Rock Phosphate, T_3- Single Super Phosphate, T_4- P-Enriched Compost, T_5- P Enriched compost (50% P) + SSP (50% P). The recommended dose of phosphorus (80 and 60 kg P_2O_5/ha) for soybean and wheat applied through different source of P as per treatment. The recommended dose of nitrogen (20 kg/ha for soybean and 100 kg/ha for wheat) and potash (40 kg K_2O/ha for both soybean and wheat) were uniformly applied through urea and muriate of potash to all the plots. The recommended packages of practices were followed to raise both the crops. Sustainable yield and value index were calculated for measuring sustainability from yield or income point of view of a cropping system under a set of management practices as per Singh *et al*. (1990).

RESULTS

Pooled analysis of soybean and wheat grain yield (4 years) indicated that application of phosphorus through SSP gave highest grain yield of soybean and wheat, which was comparable with P enriched compost and P enriched compost + SSP in soybean and wheat, respectively. However, significantly lower grain yield of soybean and wheat recorded with rock phosphate and control plot as compared to SSP, P enriched compost and P enriched compost + SSP. Response of applied phosphorus in soybean and wheat varied from 7.9 to 25.2 and 6.7 to 21.7% over the P unfertilized plot,

Table 1. Effect of different P sources on sustainable yield and value index of soybean and wheat

Treatment	Sustainable yield index		Sustainable value index	
	Soybean	Wheat	Soybean	Wheat
SSP	0.84	0.86	0.85	0.86
Rock Phosphate	0.71	0.73	0.79	0.73
P enriched compost	0.85	0.83	0.83	0.83
P enriched Compost + SSP	0.80	0.77	0.86	0.77
Control	0.68	0.66	0.73	0.66

Table 2. Effect of different P sources on agronomic efficiency (AE), Partial factor productivity (PFP), phosphorus recovery efficiency (PRE) and P harvest index (PHI) in soybean and wheat

Treatment	Soybean				Wheat			
	AE (kg grain kg/ P applied)	PFP (kg grain yield kg/P applied)	PRE (%)	P harvest Index (%)	AE (kg grain kg/ P applied)	PFP (kg grain yield kg/ P applied)	PRE (%)	P harvest Index (%)
SSP	19.5	93.8	19.8	71.2	36.9	205.0	38.5	57.8
Rock phosphate	5.9	80.2	6.3	71.8	10.4	178.0	10.5	55.6
P enriched compost	16.4	90.7	13.1	72.2	31.4	199.0	32.5	57.3
P enriched compost + SSP	13.9	88.2	15.0	72.9	21.3	189.0	23.3	55.8

respectively. Among different phosphorus sources highest response observed with SSP and response of applied phosphorus was more in soybean as compared to wheat. The sustainability of different sources of phosphorus analysed for the last four years for soybean- wheat cropping system (Table 1). In soybean highest sustainable yield index (0.85) and sustainable value index (0.86) observed with P enriched compost and P enriched compost + SSP, respectively. A high sustainable yield index indicate more progressive management practice capable of producing high yield over a period of 4 years**.** It indicate that the minimum guaranteed yield and value obtained from P enriched compost and P enriched compost + SSP is 85 and 86 percent, respectively However, in wheat crop highest sustainable yield index (0.86) and sustainable value index (0.86), observed with SSP. Agronomic efficiency (AE), Partial factor productivity (PFP), and recovery efficiency of nutrient are useful measure of nutrient utilization efficiency as it provides an integrative index that quantifies total economic output relative to the utilization of all nutrient resources in the system. Among the different P sources, SSP had highest (19.5 and 36.9 kg grain/ kg P applied) agronomic efficiency followed by P enriched compost and lowest with rock phosphate in soybean and wheat, respectively. Agronomic efficiency of applied phosphorus was more in wheat than soybean. Similarly, highest partial factor productivity (PFP) and phosphorus recovery efficiency (PRE) observed with SSP followed by P enriched compost in both crops, except PRE in soybean (Table 2). The performance of rock phosphate was very poor than SSP, P enriched compost and SSP + P enriched compost in both the crops. The difference in phosphorus-recovery efficiency under different sources may be due to availability of water soluble phosphorus and the lack of luxury consumption of phosphorus (Ogoke *et al*., 2006). Partial factor productivity (PFP)) varies from 80.2 to 93.8 and 178 to 205 kg grain yield/kg P applied in soybean and wheat, respectively. However, highest P harvest index was recorded with P enriched compost + SSP (72.9%) and SSP (57.8%) followed by P enriched compost (72.2 and 57.3%) in soybean and wheat, respectively. PHI is the ratio of removal of P by grain to removal of P by the whole plant. Better P nutrition caused higher content of P in grain and straw, resulting ultimately in higher grain yield. Thus it almost followed the same trend as grain yield and the highest and lowest values corresponded to the highest and lowest grain yields respectively.

CONCLUSION

Application of SSP resulted in the highest pooled grain yield of soybean and wheat, which was comparable with P enriched compost. The maximum agronomic efficiency was obtained under SSP followed by P enriched compost in soybean and wheat. Highest partial factor productivity and phosphorus recovery efficiency was observed with SSP followed by P enriched compost + SSP and P enriched compost in soybean and wheat, respectively. Overall, the performance of P- enriched compost was equivalent or comparable with respect to crop yield, sustainability and phosphorus utilization efficiencies. Therefore, results clearly suggest that P enriched compost can be used as an alternative source of P instead of SSP under soybean–wheat cropping system in NW Himalayas.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Productivity and economics of spring planted sugarcane (*Saccharum* spp.) varieties as influenced by nutrient management in clay loam soil of eastern Rajasthan

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Sugarcane (*Saccharum* spp. Hybrid complex) is an important commercial crop in India being cultivated on 5.06 million ha, with an average productivity of 66.9 ton/ha. We are also the second largest producer of sugarcane in the world after Brazil. It is also important cash crop of Rajasthan which is grown on 5375 ha area, with an average productivity of 73.10 ton/ha (Anonymous, 2015). Imbalanced nutrient use especially NPK, adoption of old variety and planting time in the prevalent cropping system is the major reason responsible for low yield. Yield potential of different sugarcane varieties may differ under different agro-climatic conditions because of their inherent capabilities for adaptation. Under the present situation, application of balanced fertilizers especially NPK is an important management practice for increasing sugarcane yield and sugar production without deterioration soil fertility. Hence, an attempt has been made in the present study to find out sugarcane varieties suitable for spring planting season and optimize fertilizer needs for improving productivity and quality of sugarcane.

A field experiment was conducted during the spring seasons of 2012–13, 2013–14 and 2014–15 at Agricultural Research Station, Ummedganj, Kota to study the effect of nutrient management on yield attributes, cane yield, quality and economics of sugarcane varieties under spring planting seasons in clay loam soil of eastern Rajasthan. It was laid out in randomized block design with using four sugarcane varieties, viz. 'Co 06033, CoLK 07201, CoH 06247 and CoPK 05191' and three levels of nutrient management of NPK 150 : 45 : 30, 200 : 60 : 40 and 250 : 75 : 50 kg/ha with 3 replications. The experiment soil was clay loam having pH 8.1, medium in organic carbon (0.56%), available nitrogen and P_2O_5 (352 and 23.8 kg/ha) and high in available K_2O (282 kg/ha). Sugarcane was planted as spring in the last week of February respectively years and harvested in the respectively years after attaining 11–12 month old crop. Farm yard manure at 10 ton/ha was incorporated uniformly over the field before last plouging. Full dose of PK and ¼ N were applied as basal per treatments and remaining N in 3 equal splits were top dressed on 30 and 60 days after planting and earthing up, i.e. on onset of monsoon. Gross plot area for each treatment was 27 m^2. All the agronomic and plant-protections were carried out uniformly as and when required. The average annual rainfall received during crop season was about 851.52 mm. Yield attributes, cane yield and quality parameter were workout as per standard procedure whereas, economics was worked out on prevailing market prices.

RESULTS

Pooled data of the three seasons (Table 1) indicated that number of millable canes (122,440/ha) and cane yield (97.55 t/ha) were recorded significantly higher with the variety 'CoH 06247'over 'CoLK 07201', 'CoPK 05191' and 'Co 06033', respectively, being 16.97, 8.87 and 7.22% higher in cane yield than its, owing to higher number of millable canes and optimum canes weight at harvest. Kumar *et al*. (2012) also reported similar findings. Variety 'CoPK 05191' also showed the highest pol % in juice (18.61%) and commercial cane sugar yield (11.49 t/ha) which was significantly superior to rest of varieties. This could be ascribed to its genetic potential compared to other varieties. The results indicated that maximum benefit from higher sugar produced variety 'CoPK

Table 1. Number of millable cane, cane yield, quality and economics of spring planted sugarcane as by influenced by varieties and nutrient management (pooled data of 3 years)

Treatment	NMC ($\times10^3$/ha)	Cane yield (t/ha)	Pol% in juice	CCS (t/ha)	Net return ($\times10^3$/ha)	B:C ratio
Varieties						
Co 06033	120.41	90.98	17.19	10.65	107.47	2.06
CoLK 07201	105.27	83.40	16.75	9.55	90.03	1.88
CoH 06247	122.44	97.55	17.01	11.36	122.57	2.20
CoPK 05191(c)	116.81	89.60	18.61	11.49	104.30	2.02
SEm ±	1.95	2.15	0.18	0.31	3.86	0.10
CD (P=0.05)	5.50	6.06	0.52	0.87	11.76	0.28
Nutrient management ($N:P_2O_5:K_2O$ kg/ha)						
150:45:30	107.65	82.83	17.11	9.77	90.44	1.88
200:60:40	119.02	92.86	17.33	10.94	111.77	2.10
250:75:50	122.00	95.49	17.73	11.56	117.82	2.16
SEm ±	2.78	2.42	0.36	0.37	4.27	0.09
CD (P=0.05)	7.84	6.83	NS	1.05	12.43	0.26

05191' could be harvested in December/January under spring planting situation. Among the varieties, significantly higher net return (₹ 122,570/ha) and B : C ratio (2.20) was obtained with variety 'CoH 06247', followed by 'Co 06033', owing to higher cane yield. There were differences in cost of cultivation and net return owing to different variable costs.

Nutrient management had significant impact on number of millable cane, cane yield and sugar yield. Millable cane (119,002/ha), cane yield (92.86 t/ha), sugar yield (10.94 t/ha), net return (1, 11,770 /ha) and B: C ratio (2.10) were significantly higher in the treatment receiving 200 : 60 : 40 kg NPK/ha over 150 : 45 : 30 kg NPK/ha and on par with 250 : 75 : 50 kg NPK/ha, respectively. Significantly higher millable canes and yield with nutrient management level of 200 : 60 : 40 kg NPK/ha was primarily due to the improved fertility status of the soil created congenial environment for better growth and development of sugarcane plant. Navnit Kumar (2012) also reported similar results. Nutrient management did not cause significant variation in pol % in juice. There was significantly improvement in net return with each successive increase in fertilizer level of NPK from 75% to 125% of RD, indicating the response of NPK was found positive trending upto NPK level of 250 : 75 : 50 kg/ha in spring planted crop. The results confirm the findings of Kumar *et al.* (2012).

CONCLUSION

Thus, It may be concluded that either application of NPK 200 : 60 : 40 kg/ha or 250 : 75 : 50 kg/ha were recommended for getting higher yield and monetary return with benefit: cost ratio. Among the varieties, 'CoH 06247' has a great promise for increased productivity and profitability of sugarcane, owing to higher number of millable canes and

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Wheat productivity as influenced by nutrient management and planting systems

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A field experiment was conducted at NBPGR, New Area Farm, IARI, New Delhi during rabi seasons to developed improved wheat and soil production system through integrated nutrient management (INM) and different planting system (EPS) in split plot design with 20 treatment combinations. Treatments consisted of two planting systems (conventional and FIRB) and 10 fertility treatments viz., control, RDF, 75% RDF + FYM, 75% RDF + FYM + Zn, 75% RDF + FYM + biofertilizer (BF) , 75% RDF + FYM + BF + Zn, RDF + FYM, RDF + FYM + Zn, RDF + FYM + BF and RDF + FYM + BF + Zn. The yield contributing characters of wheat, viz. number of spikes/plant and number of grains/spike were recorded significantly higher when the crop was supplied with combined application of RDF or 75% RDF along with FYM, biofertilizer and zinc over control and treatment receiving RDF only. In case of wheat yield, 10.8 and 11.3% higher yield registered with FIRB planting system over conventional system during 2007–08 and 2008–09. The increase in grain yield with application of RDF + FYM + BF + Zn over RDF alone was 16.8 and 14.1% during 2007–08 and 2008–09, respectively. No significant difference between planting systems was recorded in respect of available nitrogen, phosphorus, potassium and organic carbon status of soil after harvest of crop. The FIRB system of planting and combined application of RDF or 75% RDF along with FYM, biofertilizers and zinc not only gave higher productivity and profitability of wheat but also have positive effect on soil physico-chemical properties which resulted into better rhizospheric environment.

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Productivity and economics of wheat in pearlmillet–wheat cropping system as affected by various nutrient sources in sandy loam soils

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Pearlmillet–wheat cropping system is a popular double cropping system in sandy loam soils of arid and semi-arid areas. This cropping system is followed in an estimated area of 2.26 million ha area in India and contribution of this cropping system in total food grain production is considerably large. Integrated use of organic and inorganic sources of nutrients plays an important role for sustaining the productivity of soil and crops in an intensive cropping system in north-western India. The nature of both the crops poses a great challenge for sustainable productivity of these crops. Since pearlmillet and wheat are exhaustive crops for soil nutrients, replenishment of nutrients on regular basis becomes important aspect of management for sustainability. Research in India has indicated the need for integrated use of organic and inorganic manures for sustaining the productivity of soil and crop in an intensive cropping system (Hegde and Babu, 2004). This approach restores and sustains soil health and productivity in the long run besides meeting the nutritional deficiencies. Limited information is available on productivity and economics aspects in wheat under system base research. It is being realized that pearlmillet-wheat cropping system research in sandy loam soils on nutrient application is need of the hour for optimizing the use of different sources of plant nutrients. Present study was, therefore, undertaken to assess the effect of integrated nutrient management system on crop productivity and economics of wheat in pearlmillet-wheat cropping system in sandy loam soil conditions of Haryana.

METHODOLOGY

The field experiments were carried out in permanent laid out research plots in Agronomy Research Area at CCS Haryana Agricultural University, Hisar during the year 2013–14. The soil of the experimental site was sandy loam in texture, having pH 7.87, poor in available nitrogen (191.53 kg/ha), low in phosphorus (17.25 kg/ha) and rich in potassium (288 kg/ha). The experiment was laid out in randomized block design with 12 treatment combinations replicated thrice. The treatments were: T_1- Control (no fertilizer); T_2- 50% recommended NP to pearlmillet and wheat through fertilizers; T_3- 50% recommended NP to pearlmillet and 100% recommended NP to wheat through fertilizers; T_4- 75% recommended NP to pearlmillet and wheat through fertilizers; T_5- 100% recommended NP to pearlmillet and wheat through fertilizers; T_6- 50% NP through fertilizers + 50% N (farmyard manure) to pearlmillet and 100% NP to wheat through fertilizers; T_7- 75% NP through fertilizers + 25% N (farmyard manure) to pearlmillet and 75% NP to wheat through fertilizers; T_8- 50% NP + 50% N (wheat straw) to pearlmillet and 100% NP to wheat through fertilizers; T_9- 75% NP + 25% N (wheat straw) to pearlmillet and 75% NP to wheat through fertilizers; T_{10}- 50% NP + 50 per cent N (*Sesbania* spp.) to pearlmillet and 100% NP to wheat through fertilizers; T_{11}- 75% NP + 25% N (*Sesbania* spp.) to pearlmillet and 75% NP to wheat through fertilizers and T_{12}- farmers' practice.

RESULTS

It is clear that significantly highest yield was obtained in T_6 (3,012 kg/ha) and at par with T_5 (2,935 kg/ha) recoded 209% higher grain yield over control (Table 1) and significantly better over rest of the treatments. Biological yield was also recorded highest in T_6 (10,843 kg/ha). This might be due to easy availability of plant nutrients and higher photosynthetic activities as compared to under dose fertilized treatments. Yield components, viz. length of spike (12.2 cm) and grains/spike (44.0) were found higher when 50% RD-NP + 50% N through FYM in pearlmillet and 100% RD-NP in wheat. This could be attributed to the supply of most of the required macro and micro nutrients in adequate amount for a long time due to slow release of nutrients by the FYM. Grain and straw yield increased significantly with the application of fertilizer upto recommended dose (Table 2). T_6 produced 369% higher yield over control, 55% over T_2 (50% RD-NP in pearlmillet and 100% RD-NP in wheat). The highest harvest index (47.17) recorded in T_4 indicated that the increase in grain yield rather than straw yield could be due to more translocation of photosynthates from source to sink. Highest net returns (₹ 84,518/ha) and B : C (2.52) was obtained with the application of 50% RD-NP + 50%N through FYM in pearlmillet and 100% RD-NP in wheat.

Table 1. Effect of different treatments on biological and grain yield (kg/ha) of pearlmillet

Treatments	Seasons		Grain yield	Biological yield
	Kharif	*Rabi*		
T_1	Control (no fertilizer)	Control (no fertilizer)	976	3,220
T_2	50% rec. N and P through fertilizers	50% rec. N and P through fertilizers	1,814	6,076
T_3	50% rec. N and P through fertilizers	100% rec. N and P through fertilizers	1,932	6,607
T_4	75% rec. N and P through fertilizers	75% rec. N and P through fertilizers	2,412	8,273
T_5	100% rec. N and P through fertilizers	100% rec. N and P through fertilizers	2,935	10,272
T_6	50% rec. N and P through fertilizers + 50% N through FYM	100% rec. N and P through fertilizers	3,012	10,843
T_7	75% rec. N and P through fertilizers + 25% N through FYM	75% rec. N and P through fertilizers	2,704	9,355
T_8	50% rec. N and P through fertilizers + 50% N through wheat straw	100% rec. N and P through fertilizers	2,824	9,827
T_9	75% rec. N and P through fertilizers + 25% N through wheat straw	75% rec. N and P through fertilizers	2,472	8,503
T_{10}	50% rec. N and P through fertilizers + 50% N through green manure	100% rec. N and P through fertilizers	2,841	9,915
T_{11}	75% rec. N and P through fertilizers + 25% N through green manure	75% rec. N and P through fertilizers	2,575	8,883
T_{12}	Farmers' practice = (N, P = 49.125, 15.175 kg/ha) FYM = 37.8 q/ha.	Farmers' practice = (N, P, K = 156.25, 58.575, 3.7 kg/ha) FYM =25.1 q/ha $ZnSO_4$ = 8.4 kg/ha	2,768	9,604
	SEm±		29.3	245.8
	CD (P=0.05)		86.4	725.7

Table 2. Effect of different treatments on the yield attributes, yield and economics of wheat

Treatments	Spike length (cm)	Grains/spike	Grain yield (kg/ha)	Straw yield (kg/ha)	Harvest index (%)	Net returns (₹/ha)	B:C
T_1	6.6	29.7	1190	1309	46.73	-7,903	0.81
T_2	8.0	34.0	3610	4188	46.29	42,259	1.93
T_3	8.8	37.2	4649	5253	46.95	59,331	2.26
T_4	8.6	35.8	4640	5196	47.17	66,685	2.43
T_5	11.5	41.1	5490	6560	45.56	81,734	2.48
T_6	12.2	44.0	5582	6687	45.49	84,518	2.52
T_7	10.0	38.8	5036	5841	46.29	75,179	2.51
T_8	10.8	40.0	5127	6049	45.87	66,287	2.06
T_9	9.2	38.0	4742	5405	46.73	61,969	2.14
T_{10}	11.0	40.0	5421	6450	45.66	78,522	2.41
T_{11}	9.6	38.4	4749	5461	46.51	67,841	2.33
T_{12}	10.4	39.2	5085	5949	46.08	75,152	2.45
SEm±	0.2	0.7	16.0	27.5	0.001	–	–
CD (P=0.05)	0.5	2.0	47.3	81.1	0.002	–	–

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Direct and residual effects of organic and inorganic sources of nutrients on wheat productivity and profitability under urdbean (*Vigna mungo*)–wheat (*Triticum aestivum*) cropping sequence in vertisols of Rajasthan

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Sustainability and stability of any cropping system is that the crops engaged in rotation should complete their life cycle or the period of economic viability in the available time frame. The time used by the crops for growth and yield is determined by the inherent ability of the plant to translate the available resources to the economic yield. Hence, development of short duration, synchronous maturity and photo-insensitive varieties of urdbean has provided the necessary opportunity to expand the more area under pulse crops. Urdbean meet their N requirement through its biological fixation, making less demand for soil N, and thus allowing wheat crop to have larger share of soil N (Yadav, 1982). Inclusion of legumes in crop sequence increased the soil fertility and consequently the productivity of succeeding cereal crops. Farmyard manure (FYM) although not useful as a sole source of nutrients, is however a good complementary and supplementary source with mineral fertilizers (Chaudhary *et al.,* 2004). The management of farmyard manure and phosphorus is considered for cropping system as a whole rather than for individual crop because they cannot be fully utilized by the crop to which these are added and a substantial amount is left into the soil for subsequent crops and their residual effects thus become an important dimension for their management (Ali and Mishra, 2000). As information on these aspects is lacking in urdbean-wheat crop sequence, the present investigation was carried out in humid south eastern plains zone of Rajasthan.

METHODOLOGY

The experiment was conducted at Agricultural Research Station of the Agriculture University, Kota (Rajasthan), during the rainy (*kharif*) and winter (*rabi*) seasons of 2009–10 to 2011–12. The soil of the experimental field was clay loam, slightly alkaline in reaction (pH 7.5), poor in organic carbon (4.1 g/kg), low in available N (278.5 kg/ha), P (8.94 kg/ha), sulphur (16.1 kg/ha) and medium in available K (242.8 kg/ha). The treatments comprised 2 levels of farmyard manure (0 and 5 tons/ha) and 3 levels of P (0, 8.7 and 17.4 kg P/ha) applied to urdbean and 3 levels of nitrogen (50, 75 and 100% of recommended dose of nitrogen (RDN), i.e. 60, 90 and 120 kg/ha applied to wheat. The experiment was laid out in factorial randomized block design and replicated three times. The site was same for 3 consecutive years. Well-decomposed farmyard manure having 0.42, 0.9 and 0.36% average content of total N, P and K, respectively was applied nearly 1 week before sowing of urdbean as per treatment and succeeding wheat var. 'Raj 4037' was sown in the second week of November during 3 consecutive years.

RESULTS

Pooled data of 3 years revealed that application of farmyard manure @ 5 tons/ha significantly increased plant height, dry matter/plant, effective tillers/mrl, spike length, grains/spike, test weight, grain yield, net return and B : C ratio compared to without farmyard manure (Table 1). There were 25.1 and 35.2 per cent increase in grain yield and net return over without farmyard manure. Higher growth, yield attributes and yields might be owing to better growth and metabolism of carbohydrates which readily translocated to the reproductive parts under farmyard manure application.

The residual effect of phosphorus was evident on growth, yield attributes and yield of wheat in 3 consecutive years. Application of phosphorus 17.4 kg P/ha to the preceding urdbean significantly increased the growth (plant height and dry matter/plant), yield attributes (effective tillers/mrl, spike length, grains/spike) as well as grain yield, net return and B: C ratio of succeeding wheat compared to 8.7 kg P/ha and no phosphorus application (control). The residual effect of 17.4 kg P/ha was quite more pronounced, and resulted in 7.0 and 35.0 and 9.3 and 33.6 per cent higher grain yield and net return over 8.7 kg P/ha and no phosphorus application, respectively. This might be owing to better proliferation of roots and absorb more nutrients from deeper soil layers. Results corroborate the findings of Shrivastava *et al.*, 2003.

The direct application of recommended dose of nitrogen 120 kg/ha significantly increased the growth (plant height & dry matter/plant) and yield attribute (spike length) compared with lower levels of RDN whereas, effective tillers/mrl, grains/spike, grain yield, net return and B : C ratio being on par with that of 90 kg N/ha, significantly increased over 60

Table 1. Effect of organic and inorganic fertilizers on growth, yield attributes, yield and economics of wheat under urdbean–wheat cropping system (Pooled data of 3 years)

Treatment	Plant height (cm) at harvest	Dry matter (g)/plant	Effective tillers/ mrl (Nos)	Spike length (cm)	Grains/ spike (Nos)	Test weight (g)	Grain yield (kg/ha)	Net return (₹/ha)	B:C ratio
Organic manure									
0 t FYM/ha	67.26	2.67	62.48	8.55	34.06	35.23	4360	43,008	2.47
5 t FYM/ha	78.65	3.24	79.24	9.08	41.88	36.66	5454	58,147	3.34
SEm ±	0.73	0.03	1.38	0.07	0.53	0.16	61.9	858	0.05
CD (P=0.05)	2.05	0.10	3.88	0.19	1.48	0.45	173.2	2,401	0.14
Phosphorus levels (P kg/ha)									
0	67.68	2.68	62.70	8.50	35.20	35.45	4076	39,069	2.25
8.7	73.26	2.96	71.55	8.83	38.22	35.97	5142	53,833	3.09
17.4	77.92	3.22	78.32	9.11	40.49	36.41	5503	58,830	3.38
SEm +	0.90	0.04	1.70	0.09	0.65	0.20	75.8	1,050	0.06
CD (P=0.05)	2.52	0.12	4.76	0.26	1.83	0.55	212.3	2,939	0.17
Nitrogen levels (N kg/ha)									
50% RDN	69.46	2.78	66.12	8.55	35.64	35.67	4536	45,824	2.69
75% RDN	73.40	2.97	71.42	8.87	38.50	35.94	5000	51,874	2.98
100% RDN	76.00	3.11	75.03	9.03	39.78	36.21	5185	54,033	3.04
SEm ±	0.90	0.04	1.70	0.09	0.65	0.20	75.8	1,050	0.06
CD (P=0.05)	2.52	0.12	4.76	0.26	1.83	NS	212.3	2,939	0.17
CV (%)	6.12	7.97	11.95	5.06	8.43	2.65	7.70	10.35	10.47

kg N/ha. Over the seasons, application of 90 kg N/ha to wheat increased the grain yield and net return by 14.3 and 17.9 per cent as compared to direct application of N 60 kg/ha, respectively.

However, 100% RDN (120 kg N/ha) being at par with 75% RDN (90 kg/ha) resulted significantly higher values of all attributes than 50% RDN (60 kg/ha). The increase in yields with RDN was due to continued and balanced supply of nutrients could be attributed to higher in growth, yield attributes and ultimately the yield.

CONCLUSION

The study suggests that efficient utilization of farmyard manure @ 5 tons/ha and 17.4 kg P/ha applied in preceding urdbean crop and a substantial amount is left into the soil for sequent crop and application of 75% recommended dose of nitrogen (N_{90}) in wheat was found more remunerative and sustainable production and 25% nitrogen, i.e. 30 kg/ha could be saved in urdbean–wheat cropping system.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Integrated nutrient management in grain amaranth (*Amaranthus hypochondriacus* L.) under middle Gujarat conditions

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Grain amaranth/ Rajagira (*Amaranthus hypochondriacus* L.), a potent upcoming subsidiary food crop of the future, belonging to the family Amaranthaceae*,* is a quick growing, bushy plant with thick stalks. Being a C_4 plant, it has more efficiency of nitrogen utilization and photosynthesis (Magomedov *et al*., 1997). Besides a better source of enriched infant food, the unique features of amaranth like low water and input (25 kg N + 12.5 kg P_2O_5/ha) requirement, tolerance to moisture stress with lesser growing period and wide adaptability have created interest among the farmers for its cultivation in arid and semi-arid regions of Gujarat. Proper nutrient management is very much important for increasing the productivity of the crop. Nitrogen forms a basic input for the growth of the plant. The increasing cost of fertilizers and its scarce availability lead to incredible rise in the cost of production and thereby reduction in profit. In this aspect, the integrated nutrient management has gained importance in the present day. Chaudhari *et al*. (2009) suggested integration of cost-effective and eco-friendly bio-fertilizers with chemical fertilizers and organic manures as an alternate way for saving N fertilizers. Integration of chemical and organic sources and their effective management has shown great promise in not only sustaining the productivity and soil health but also in meeting a part of the chemical requirement of crops. Integrated use of fertilizers and organic manures not only makes higher yields possible, but also provides greater yield stability (Narain, 1999). Keeping all the above aspects in view and in order to test the integrated effect of the various nutrient sources at various levels of application on growth, yield attributes, quality, soil fertility status and economics of grain amaranth, the present field trial was conducted.

METHODOLOGY

The present field investigation was conducted during the *rabi* season of the year 2011–12 at the Agronomy Farm, Anand Agricultural University, Gujarat. Anand region has semi-arid and sub-tropical climatic feature with hot summer and cool winter. The experiment was laid out in randomized block design (RBD) with ten treatments and four replications. The treatment details (T_1 to T_{10}) of various nutrient combinations and the nutrient contents of various organic manures used were as follows: (T_1): Recommended dose of fertilizer (RDF) (25 : 12.5 : 0 kg NPK/ha). (T_2): 100% RDF + NADEP compost @ 2 t/ha, (T_3): 75% RDF + NADEP compost @ 3 t/ha mixed with *Azotobacter* and PSB (1 litre/ 10 t compost), (T_4): 50% RDF + NADEP @ 4 t/ha mixed *Azotobacter* and PSB (T_5) : 100% RDF + vermicompost @ 1 t/ha, (T_6): 75% RDF + vermicompost @ 1.5 t/ha mixed with *Azotobacter* and PSB (1 litre/10 t vermicompost, (T_7): 50% RDF + vermicompost @ 2 t/ha mixed with A*zotobacter* and PSB, (T_8): 100% RDF + vermiwash (1 : 1) foliar spray (3 time at 30, 45 and 60 DAS), (T_9): 75% RDF + vermiwash mixed with *Azotobacter* foliar spray (at 30, 45 and 60 DAS 5 ml/litre) and (T_{10}): Vermicompost @ 2 t/ha + *Azotobacter* foliar spray (at 30, 45 and 65 DAS (5 ml/litre) with four replications. All recommended agronomical practices carried out during experiment periods.

RESULTS

The plants of treatment T_7 [(50% RDF + Vermicompost at the rate of 2 t/ha mixed with *Azotobacter chroococcum* (ABA 1) and PSB)] was found to be superior in plant height at 45, 60 DAS (Table 2). The increased plant height during the later stages was mainly due to the integration of various nutrient sources as against RDF. This may be due to the constant nutrient supply through mineralization from organic sources at later stages of crop growth as compared to the initial stages. Highest value for lodging % was recorded under treatment T_5 due to the high vegetative growth, which may lead to lodging at later stages. The data revealed that the yield attributes like the panicle length, number of panicles/ plant, test weight of grains, grain and Stover yield were also significantly influenced by various treatments. Superior results were observed in treatment T_7 [(50% RDF + Vermicompost at the rate of 2 t/ha mixed with *Azotobacter chroococcum* (ABA 1) and PSB)] in panicle length (78.09 cm) and number of panicles/plant (6.69). The integrated approach was found to be superior in these aspects which were in agreement with the results of Parmar and Patel (2009) in amaranth. The grain yield (2,785 kg/ha), stover yield (6,275 kg/ha) and test weight (0.89 g) were also found to be superior with treatment T_7 Integrated nutrient management practices have resulted in higher grain and Stover yield of grain amaranth due to its influence on the plant growth and development. Prolonged availability of moisture due to organic manure, increased uptake of nutrients, release of phyto-hormones and organic acids which provides food for beneficial bacteria might have contributed to the yield. The results were in agreement with the findings of Jaybal *et al.* (1998) in maize. The significant increase in test weight was mainly due to the increase in photosynthesis and better transfer of assimilates. Highest protein content (%) was recorded in grains of treatment T_7 followed by T_2, T_5, T_3 and T_4. Higher protein content under these treatments could be due to the higher vegetative growth and yield attributing characters, which might have helped in the increased uptake of nitrogen. Application of nutrients of treatment T_7 [50% RDF along with Vermicompost at the rate of 2 t/ha mixed with *Azotobacter chroococcum* (ABA 1) and PSB] resulted in maximum residual available N, which was on par with T_5 and T_2 (Table 2). This may be attributed to the high content of nitrogen in vermicompost, applied in high quantity along with 50% RDF. Highest value of available P_2O_5 was observed on application of nutrients of treatment T_5 (100% RDF + Vermicompost at the rate of 1 t/ha), followed by T_4, T_7 and T_3. This might be due to the higher content of P_2O_5 in vermicompost supplemented with 100% RDF. Available K_2O was observed to be highest on application of nutrients of treatment T_{10} [Vermicompost at the rate of 2 t/ha + *Azotobacter chroococcum* (ABA 1) foliar spray at 30, 45 and 60 DAS], which indicated the profound influence of the combined application of organic and inorganic sources on the soil nutrient pool. The results were in agreement with the findings of Thenmozhi and Paulraj (2010) in amaranth. The effect of treatments on economics indicated that, the

Table 1. Growth attributes, soil fertility status and economics of various treatments involved

Treatments	Plant height (cm)			Lodging (%) (75 days)	Soil NPK status (kg/ha)			Economics (₹/ha)		B:C ratio
	30 DAS	45 DAS	60 DAS		N	P_2O_5	K_2O	Cost of cultivation	Net realization	
T_1	70.8	82.5	128.5	11.3	118.8	42.0	297.7	14,358	88,975	6.2
T_2	82.6	97.0	134.6	12.4	122.6	52.5	328.2	18,758	74,376	4.0
T_3	87.7	100.6	141.9	10.7	116.2	73.1	293.7	21,660	89,367	4.1
T_4	92.7	108.4	138.6	11.7	102.0	76.4	302.1	23,701	77,698	3.4
T_5	90.4	103.1	149.5	21.3	124.1	81.0	313.9	18,758	87,375	4.7
T_6	82.7	93.6	128.9	11.1	106.0	63.8	295.2	21,611	81,225	3.8
T_7	91.2	102.3	140.8	15.0	126.1	75.7	307.2	23,635	90,903	3.9
T_8	86.2	99.7	137.4	16.0	117.9	53.6	326.8	23,466	77,028	3.3
T_9	86.3	99.4	144.1	12.2	101.5	60.2	271.7	24,350	81,999	3.4
T_{10}	82.2	91.9	134.8	11.0	109.2	71.7	412.6	24,657	59,407	2.4
SEm±	4.4	4.8	3.9	0.7	4.8	1.6	16.7	–	–	–
CD(P=0.05)	NS	13.8	11.4	2.1	14.0	4.5	48.4	–	–	–

Selling price of grain: ₹ 40/kg Selling price of Stover: ₹ 0.50/kg

Table 2. Yield attributes, yield and quality parameters involved for various treatments

Treatments	Panicle length (cm)	No. of panicles/plant	Grain yield (kg/ha)	Stover yield (kg/ha)	Test weight (1000-seed wt.)	Protein content (%)
T_1	76.1	4.4	2,508.0	6,025.0	0.8	15.4
T_2	75.5	3.7	2,258.0	5,627.0	0.8	16.7
T_3	77.1	4.2	2,705.0	5,654.0	0.8	16.5
T_4	75.2	4.9	2,458.0	6,157.0	0.8	16.4
T_5	75.8	6.4	2,588.0	5,226.0	0.8	16.7
T_6	74.6	4.8	2,506.0	5,191.0	0.7	14.5
T_7	78.1	6.7	2,785.0	6,275.0	0.9	18.0
T_8	71.7	4.3	2,445.0	5,388.0	0.8	14.0
T_9	74.1	4.0	2,586.0	5,818.0	0.8	15.2
T_{10}	66.5	3.6	2,044.0	4,607.0	0.8	14.1
SEm±	2.0	0.3	101.3	279.2	0.0	0.3
CD (P=0.05)	5.7	0.9	294.1	810.4	0.1	0.8

maximum net realization to the tune of ₹ 90,903/ha was obtained on application of treatment T_7 [(50% RDF + Vermicompost at the rate of 2 t/ha mixed with *Azotobacter chroococcum* (ABA 1) and PSB)]. The increase in profit was mainly due to the high grain and stover yield. But the maximum B : C ratio was obtained on application of RDF, which may primarily be due to the low cost of cultivation. ANOVA values indicated significant difference between various treatments for the parameters studied in the current experiment.

CONCLUSION

The results of the study indicate that the integrated nutrient management system as the best system for raising grain amaranth, not only in terms of economics but also with respect to growth, quality parameters and soil health. Though raising the crop with RDF alone has economic benefits, but considering the sustainability in crop production, the integrated approach can be a better option for the successful raising of grain amaranth under middle Gujarat conditions. Of the various integrated treatments, application of nutrients of treatment T_7 [(50% RDF along with vermicompost at the rate of 2 t/ha mixed with *Azotobacter chroococcum* (ABA 1) and PSB)] was found to be superior to other treatments.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Tillage and nutrient options for *rabi* maize

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Rice in *Kharif* season followed by irrigated maize in *rabi* season has evolved as major cropping system in Andhra Pradesh and Telangana over the last decade. The current practice of growing puddled transplanted rice and maize with conventional, repeated tillage degrades soil structure, delays maize planting, and reduces its yield potential, increasing energy and labour requirements, ultimately leading to high production costs. Possibility of rice cultivation under irrigated dry conditions followed by maize after *kharif* rice under zero-tilled conditions offers great scope as resource conservation technology in saving time, labour, energy and cost. The sustainability of the system in terms of soil fertility is also an important criteria as this system is high yielding, input intensive, exploitative of the soil and subject to declining factor productivity and profitability (Saiful Islam *et al*., 2014). Hence, the study has taken upto evaluate the effect of tillage and nutrient options on growth, yield and nutrient use in *rabi* maize grown after *kharif* rice under conventional and zero-tillage conditions.

METHODOLOGY

A field study was conducted during *Kharif-rabi* season of 2012–14 at Maize Research Centre, Hyderabad on sandy clay loam soil with pH 7.4, low in organic carbon (0.50%) and N (220.6 kg/ha), medium in P_2O_5 (56.8 kg/ha) and high in K_2O (601.6 kg/ha) availability with three tillage options, viz. conventional tillage in rice followed by conventional tillage in maize (CT-CT), conventional tillage in rice followed by zero-tillage in maize (CT-ZT) and zero-tillage in rice followed by zero-tillage in maize (ZT-ZT) as main-plot and three nutrient options as Recommended dose of fertilizer (RDF 240-80-80 kg

N-P_2O_5-K_2O/ha, Site specific nutrient management (SSNM based on nutrient expert 140-47-56 kg N-P_2O_5-K_2O /ha) and Farmer practice (214-50-40 kg N-P_2O_5-K_2O/ha) as sub-plot treatments laid out in split-plot design and replicated thrice. During *kharif s*eason direct dry seeding of rice was grown with variety MTU 1010. In rice cultivation, CT consisted of 2 passes primary tillage by secondary tillage and leveling whereas the ZT plots are cultivated without any tillage, and seeds were sown by opening a furrow in solid rows by adopting line spacing of 20 cm. During *rabi,* maize hybrid DHM117 seed was dibbledby adopting 60 cm × 20 cm spacing .The fertilizer doses were applied for maize as per the treatments and for rice the recommended dose of fertilizers (160-60-40 kg N-P_2O_5-K_2O/ha) were applied uniformly through urea, single super phosphate and muriate of potash. Total productivity of the system was assessed in terms of maize equivalent yield. The paired T-test was employed for comparing the yield of rice during *rainy* season and maize in *winter* season laid out under split- plot design and analyzed the data by applying factorial analysis of variance.

RESULTS

The pooled data indicated that, the grain yield and nutrient uptake by *rabi* maize were significantly influenced by different tillage and nutrient practices and the maximum increment of 23.82% and 20.59% was recorded in maize grown under CT-CT (7,412 kg/ha) and CT-ZT (7,219 kg/ha) treatments and was superior over ZT-ZT treatment (5,986 kg/ha) (Fig 1). Similarly, the entire yield attributes, viz. plant population per hectare, plant height, number of cobs per hectare, cob length, cob girth, number of seeds per row and 100 seed weight were also found to be maximum for the same treatments (Table 1). These results are supported by Gangwar *et al*. (2004) and Mahesh, K.Gathala *et al*. (2010) in wheat crop after rice. The system productivity was also significantly higher with CT-CT and CT-ZT treatments.

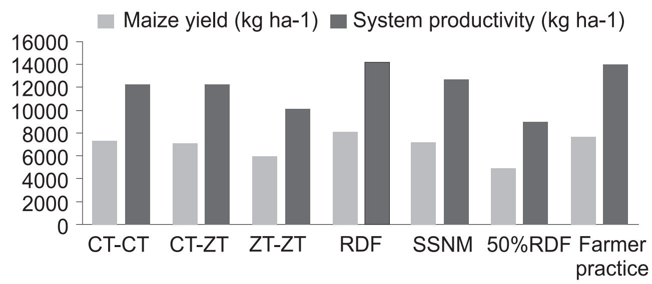

Fig. 1. Effect of tillage and nutrient options on grain yield and system productivity (kg/ha) of *rabi* maize

Table 1. Effect of tillage and nutrient options on yield attributes of *rabi*maize

Treatments	Plant population ('000 ha)	Plant height (cm)	No. of Cobs ('000 ha)	Cob length (cm)	Cob girth (cm)	No. of Seeds/row	100 Seed weight (g)	Net returns (₹ ha)	B:C ratio
Tillage practices									
CT-CT	62.0	204.4	57.8	16.0	14.6	28.0	27.0	41,936	1.77
CT-ZT	62.2	204.9	59.5	16.3	14.9	27.7	26.2	41,397	1.76
ZT-ZT	58.3	190.3	55.9	14.8	14.1	23.7	22.6	27,618	1.55
CD (P=0.05)	1.2	9.1	2.2	0.7	0.8	2.8	2.7	–	
Nutrient options									
RDF	64.3	224.4	60.8	17.5	15.5	30.2	28.9	53,193	1.98
SSNM	64.2	209.6	57.9	16.3	14.6	27.9	265	39,412	1.70
50% RDF	56.8	177.4	53.6	13.2	12.5	21.0	19.1	21,320	1.36
Farmer Practice	63.2	212.2	58.9	16.6	14.9	28.4	27.2	46,258	1.84
CD (P=0.05)	1.8	9.2	1.9	0.8	1.3	1.9	4.2	–	–
CV%	2.5	3.8	2.8	4.4	7.5	6.2	6.7	–	–

Table 2. Effect of tillage and nutrient options on nutrient uptake, soil available nutrients and organic carbon of *rabi* maize

Treatments	Nutrient uptake (kg/ha)			Soil available nutrients (kg/ha)			Organic Carbon (%)
	N	P	K	N	P_2O_5	K_2O	
Tillage practices							
CT-CT	119.2	32.4	147.8	187.2	60.3	569.4	0.52
CT-ZT	113.3	29.6	142.2	209.2	65.3	589.8	0.53
ZT-ZT	98.2	23.2	140.4	209.2	68.2	592.3	0.54
CD (P=0.05)	2.56	1.02	3.21	14.9	5.37	65.0	0.02
Nutrient options							
RDF	126.2	33.9	147.2	175.6	65.3	587.2	0.52
SSNM	115.6	27.1	138.2	167.8	67.9	568.2	0.51
50% RDF	95.4	24.2	130.4	159.6	64.2	523.2	0.51
Farmer Practice	110.8	29.6	142.2	169.6	66.8	572.6	0.52
CD (P=0.05)	3.28	0.92	3.42	13.8	1.2	63.2	0.02

Higher nutrient uptake by *rabi* maize realized under CT compared to ZT but the soil available nutrients were found to be maximum under ZT than under CT during the three years of the study. A marginal increase in organic carbon content (%) was observed with regard to ZT than with CT conditions (Table 2). Among the different nutrient options, *rabi* maize performed superior with RDF (8,261 kg/ha) followed by farmer practice (7,762 kg/ha) and SSNM (7,319 kg/ha) but superior over 50% RDF (5072 kg/ha). Maize grown with RDF under zero-tillage after rice realized comparable higher net returns and benefit cost ratios with that of conventional tillage.

From the study it is evident that, possibility of irrigated dry rice during *kharif* season followed by irrigated maize during *rabi* season under zero-tillage conditions could be a viable option in terms of productivity, cost and soil health under rice–maize cropping sequence.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Response of soybean to lime and integrated nutrient management under acidic soils of Nagaland

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Soybean (*Glycine max*. L. Merill) is an important pulse crop that is grown in diverse environments throughout the world. Being a leguminous crop, it helps to enrich the soil by fixing atmospheric nitrogen through root nodule. It is one of the most popular food items of the majority of the people of Nagaland and is utilized as a pulse crop and as a fermented product locally known 'Akhuni' or 'Axone'. Lime as an amendment for increasing nutrient availability in acid soils is considered to be the most important ameliorant for better growth, nodulation, and higher nitrogen fixation by legumes especially in north eastern states where most of the soil is acidic in nature. Soil acidity is known to induce nitrogen deficiency in legume if they depend solely on symbiotic nitrogen fixation. Soybean being a high protein and energy crop and its productivity is often limited by the low availability of essential nutrients or imbalanced nutrition forming one of the important constraints to soybean productivity in India. Hence there is an urgent need of 'Integrated Nutrient Supply and Management' system for promoting efficient and balance use of plant nutrients where the emphasis should be given on increasing the proper and balance use of mineral fertilizers, organic manures, biofertilizers, green manuring etc. The conjunctive use of fertilizers, organics and biofertilizers and their practices improve soil structure, physical properties and especially the water holding capacity of soil which could be the great asset in increasing agriculture production. Keeping in view the deteriorating soil nature due to over use of synthetic chemicals along with the need to ameliorate acidic soil particularly in Nagaland condition as well as taking into consideration the importance of soybean in the economy of the state, a field experiment was conducted to study the response of soybean to lime and integrated nutrient management under acidic soils of Nagaland with the objectives to find the most effective level of lime, nutrient management and to study the combined effect of different levels of lime treatments with different nutrient management on the growth and yield of soybean.

METHODOLOGY

A field experiment was carried out at School of Agricultural Sciences and Rural Development (SASRD), Nagaland University during the period of July to September 2015. The experimental site was located at an altitude of 25°45′43″ N latitude and 95°53′04″ E longitude at an elevation of 310 m above mean sea level. The climate of the experimental area is broadly classified as subtropical humid. The experimental design was split plot design (SPD) with three replications. The main plot treatments consists of four levels of lime: (L_1): 0 t/ha, (L_2): 0.5 t/ha, (L_3): 1.0 t/ha and (L_4): 1.5 t/ha while the sub-plot treatments consists of four sources of nutrients: (N_1): 100% RDF, (N_2): 50% RDF + FYM @ 5 t/ha + Vermicompost @ 2 t/ha , (N_3): 50% RDF + Rhizobium @ 20 g/kg seed + Phosphate solubilising bacteria (PSB) @ 20 g/kg seed and (N_4): FYM @ 5 t/ha + Vermicompost @ 2 t/ha + Rhizobium @ 20 g/kg seed + Phosphate solubilising bacteria (PSB) @ 20 g/kg seed. Soybean variety JS-9560 was sown at a spacing of 40 cm × 10 cm and the recommended package of practices were followed. The soil was sandy loam and acidic in reaction (pH 4.7). The soil contained 1.2% oxidizable organic carbon, 109 kg/ha mineralizable nitrogen, 200 kg/ha available potassium and 7.84 kg/ha available phosphorus. Fertilizers were applied uniformly to all plots at recommended rates (20 kg N/ha, 80 kg P_2O_5/ha and 60 kg K_2O/ha in the form of urea, single super phosphate and muriate of potash, respectively. Growth characters, including plant height, number of primary branches/plant, leaf area index, plant dry weight accumulation, crop growth rate, number of root nodules/plant were recorded for five randomly selected plants from the representative net plot. Different yield attributes including number of pods/plant, number of seeds /pod, test weight, seed yield, stover yield were also recorded at harvest from five randomly selected plants of the net plot area. Harvest index (%) was computed by dividing seed yield by biological yield. Surface soil samples (0–15 cm) were collected, ground, passed through a 2 mm sieve, and assayed for different physico-chemical parameters by standard methods.

RESULTS

Highest seed yield (2.71 t/ha) and stover yield (2.97 t /ha) may be due to the fact that liming helps increased in vegetative growth which resulted in increased dry matter production, excellent seed filling and ultimately seed yield and stover yield of the crop (Table 1). The addition of lime increased soil pH, an effect that may have accelerated the process of mineralization of nitrogen leading to higher growth and yield attributes of soybean. Highest pH (5.07) was recorded with the application of 1.5 t/ha. This might be due to a higher amout of exchangeable calcium concentration which replaced the exchangeable aluminium (Al^{3+}) with increasing lime levels which is in line with the findings of Verma and Singh (1996). Similarly highest available nitrogen (243 kg/ha) in the soil following liming may have resulted from an increase in soil pH that accelerated the rate of decomposition and mineralization of organic matter. Nitrogen fixation may also be increased by increasing microbial activity under a favorable soil environment. Highest available phosphorus (18 kg/ha) in the soil may be due to dissolution of complex Fe and Al phosphates, making phosphate available in the form of monocalcium phosphate. Highest available soil potassium (275 kg/ha) may be due to the fact that liming increases potassium availability, owing to the displacement of exchangeable K by Ca. Growth parameters

Table 1. Effect of lime and integrated nutrient management on number of pods/plant, number of seeds/pod, test weight, seed yield, stover yield and harvest index

Treatment	No. of pods/ plant	No of seeds/ pod	Test weight (g)	Seed yield (t/ha)	Stover yield (t/ha)	Harvest index (%)
Lime application (t/ha)						
L_1	18.40	3.08	140.44	1.52	1.87	44.86
L_2	21.37	3.12	143.03	1.81	2.14	45.84
L_3	27.04	3.24	144.67	2.21	2.57	46.16
L_4	30.26	3.28	144.87	2.71	2.97	47.67
SEm±	0.78	0.09	1.21	0.03	0.07	0.88
CD (P=0.05)	2.71	NS	NS	0.10	0.23	NS
INM						
N_1	23.02	3.16	142.84	2.05	2.36	46.02
N_2	25.25	3.24	143.62	2.07	2.43	45.79
N_3	26.35	3.33	143.91	2.14	2.46	45.80
N_4	22.48	2.98	142.64	2.00	2.29	46.91
SEm±	0.93	0.10	1.35	0.02	0.04	0.53
CD (P=0.05)	2.69	NS	NS	0.05	0.12	NS
Interaction						
L_1N_1	18.35	3.20	141.47	1.50	1.80	45.45
L_1N_2	18.52	3.20	140.18	1.51	1.94	44.04
L_1N_3	18.30	3.20	140.57	1.52	1.96	43.76
L_1N_4	18.45	2.73	139.56	1.55	1.81	46.18
L_2N_1	21.04	3.33	142.26	1.79	2.11	45.93
L_2N_2	21.75	3.07	142.00	1.81	2.15	45.63
L_2N_3	22.15	3.07	145.33	1.83	2.26	44.61
L_2N_4	20.55	3.00	142.52	1.80	2.03	47.16
L_3N_1	22.42	3.07	145.43	2.10	2.54	45.19
L_3N_2	31.93	3.33	145.67	2.20	2.60	45.82
L_3N_3	31.30	3.50	142.40	2.29	2.58	47.06
L_3N_4	22.51	3.00	145.18	2.23	2.56	46.55
L_4N_1	30.19	3.07	142.22	2.71	3.00	47.50
L_4N_2	28.81	3.36	146.63	2.76	3.03	47.65
L_4N_3	33.64	3.57	147.33	2.80	3.10	47.79
L_4N_4	28.41	3.20	143.33	2.54	2.78	47.74
SEm±(L×N)	1.85	0.208	2.69	0.04	0.08	1.05
SEm±(N×L)	2.39	0.27	3.51	0.05	0.13	1.56
CD (P=0.05) (L×N)	NS	NS	NS	0.10	0.12	NS
CD (P=0.05) (N×L)	NS	NS	NS	0.16	NS	NS

L_1= 0, L_2 = 0.5, L_3 = 1, L_4 = 1.5, N_1=100% RDF (20:80:60 NPK kg/ha), N_2= 50% RDF+ FYM @ 5 t/ha + Vermicompost @ 2 t/ha, N_3 = 50% RDF+ Rhizobium @20 g/ kg seed + Phosphate solubilising bacteria (PSB) @20 g/kg seed, N_4 = FYM @ 5 t/ ha + Vermicompost @ 2 t/ha + Rhizobium @20 g/kg seed + Phosphate solubilizing bacteria (PSB) @20 g/kg seed, NS = not significant, RDF= recommended dose of fertilizers were influenced significantly due to the different sources of nutrients where highest value of plant height (45.09 cm), number of primary branches/plant (3.94), plant dry weight accumulation (62.83 g/plant), crop growth rate (1.78 g/m^2/day) and highest number of root nodule/plant (64.98) was recorded with treatment 50% RDF + Rhizobium @ 20 g/kg seed + Phosphate solubilising bacteria (PSB) @ 20 g/kg seed. Highest number of root nodule/ plant might be due to higher number of bacteria available under *Rhizobium* inoculation and PSB which increased the symbiotic N fixation and increased the nodulation. Similarly yield attributes including number of pods /plant, seed yield and stover yield were recorded significantly with the application of 50% RDF + Rhizobium @ 20 g /kg seed + Phosphate solubilising bacteria (PSB) @ 20 g/ kg seed. Increased activity of microorganisms in root zone due to bio-inoculation was reflected in the significant improvements in growth parameters and this better growth might have possibly paved the way for significant improvements in yield contributing characters as reported by Bodkhe and Syed (2014). Highest seed yield (2.14 t/ha) and stover yield (2.46 t/ha) might be due to increased biological nitrogen fixation and solubilisation of more amount of P by phosphate solubilising bacteria and improve soil condition favourable for availability of nutrients to crop throughout the growth period. Interaction due to levels of lime and different sources of nutrients did not show any significant effect on growth attributes. However, highest seed yield (2.80 t/ha) was recorded significantly with the application of 1.5 t/ha of lime with 50% RDF + Rhizobium @ 20 g/kg seed + Phosphate solubilising bacteria (PSB) @ 20 g/kg seed and was statistically at par with the application of 1.0 t/ha of lime with 50% RDF + FYM @ 5 t/ha + Vermicompost @ 2 t /ha. This could be related to the fact that application of lime increased the Rhizobium colonies and also improved the root distribution in the soil which leads to increased seed yield.

CONCLUSION

Soil acidity problems for soybean production in Nagaland can be overcome by the combined application of 1.5 t/ha of lime with 50% RDF + Rhizobium @ 20 g/kg seed + Phosphate solubilising bacteria (PSB) @ 20 g /kg seed which increased the growth and yield attributes and also improved the soil health for soybean cultivation in acid soils of Nagaland. However, further investigation is advisable for recommendation for farming since these results are based upon only one year of investigation.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Foliar nutrition on green gram Wilczek] productivity

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Green gram is one of the major pulse crops of world as well as country and also it serves as an important protein source of our Indian diet. Being rich in quality proteins, minerals and vitamins, mungbean is an in separable ingradient in the diets of vast majority of population in Indian sub continents. The mungbean area in Madhya Pradesh was 389.9 thousand hectare which produce 191.8 thousand tonnes with a productivity of 492 kg/ha. Due to (Anonymous, 2014). In spite of having the larger area under mungbean in the country and state as well, its productivity is not satisfactory which yet to see a major breakthrough. The low productivity of mungbean is due to biotic and abiotic factors. Among them, imbalance use of nutrients is one of the most important factor. To meet the additional nutritional requirement of ever increasing population, it is very much essential to enhance the production of pulses. Evaluation of suitable management practices to increase the productivity of pulses even under rainfed situation is essential. Foliar feeding of nutrients (Nitrogen and phosphorous) has been found and efficient method of applying nutrients in rainfed conditions .Foliar application of fertilizers may be a good source of nutrient supply in small amounts. It may be prove an alternative for low input technology. It is 2 to 3 times better than soil application. Thus foliar application of fertilizer either alone or with soil application may be useful in increasing the yield of mungbean crop under rainfed condition.

METHODOLOGY

The field experiment was conducted at Mahatma Gandhi Chitrakoot Gramodaya Vishwavidhyalaya, Chitrakoot, Satna, Madhya Pradesh, India. during kharif season of 2015–16. The soil of experimental field was sandy loam in texture, neutral in reaction (pH 8.02), low in organic carbon 0.06%, available nitrogen 135.4 kg/ha high in available phosphorus (32.9 kg/ha) and potassium (26.9 kg/ha). The 8 treatments were tested in a 3 replicated randomized block design. The treatments were T_1: Control (Water spray),T_2: Urea 2% spray at flower initiation ,T_3: TNAU Pulse wonders @ 5 kg/ha at flower initiation,T_4: Salycilic acid 75 ppm at flower initiation and 7 day after Ist spray, T_5: 18:18:18 (NPK) at flower initiation ,T_6: Urea 2% + Salycilic acid at flower initiation, T_7: Boron 0.25 ppm spray at flower initiation, T_8: Thiourea 500 at flower initiation. Experiment was conducted in randomized block design with 3 replications.

RESULTS

The result revolved that the Table 1 Grain yield revealed that Urea 2% (T_2) registered significantly higher seed yield (588 kg/ha) among all the treatments. However application of Urea 2% + Salicylic acid (T_6) and TNAU pulse wonder ($T_{3)}$ yielded (582 kg/ha) same field and almost equal with Urea 2% (T_2). The lowest grain yield was recorded under application of water spray.it was attributed due to higher value of short and root growth and yield attributed which resulted significantly greater grain yield of these treatments. Straw yield of green gram was recorded significantly superior under application of thiourea (T_8) (694 kg/ha) than water spray (T_1) and remained significantly at par Application of T_5, T_6, T_4, T_3, T_2, and T_7 treatment gave 995 kg/ha, 954 kg/ha, 954 kg/ha, 954 kg/ha, 945 kg/ha, 935 kg/ha and 914 kg/ha. Lower straw yield than thiourea, significantly Minimum straw yield was noted in water spray (813 kg/ha). This was attributed due to higher value of growth characters. It might be due to the reason that at lower level of fertility, foliar fertilization has increased the availability of N and P to the crop plants, while at higher fertility level, crop requirement of N and P was fulfilled from basal application only result similar found as Mathur *et al.* (2006). Harvest index was also significantly affected by treatments .Application of urea 2% recorded significantly higher harvest index (39.99) than water spray TNAU Pulse Wonder, 18:18:18 (NPK), borax 0.25 ppm and Thiourea, and remained T_4 Salicylic acid 75 ppm and urea 2% + salicylic acid treatment statistically at par. The lowest harvest index was recorded under application of water spray. The marginal profit of Rs 26,414/ha was obtained when crop was without fertilization treated (only water spray) the crop season. The maximum and significant higher NMR was recorded under T_2 Urea 2% (Rs.42146 / ha) followed by T_4 Salicylic acid (Rs. 41153 /ha), T_6 Urea 2%+ Salicylic acid (Rs. 41018 /ha) and T_5 18:18:18 (NPK).2% (Rs.39356 /ha$^)$.minimum net monetary returns was obtained under water spray treatment. The benefit: cost ratio was significantly influenced by various foliar nutrition treatments. Benefit :Cost ratio was obtained higher under the application of urea 2% (T_2) followed by Salicylic acid (T_4), Urea 2% + Salicylic acid (T_6) , T_5 18 : 18 : 18 (NPK) (T_5) which shoved significantly greater than water spray. Application of boron 0.25 ppm and thiourea also observed significantly lower B : C ratio compared to urea 2%.

CONCLUSION

Application of urea 2% at FI closely followed by urea 2% + salicylic acid 75 ppm at FI. Proved to be best combination for obtaining better growth and yield of green gram. Application of urea 2% and + salicylic acid 75 ppm at FI was found best foliar fertilization treatment in respect of productivity. The maximum net profit of ₹ 42,146/ha and benefit : cost ratio of 3.49 was earned in green gram with the Application of urea 2% (T_2) at FI. Thus, it can be concluded that the application of urea 2% at FI was found the best treatment for obtaining greater yield and maximum profit of green gram in Chitrakoot area.

Table 1. Effect of different treatments on, Grain yield, straw yield, harvest index and economics of green gram

Treatment		Grain yield (kg/ha)	Straw yield (kg/ha)	Harvest Index (%)	Economics	
					Net returns (₹/ha)	B :C Ratio
T_1	Water spray	423	813	34.20	26,414	1.58
T_2	Urea 2% FI	588	935	39.99	42,146	2.49
T_3	TNAU Pulse Wonder @ 5 kg/ha FI	582	945	35.19	34,968	3.08
T_4	Salicylic acid 75 ppm	580	954	37.79	41,153	2.25
T_5	18:18:18 (NPK) 2% FI	566	955	37.17	39,356	2.14
T_6	(Urea 2%+Saly-acid FI	582	954	37.80	41,018	2.27
T_7	Boron 0.25 ppm FI	521	914	36.31	35,229	1.98
T_8	Thiourea 500 ppm F I	569	964	37.07	38,925	2.00
	CD (P=0.05)	77.35	53.4	2.73	7,394	0.43

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Effect of nutrient management option on crop yield and nutrient uptake by wheat (*Triticum aestivum* L.) in western Uttar Pradesh

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The field experiment was conducted at CRC, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut during *rabi* 2013–14 and 2014–15. Influence of organic and inorganic sources on nutrient uptake and yield of wheat (*Triticum aestivum* L.) in Western Uttar Pradesh. Addition of 100% NPK (2% Urea spray at tillering and jointing stage) (RDF-recommended dose of fertilizer, i.e. 150 : 75 : 60 kg NPK/ha was recorded significantly higher value of nutrient uptake and grain yield (49.51 and 47.23 q/ ha) was recorded yield which was at par with 75% NPK + Vermicompost 2 t/ha (2% Urea spray at tillering and jointing stage) (48.93 and 46.83 q/ha) grain was recorded yield. Nitrogen, phosphorous and potash content and uptake in grain is also increased with the application of 100% NPK (2% Urea spray at tillering and jointing stage). Which was at par with the 75% NPK + Vermicompost 2 t/ha (2% Urea spray at tillering and jointing stage). Highest organic carbon% in soil was recorded in 75% NPK + Vermicompost 2 t/ha (2% Urea spray at tillering and jointing stage). The integrating of 75% NPK + Vermicompost 2 t/ha (2% Urea spray at tillering and jointing stage) found more productive by maintain or improving the soil health.

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Standardization of potassium management practices for paddy in command areas of Karnataka

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Although Green Revolution had tremendous impact on nitrogen fertilizer use in Asia, it had much less impact on the use of phosphorous and potassium fertilizers (Ranjha *et al.,* 2001). Rice is one such crop which consumes considerable amount of potassium due to lack of distinct recommendations and methods we are left with lower potassium use efficiency. In order to standardize the potassium fertilization methods a field experiment was conducted and salient findings are

Table 1. Yield attributes and yield of paddy as influenced by different potassium management treatments

Treatment	Productive tillers (No.)	Panicle weight (g)	Panicle length (cm)	Grains perpanicle (No.)	Test weight (g)	Grain yield (t/ha)	Stoveryield (t/ha)
Levels of K (M)							
M_1	19.00	15.40	10.05	49.46	19.40	5.65	6.11
M_2	19.50	15.75	10.15	50.51	19.75	5.75	6.23
M_3	20.00	16.10	10.35	51.39	20.20	5.87	6.32
SEm±	0.13	0.17	0.09	0.44	0.25	0.02	0.02
CD (P=0.05)	0.48	0.68	0.35	1.72	0.96	0.07	0.09
Time of application (S)							
S_1	17.90	14.50	17.90	46.98	9.90	5.35	5.84
S_2	21.30	17.05	20.75	54.41	11.75	6.21	6.62
S_3	19.30	15.65	19.10	49.97	10.50	5.71	6.20
SEm±	0.15	0.18	0.23	0.37	0.11	0.03	0.03
CD (P=0.05)	0.46	0.59	0.74	1.21	0.35	0.09	1.10
Foliar spray (F)							
F_1	18.80	15.20	18.70	48.80	10.40	5.57	6.02
F_2	19.70	15.85	19.45	51.01	10.80	5.76	6.28
F_3	19.95	16.10	19.65	51.50	10.95	5.90	6.36
SEm±	0.12	0.14	0.20	0.32	0.09	0.02	0.03
CD (P=0.05)	0.35	0.39	0.57	0.90	0.25	0.06	0.07

M_1- 50 kg/ha; M_2- 75 kg/ha; M_3- 100 kg/ha; S_1- 100% basal; S_2- 50% basal S_3- 25% basal; F_1- Foliar application of 0% K_2SO_4 at 75 DAT; F_2- Foliar application of 1% K_2SO_4 at 75 DAT; F_3- Foliar application of 2% K_2SO_4 at 75 DAT

discussed in this paper.

METHODOLOGY

A field experiment was conducted for two consecutive seasons of 2014 and 2015 at Agriculture and Horticulture Research Station, Honnavile, University of Agricultural and Horticultural Sciences, Navile, Shivamogga. The experiment consists of different levels, time and varied concentration of foliar applications and was planned by adopting split–split plot design with three replications. All the crop management practices are adopted as per the recommendations of the University, observations and statistical analysis was carried out by adopting standard methodology suggested.

RESULTS

Data presented in the Table 1 indicated that, significantly higher grain (5.87 t/ha) and stover (6.32 t/ha) yields of paddy was obtained with application of potassium at 100 kg/ha. Significant improvement of grain yields of paddy in the said treatment was traced back to the significant improvement in yield attributing traits such as number of productive tillersper plant (20), panicle weight (16.10 g), panicle length (10.35 cm), number of grains per panicle (51.39) and test weight (20.20). Among the different time of application, 50 per cent of recommended potassium applied at basal coupled with remaining 50 per cent as top dressing recorded significantly higher grain and stover yields of paddy. It could be due to continuous availability of the potassium in the soil nutrient pool during major part of crop growth might have favored the crop growth and was also reflected through higher values of yield attributing characters of paddy (Table 1). Among the various foliar feeding treatments tried in the study, grain yields of paddy improved as the concentration of potassium increases up to 2 per cent K_2SO_4. Present findings are in the line of Ranjha *et al.* (2001). Excellence grain yields of paddy with foliar feeding of potassium with 2 per cent K_2SO_4 at 75 DAT was traced back to the superiority of yield attributing characteristics such as number of productive tillers per plant (19.95), panicle weight (16.10 g), panicle length (19.65 cm), number of grains per panicle (51.50) and test weight (10.95 g). It could be due to direct supply of higher amount of readily available potassium to the metabolic site might have favored the crop during flowering to grain filling stage. These finding are in agreement with the findings of Ebrahimi *et al.* (2012).

CONCLUSION

Paddy crop fertilized with 100 kg/ha of potassium coupled with 50% as basal and one foliar of 2% K_2SO_4 at 75 DAT found significantly superior by recording higher grain yield of paddy in command area of Southern Transitional Zone of Karnataka.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Nutrient management in *Bt* cotton based cropping system

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Cotton 'White Gold' is an important raw material for the Indian textile industry and important cash crop of the country. India ranks first in area and second in production with an average productivity of 496 kg/ha. Optimum plant density for *Bt* cotton was studied for black cotton soils of Marathwada and 18,518 plants/ha were found an optimum plant density for the region (Khargkharate *et al*., 2008).

METHODOLOGY

The experiment was conducted on black cotton soil having low organic matter, low in available nitrogen, medium in available phosphorus and high in available potassium. FRBD design with three replications. Three intercropping treatments, two plant geometries and four nutrient levels.

RESULTS

The cropping system, cotton + green gram and cotton + soybean were found significant over sole cotton. Seed cotton equivalent yield (SCEY), The yield of seed cotton was significantly higher in sole cotton treatment while in case of geometry it was significantly higher in 120 cm × 45 cm. In nutrient treatments N4 was found superior over rest of treatments excluding N3 treatment. Similar trend was observed in yield attributing characters also i.e. boll weight and number of bolls per plant. The differences in monetary returns as influenced by different intercropping treatments were significant. Cotton + Green gram gave highest / hectare followed by Cotton + Soybean. Lowest monetary returns were received from Sole Cotton. Plant geometry 120 cm × 45 cm recorded significantly highest monetary returns compared to 90 cm × 60 cm. Nutrient application of 125% RDF + $MgSO_4$ soil application + foliar spray of DAP, K and Boron recorded highest monetary returns was at par with 125% RDF. Interactions intercrop × geometry, intercrop × nutrient levels were found significant. However crop geometry × nutrient levels and intercrop × geometry ×

Table 1. Seed cotton yield (SCY in kg/ha), Seed cotton equivalent yield (SCEY in Kg/ha) and gross monetary return, net monetary returns, boll weight and no. of bolls/plant during the year 2011–12

	SCY (kg/ha)	SCEY (kg/ha)	GMR (₹/ha)	NMR (₹/ha)	Boll wt. (g)	No. of bolls/plant
Plant density (Plants/ha)						
I_1- Cotton + Green gram	1,444	1,949	77,970	44,928	3.04	42.64
I_2- Cotton + Soybean	1,330	1,801	72,049	39,563	3.06	40.02
I_3- Sole cotton	1,601	1,601	64,045	30,476	3.29	52.65
CD (P=0.05)	101.82	100.14	4,005	3,677	0.20	2.57
Geometry (Plants/ha)						
G_1- 90 × 60 cm	1,431	1,727	69,080	36,191	3.09	44.40
G_2- 120 × 45 cm	1,485	1,840	73,629	40,454	3.16	45.82
CD (P=0.05)	83.13	81.76	3,270	3,003	N.S.	2.10
Nutrient treatment						
N_1= 100% RDF (N and K in 4 splits) + Foliar DAP 1.5% + K 0.5%	1,309	1,606	64,256	32,706	2.86	38.70
N_2 = N_1 + Mg SO_4 (20 kg/ha soil application as basal) + Foliar spraying of DAP 1.5%, K 0.5%, Mg SO_4 (0.5%) + Boron as solubor (0.15%)	1,398	1,722	68,910	35,467	2.97	41.68
N_3 =125% recommended NPK (N and K in 4 equal Splits) + Foliar DAP 1.5% + K 0.5% and	1,524	1,849	73,990	41,529	3.30	48.66
N_4 = - N_3 + Foliar spraying of DAP 1.5%, K 0.5%, Mg SO_4 (0.5%) + Boron as solubor (0.15%)	1,602	1,956	78,264	43,587	3.38	51.38
CD (P=0.05)	117.57	115.64	4,625	4,246	0.28	2.97

nutrient interactions were found non-significant.

CONCLUSION

Cotton equivalent yield and GMR have been appreciably enhanced by Cotton + Green gram intercropping treatment. Geometry 120 cm × 45 cm performed significantly superior over 90 cm × 60 cm for SCEY and monetary returns. Nutrient treatment 125% RDF with foliar application of nutrients recorded significantly superior for yield and economics over 100% RDF along with foliar and 100% RDF with micronutrient.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Foliar nitrogen management for enhancing growth and yield of wheat in Indo-Gangetic Plains of Bihar

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Globally wheat (*Triticum aestivum* L.) is the most widely cultivated food crop occupying significant position among the cereals. In India, wheat is the second most important cereal crop next to rice, contributing nearly 35% to the national food basket and plays an important role in food and nutritional security of the nation. Cultivation of wheat has been the symbolic of green revolution and self sufficiency in food grain production of the nation. In the world, India is the second largest producer with the production of 95.9 mt, in an area of about 31.1 mha with a productivity of almost 30.7 q/ha (Agriculture Statistics, 2014). Farmers are acquainted with blanket application of macro nutrient which is the traditional practice to keep the crop greenish and to avoid the risk of crop failure. This technique is to some extent success in large tracts but for smallholdings it reduces the partial factor productivity. Indian soils are deficient in nitrogen and are supplemented with chemical fertilizer for enhancing the crop productivity. However, only 20–50% of the soil applied nitrogen is recovered by the annual crops. The left over nitrogen is lost from the soil system through denitrification, volatilization and leaching. Moreover, fertilizers are energy intensive to produce and are very expensive. The present price hike of fertilizers is one of the main constraints to increase the economic yield of crops. Thus efforts are needed to minimize its losses and to enhance its economic use.

Foliar fertilization, that is nutrient supplementation through leaves, is an efficient technique of fertilization which enhances the availability of nutrients. It has been observed that utilization of fertilizers especially urea applied through soil is not as effective as when it is supplied to the plant through foliage along with soil application. Foliar feeding also ensures the ample availability of nutrients to crops for obtaining higher yield (Arif *et al.,* 2006). Keeping in view the price hike and unavailability of N fertilizer (especially urea) during peak period of growing season, the present investigation has been planned to address the issue so that the yield losses due to non availability of urea can be reduced by foliar application at various growth stages of wheat and economic use of N fertilizer.

METHODOLOGY

The present investigation entitled 'Response of wheat (*Triticum aestivum* L.) to foliar and soil application of Nitrogen' was conducted during winter season of 2013–14 and 2014–15 at Bihar Agricultural college farm, Sabour, Bhagalpur, Bihar, which is situated at longitude 87°22′ 423″ East and Latitude 25°152′ 403″ North, at an altitude of 46 meters above mean sea level in the heart of the vast Indo-Gangetic plains of north India. The climate of this place is subtropical, slightly semi-arid in nature and is characterized by very dry summer, moderate rainfall and very cold winter. The soil of the experimental plot was sandy loam in texture and low in fertility as envisaged through status of organic carbon (0.56%), available N (175 kg/ha), P_2O_5 (24 kg/ha) and K_2O (181 kg/ha) in the soil. The soil reaction was in the neutral range with pH of 7.4 exhibiting suitability for cultivation of wheat. Experiment comprising eight different treatments, viz. T_1-100% RDN (50% Nitrogen at Basal + 25% N at CRI stage + 25% at jointing stage), T_2- 50% Nitrogen at Basal + 25% N at CRI stage + 2% urea solution at tillering stage, T_3- 50% Nitrogen at Basal + 2% urea solution at CRI stage and tillering stage, T_4- 50% Nitrogen at Basal + 3% urea solution at CRI stage and tillering stage, T_5- 50% Nitrogen at Basal + 4% urea solution at CRI stage and tillering stage, T_6- 50% Nitrogen at Basal + 2% urea solution at CRI stage, tillering stage and late jointing, T_7- 50% Nitrogen at Basal + 3% urea solution at CRI stage, tillering stage & late jointing,T_8- 50% Nitrogen at Basal + 4% urea solution at CRI stage, tillering stage & late jointing. The recommended fertiliser dose was 120 : 60 : 40 kg N : P_2O_5 : K_2O/ha. The experiment was laid out in completely randomized block design with three replications.

RESULTS

The pooled results indicated that maximum grain yield of wheat (4.88 t/ha) was recorded when the crop was grown with recommended doses of fertilizers, i.e. 50% of RDN as basal and remaining N in two split application at CRI and jointing stages of crop growth (T_1), which was statistically at par with the grain yield of 4.64 t/ha, obtained under treatment receiving 50% N as Basal + 25% N at CRI stage + 2% urea solution at tillering stage (T_2) and 50% N as Basal + 4% urea solution at CRI stage, tillering and late jointing stages (T_8) respectively and these in turn were significantly superior to the grain yield obtained under rest of the treatments (Table 1). Growth and yield attributing characters, viz. plant height, LAI, dry matter accumulation, crop growth rates at different growth stages, number of tillers/m^2, days to 50% heading, length of ear head, ear head/m, spikelets/spike, number of grains/earhead, test weight of grains, days to maturity, grain yield, straw yield, harvest index and total nutrients uptake were recorded maximum under the treatment T_1, being at par with the treatments T_2 and T_8. Maximum net return of ₹ 66,059/ha was recorded under treatment T_1 and was followed by that of treatment T_2 (₹ 61,624/ha) and T_8 (₹ 57,781/ha) respectively. Similarly, highest B : C ratio of 2.31 was recorded with T_1 followed by the treatment T_2 (2.18) and T_8 (1.98).

CONCLUSION

It may be concluded that one foliar spray of 2% urea along with soil application of 50% N at basal and 25% N at CRI and three spraying of 4% urea at CRI, tillering and late jointing stages along with soil application of 50% N as basal have been found effective in obtaining at par yield to that of soil application of recommended doses of fertilizers, Hence, reduced dose of soil N and foliar feeding of urea may be an economically viable and ecologically sound option for nutrient supplementation of wheat during in season crisis of urea without having significant yield reduction compared to recommended doses of fertilizers with an added advantage

Table 1. Grain yield, % saving of N and economics as influenced by treatments in wheat

	Treatments	N supply (kg/ha) through Foliar Spray	Total N supply (kg/ha)	% saving of N/ ha	Grain yield (t/ha) (2012–13)	Grain yield (t/ha) (2013–14)	Pooled Grain yield (t/ha)	Net return (₹ /ha)	B:C Ratio
T_1	RDN (50% N basal + 25% N at CRI + 25% N at jointing.	–	120	–	4.79	4.97	4.88	66,059.1	2.34
T_2	50% N basal + 25% N at CRI + 2% Urea at Tillering	4.6	94.6	21	4.53	4.76	4.64	61,624.3	2.18
T_3	50% N basal + 2% Urea at CRI & at Tillering (Two spraying)	9.2	69.2	42	3.80	4.31	3.99	48,714.9	1.72
T_4	50% N basal + 3% Urea at CRI and at Tillering (Two spraying)	14	74	38	4.09	4.44	4.26	54,277.6	1.91
T_5	50% N basal + 4% Urea at CRI and at Tillering (Two spraying)	18	78	35	4.19	4.48	4.33	54,952.2	1.89
T_6	50% N basal + 2% Urea at CRI, at Tillering and at late jointing (Three spraying)	14	74	38	4.21	4.51	4.36	55,150.4	1.90
T_7	50% N basal + 3% Urea at CRI, at Tillering and at late jointing (Three spraying)	21	81	32.5	4.25	4.55	4.38	55,708.1	1.91
T_8	50% N basal + 4% Urea at CRI, at Tillering and at late jointing (Three spraying)	28	88	26.6	4.35	4.62	4.49	57,781	1.98
	CD (P=0.05)				0.487	0.426	0.277		

of 21 to 26.61% saving in N, along with saving an appreciable amount of subsidy by Government of India, on nitrogenous fertilisers.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Nutrient management in chewing tobacco + annual *moringa* inter cropping system

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Chewing tobacco (*Nicotiana tabaccum*) is one of the commercial crop grown in an area of around 10,000 to 15,000 ha in different districts of Tamil Nadu. Annual *moringa* (*Moringa oleifera*) is grown throughout Tamil Nadu as a pure crop and also as an intercrop in chillies, tobacco, onion etc., since the growth habit of the crops, viz. tobacco and annual moringa varied, farmers cultivate chewing tobacco intercropped with annual *moringa*. Intercropping increases not only productivity per unit area but also the net returns. Kumaresan and Rao (2013) reported that the Tobacco equivalent yield was higher with chewing tobacco + Annual moringa intercropping system as compared to many other crops grown in *rabi* season. The existing nutrient management practices are based on individual crop and very little information is available on nutrient management in intercropping systems. Hence the present study was conducted to find out a suitable nutrient management practice for chewing tobacco + annual moringa intercropping system, where annual moringa was planted at different populations.

METHODOLOGY

A field experiment was conducted at the farm of the ICAR-Central Tobacco Research Institute Research Station, Vedasandur during 2012–13 to 2014–15. The experiment was laid out in a split plot design with three replications. The main plot treatment consisted of Chewing tobacco + Annual moringa (100% population), Chewing tobacco + Annual moringa (75% population), Chewing tobacco + Annual moringa (50% population). The sub-plot treatments consisted of 125, 100 and 75% recommended dose of fertilizer (RDF) applied to both chewing tobacco and annual moringa. The sole crop of chewing tobacco and annual moringa was raised in a separate plot for comparison. The recommended dose of fertilizers for chewing tobacco and annual moringa was 125 + 50 + 50 and 90 + 30 + 60 kg/ha N + P_2O_5 + K_2O, respectively. Farmyard manure @ 25 t/ha was applied basally. The variety of chewing tobacco and annual moringa raised was Abirami and PKM-1, respectively. The first grade leaf yield (FGLY) and total cured leaf yield (TCLY) was recorded after bulking and standard processing. Economics was calculated based on the prevailing market prices of inputs and economic produce value.

RESULTS

The annual moringa intercropped at different population levels did not affect the FGL and TCLY of chewing tobacco (Table 1). The fertilizer levels significantly influenced the tobacco yield. The RDF at 125 and 100% recorded a comparable FGLY and TCLY. Annual *moringa* yield increased with increase in population. The annual *moringa* yield increased when there was an increase in fertilizer level. Higher annual *moringa* yield of 3,362 kg/ha was recorded at 125% RDF applied to tobacco and annual *moringa*. The Gross return, Net return and B:C ratio were higher with chewing tobacco + 100% Annual Moringa population. The 125% RDF to chewing tobacco + Annual Moringa recorded a higher gross return, Net return and B:C ratio followed by 100% RDF (Table 1). Tobacco equivalent Yield (TEY) was higher with Chewing tobacco + 100% Annual Moringa population (4578 kg/ha) and at 125% RDF to chewing tobacco + Annual Moringa (4607 kg/ha), followed by Tobacco + Annual Moringa at 75% population fertilized with 100% RDF to both chewing tobacco and Annual moringa .

Table 1. Yield and Economics of Chewing tobacco+Annual moringa intercropping system as affected by inter crop plant population and fertilizer rate

Treatment	FGLY (kg/ha)	TCLY (kg/ha)	*Annual Moringa (kg/ha)	*Gross return (₹ × 10^3)	*TEY (kg/ha)	*Net return (₹ × 10^3)	*B:C ratio
Inter cropping system							
Tobacco + Annual moringa (100%)	2,731	3,399	3,745	314.24	4,497	202.74	1.86
Tobacco + Annual moringa (75%)	2,805	3,410	3,033	304.03	3,858	194.33	1.78
Tobacco + Annual moringa (50%)	2,867	3,464	2,398	288.78	3,496	184.00	1.76
SEm±	42	31					
CD (P=0.05)	NS	NS					
Fertilizer level							
75% RDF	2,652	3,245	3,017	293.08	3,826	185.54	1.76
100% RDF	2,855	3,431	3,038	304.10	4,004	192.15	1.79
125% RDF	2,939	3,510	3,122	310.83	4,067	209.39	1.80
SEm±	32	51					
CD (P=0.05)	102	157					
Sole tobacco	2,790	3,383		213.58	3,383	127.03	1.93
Sole Annual moringa	–	–	3,542	73.05	2,285	9.58	0.49

*Data not statistically analysed

CONCLUSION

Annual moringa at different population levels does not significantly affect the yield of chewing tobacco in chewing tobacco + annual moringa intercropping system. Similarly, application of fertilizers in excess of recommended dose has not resulted in significant improvement in tobacco yield. However, increased rate of fertilizer application @ 125% RDF proved beneficial in terms of TEY and net returns.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Influence of nutrient management for mesta-rice cropping system using soil test target yield equation

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Balanced fertilizer application in a cropping system is pre-requisite for sustainable production system as well as appropriate soil nutrient resilience. With the development of high yielding and fertilizer responsive varieties of almost all crops escalated the indiscriminate use of fertilizers thus increases cost of cultivation and environment pollution. Hence, need based estimation of N, P and K correlating their requirement with specific target yield depending on their native soil status may fit to balanced application of NPK fertilizers. The 'target yield equation' (TYE) is considered as a soil and fertilizer based precision farming strategy to meet nutrient demands for a specified yield (Balasubramanian *et al*., 1999). However, application of N,P and K fertilizer on soil test target yield (ST-TY) based may meet the productivity but it has negative impact on soil health, hence, integrated nutrient management, i.e. combination of inorganic and organic in mesta-rice cropping system help to enhance the mesta and rice productivity while maintaining the soil health (Ghosh, 2008). Hence, the present investigation was undertaken to achieve the target yield of mesta and rice and their effect of soil nutrient status for mesta-rice cropping system.

METHODOLOGY

The experiment was conducted at Tamil Nadu Rice Research Institute, Aduthurai under mesta-rice system during 2014–16. The soil of experimental field was sandy loam with pH 7.14, organic carbon 0.57% and available N, P and K 185, 55 and 265 kg/ha, respectively. Doses of N, P_2O_5 and K_2O calculated on soil test basis by using following equations: For *Mesta:* FN=9.72T–0.41 SN; FP=8.5T-6.58 SP; FK=8.60T–063 SK For *rice:* FN = 5.29 T–0.39 SN; FP=1.03 T–0.24 SP; FK = 1.98 T–0.20 SK; For organic *manure:* FN = 5.29 T–0.39 SN–0.12 ON; FP = 1.03 T–0.24 SP–0.11 OP; FK =1.98 T–0.20 SK–0.07 OK; Where T = yield target; FN, FP and FK is fertilizer N, P_2O_5 and K_2O (kg/ha); SN, SP and SK are available N, P and K of soil (kg/ha); ON, OP and OK are organic N, P and K in kg/ha; Seven nutrient management practices, viz. T_1- Control, T_2- Recommended dose of fertilizer (RDF), i.e. for mesta 60 kg N, 13 kg P_2O_5 and 25 kg K_2O/ha and for rice 120 kg N, 50 kg P_2O_5 and 50 kg K_2O/ha, T_3- RDF + organic manure (equivalent to 5 t/ha of FYM), T_4- 100% NPK on ST-TY (Target for mesta -3.0 t/ha and for rice- 4.5 t/ ha), T_5- 100% NPK on ST-TY (Target for mesta- 3.5 t/ha and for rice 5.0 t/ha), T_6- T_4 + organic manure (equivalent to 5 t/ha of FYM) and T_7- T_5 + organic manure (equivalent to 5 t/ha of FYM) were tested in randomized block design with three replications for mesta and rice. Soil and plant samples were collected at harvest were dried, processed and analyzed for available N by alkaline permanganate method, available P by Olsen's method and available K by flame photometer following standard procedures (Jackson, 1973). All parameters were analyzed statistically (Gomez and Gomez, 1984).

RESULTS

The target yield of mesta (3.5 t/ha) was achieved with (Table 1) with application of 100%NPK based on Soil Test Target Yield (ST-TY) equation along with organic manure (equivalent 5 t/ha of FYM) (T_6). The 100% NPK application on ST-TY achieved only 87.9% of target mesta fibre yield. The higher mesta fibre target yield (3.5 t/ha) could not achieved by any treatments. The target yield of rice (5.0 t/ ha) was also achieved with T_6. The higher target yield (5.0 t/ha) of rice could not achieved by any treatments, however, 100% NPK based on ST-TY along with organic manure (equivalent to 5 t/ha of FYM) was achieved 124.4% of this target yield. The integration of inorganic with organic (FYM) was ensured the achievement of target yield of mesta and rice and only inorganic (N, P and K) did not achieve the target yield in both mesta and rice. It provides adequate nutrients to crop uptake which promotes mesta and rice growth and subsequent development of yield attributes lead to higher yield. The system productivity and benefit cost ratio was significantly higher in T_6 and T_7, where organic manure was integrated with ST-TY based application of NPK compared to T_1, T_2 and T_3 treatments (Table 1). The higher nutrient uptake 94.4 N, 40.6 P and 105 K kg/ha by mesta and 118.6 N, 63.82 P and 91.4 K kg/ha by rice crop were recorded under T_7. The higher uptake of nutrients under T_7 which was might be due to higher application of nutrients along with organic manure. Available nutrient status was also higher in T_6 and T_7 where FYM was applied. When we apply FYM in soil the entire amount of its NPK constituent was not made available at a time in one season; rather, a gradual release took place over a period of years.

Table 1. Mesta fibre yield, rice yield, percent achievement of target yield, system productivity and benefit-cost ratio under mesta- rice cropping system (pooled data)

Treatment	Fibre yield (t/ha)	% achievement of mesta fibre target yield	Rice Yield (t/ha)	% achievement of rice target yield	System productivity (t/ha)	B:C
T_1 : Control (without any fertilizer /FYM)	1.50	50.1	3.98	88.4	3.13	2.11
T_2 : Recommended dose of fertilizer (RDF) (60:30:30 kg NPK)	2.22	73.9	4.15	92.2	4.62	2.42
T_3 : RDF +organic manure(equivalent to 5 t /ha of FYM)	2.37	78.9	4.25	94.4	4.93	2.32
T_4 : 100% NPK on ST-TY(Target : Mesta-3.0 t/ha, rice 4.0 t/ha)	2.45	81.5	4.60	102.2	5.09	2.62
T_5 : 100% NPK on ST-TY(Target : Mesta-3.5 t/ha, rice 5.0 t/ha)	2.46	70.4	4.80	96.0	5.13	2.63
T_6 : T_4 + organic manure(equivalent to 5 t /ha of FYM)	2.64	87.9	5.10	113.3	5.49	2.65
T_7 : T_5 + organic manure(equivalent to 5 t /ha of FYM)	2.67	76.2	5.60	124.4	5.56	2.70
SEm ±	1.07		0.17		1.40	0.31
LSD (P=0.05)	2.14		0.38		2.96	0.69

Achievable yield of higher target, i.e. #Mesta -3.0 t/ha; ##Mesta -3.5 t/ha and $ rice 4.5 t/ha; $$ rice 5 t/ha

CONCLUSION

The present study concluded that the application of N, P and K based on STCR equation with organic manure (equivalent to 5 t/ha FYM) achieved target yield of mesta fibre and rice and recorded higher system productivity and benefit-cost ratio.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Yield maximisation in paddy through different sources

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In view of yield stagnation due to soil health problems and poor supply of nutrients to the crop there is need to improve the yield through foliar nutrition. Vigore is said to be a Nano Technology product which includes all the nutrients required for complete and healthy development of the plant. It is said to be an eco friendly product and non toxic for human, animals and plants as it has been prepared from substances found in nature made from not only plants, but minerals or other substances found in nature by using infinite decimal doses and with the process of denomination and potentiating which increases effectiveness and removes toxicity. Studies conducted at Gangavathi revealed that BPH incidence was low with application of vigore (Annual Report, IIRR, 2014) . Hence it is to be tested for the improvement of paddy yield.

METHODOLOGY

A field investigation was carried out at Andhra Pradesh Rice Research Institute, Maruteru, Andhra Pradesh, India during *kharif*, 2015. The experimental site was clay loam , neutral in p^H (6.66), normal in E.C (0.51 m. mohs/cm), low in available nitrogen (123 kg/ha), high in available

Table 1. Yield attributes and yield of paddy as influenced by different sources of nutrition

Treatments	No. of Tiller/m^2	No. of panicle/m^2	Panicle weight (g)	Grain yield (kg/ha)	Straw yield (kg/ha)
T_1: Recommended Fertilizers (RDF)	247	232	3.97	4,693	6,327
T_2: RDF + Vigore application @ 625 g /ha as basal	236	229	3.94	4,728	6,250
T_3: RDF + Vigore @ 625 g/ha as basal + Spray @ 1.25 g/l at PI	247	235	4.07	4,762	6,285
T_4: RDF + Tabsil (Silicate Tablets) 2.5 kg/ha at 25 days after transplanting	241	233	3.97	4,647	6,265
T_5: RDF + Tabsil (Silicate Tablets) 5.0 kg/ha at 50 days after transplanting	232	237	4.02	4,702	6,313
T_6: RDF + Tabsil (Silicate Tablets) 2.5 kg /ha each at 25 and 50 days after transplanting	242	239	4.06	4,850	6,339
T_7: Farmers practice	220	207	3.54	4,060	6,503
T_8: Absolute control (Without N: P: K)	190	173	3.17	2,498	4,595
SEm ±	9.6	9.8	0.13	96.9	149
CD (P=0.05)	30	30	0.39	297	456
CV	7.2	7.6	5.74	4.9	4.0

phosphorus (102 kg/ha) and potassium (412 kg/ha). The experiment was laid out in a Randomized Block Design with 8 treatments consisting of six nutritional treatments along with farmers practice and absolute control, i.e. without N, P and K. The variety under test was MTU 1075. The data on no. of tillers, no. of panicles, panicle weight, grain yield and straw yield were recorded.

RESULTS

Highest number of tillers/m^2 were recorded with Recommended Fertilizers (RDF) and RDF + Vigore application @ 625 g/ha as basal +Vigore spray @ 1.25 g/l (247) and on par with all other nutritional treatments and farmers practice except absolute control. Similar trend was noticed with panicle number also. Panicle weight was highest with RDF + Vigore application @ 625 g/ha as basal +Vigore spray @ 1.25 g/l (4.07) which was on par with all other nutritional treatments except farmers practice and absolute control. Highest grain and straw yields were recorded with RDF + Silicate Tabs SiO_2 @ 2.5 kg/ha at 25 DAT and 50 DAT (4,850 kg/ha and 6,339 kg/ha) followed by RDF + Vigore application @ 625 g/ha as basal application + Spray @ 1.25 g/litre at panicle stage (4,762 kg/ha and 6,285 kg/ha respectively) compared to other treatments but was on par with all other nutritional treatments except farmers practice and absolute control. (Table 1).

CONCLUSION

The nano technology yield enhancers tabsil and vigore helped in increasing paddy yield (3.34% and 1.5% respectively) by improving panicle weight but statistically similar to recommended dose of fertilizer application.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Influence of integrated nutrient management on growth and yield of *kharif* sorghum

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Grain sorghum (*Sorghum bicolor* L. Monech) is a major dry land crop and one of the most important dietary sources of calories for the world's population and it is a major staple food grain of many people living in semi-arid tropical regions of Africa and Asia. Green revolution with its higher production capabilities has gradually depleted the major, secondary and micronutrients in early eighties. These deficiencies are to be met with proper amelioration techniques. Due to high prices of fertilizers, there is needed to substitute the part of it through organic manures like vermicompost, FYM, pressmud and biofertilizers. The continuous use of chemical fertilizers over a long period may cause imbalance of microflora and thereby directly affect the biological properties. To sustain the crop yield and increase land productivity, combination of organic manures and fertilizers not only increase the crop yield of sorghum but also improves physical and biological properties of soil. Integrated nutrient management is the alternative to increase the productivity through proper management. This not only sustains the soil fertility and productivity but also keeps the environment intact with reduced cost increment. Integrated and balanced use of nutrient through inorganic and organic sources like FYM, vermicompost, pressmud and biofertilizers is pre-requisite to sustain soil fertility, supply of nutrient at an optimum level and to produce maximum crop yield with minimum inputs. Therefore, an attempt has been made to study the impact of inorganic fertilizer, FYM, vermicompost, pressmud, and micronutrients ($ZnSO_4$) on growth and yield in Sorghum.

METHODOLOGY

The experiment was conducted during *kharif* season of the year 2014 at Experimental Farm, Department of Agronomy, College of Agriculture Latur under Vasantrao Naik Krishi Vidyapeeth, Parbhani the soil was low in available nitrogen (118.86 kg/ha), medium in available phosphorus (20.42 kg /ha), very high in available potassium (385.89 kg/ha) content and alkaline in reaction having pH of 8.17. The experiment was laid out by using randomized block design with three replications. The treatments were consisting of RDF, FYM, pressmud, Vermicompost and $ZnSo_4$ constituting seven treatments, viz. T_1- Control, T_2- RDN

Table 1. Yield attributes and yields of sorghum as influenced by various treatments at harvest

Treatment	Number of grains/plant	Weight of earhead (g)	Weight of grains/ plant (g)	Grain yield (kg/ha)	Fodder yield (kg/ha)
T_1 - (Control)	1,002.00	25.88	17.68	786	1,156
T_2 - 100% RDN	2,055.15	47.76	38.34	2,156	2,738
T_3- 75% RDN + 25% N through pressmud	1,549.67	37.33	34.74	1,904	2,096
T_4 - 75% RDN + 25% N through vermicompost	1,433.22	42.79	30.10	2,112	2,918
T_5 - 75% RDN + 25% N through FYM	1,586.19	43.76	34.95	1,955	2,088
T_6 - 75% RDN + 25% N through FYM + $ZnSO_4$ @ 20 kg/ha)	1,685.21	43.35	36.24	2,144	3,282
T_7- 75% RDN + 25% N through vermicompost + $ZnSO_4$ @ 20 kg/ha)	2,223.94	43.38	43.07	2,383	3,570
CD (P= 0.05)	275.99	3.74	3.85	131.6	315.6

(Recommended Dose of Nitrogen), T_3- 75% RDN + 25% N through pressmud, T_4- 75% RDN + 25% N through vermicompost, T_5- 75% RDN + 25% N through FYM, T_6- 75% RDN + 25 N through FYM $ZnSO_4$ @ 20 kg/ha, T_7- 75% RDN + 25% N through vermicompost + $ZnSO_4$ @ 20 kg/ha. Organic manures, viz. FYM, pressmud, Vermicompost were also applied before sowing to the plots as per the given treatments. The complete dose of nitrogen, phosphorus, potassium as per treatment was drilled at the time of sowing uniformly in the plots by using the urea, single superphosphate, murate of potash, zinc sulphate. The variety used was Proagro-8340 (Hybrid).

RESULTS

Application of 75% RDN + 25% N through vermicompost + $ZnSO_4$ @ 20 kg/h (T_7) produced significantly taller plant, more number of leaves/ plant leaf area/ plant and dry matter/ plant as compare to control treatment. It was followed by 100% RDN application (T_2) which was the second best treatment. The application N (organic and inorganic sources) and K improved nutrient uptake in crop which in turn might have more stimulation of enzymes present in tissue and increased cell division and cell elongation of crop. Ultimately, it results in to increased number of leaves, leaf area production of more photosynthates. This may be due to availability of more nutrients to the plants. Data on number of grains per plant was significantly influenced by different treatments. Treatment T_7 (75% RDN + 25% N through vermicompost + $ZnSO_4$ @ 20 kg /ha) was found significantly superior over all other treatments. It was followed by Treatment T_2 (100% RDN). Perusal of data on weight of ear head (g) presented in Table 1 would revealed that treatment T_2 (100% RDN) was significantly superior over all other treatments. Treatment T_5 (75% RDN + 25% N through FYM) was at par with treatment T_4, T_6, T_7. In case of weight of grains per plant Treatment T_7 (75% RDN+25% N through vermicompost + $ZnSO_4$ @ 20 kg/ha) was found significantly superior over all other treatments. Treatment T_2 (100% RDN) was found second best treatment in recording more weight of grains per plant. It may be attributed to increased easily availability of nutrients due to improvement in physio-chemical and biological properties of soil, which promote cell division and enlargement of plant over rest treatment, but at par with 75% RDN + 25% N through pressmud. The treatment T_7 (75% RDN + 25% N through vermicompost + $ZnSO_4$ @ 20 kg /ha) recorded significantly higher grain yield (2,383 kg/ha) and fodder yield (3,570 kg/ha) while it was at per with treatment T_6 (75% RDN + 25% N through FYM + $ZnSO_4$ @ 20 kg/ha) in case of fodder yield. The lowest grain and fodder yield of sorghum was recorded by treatment T_1 (control).

CONCLUSION

Based on the finding of this experiment, it may be concluded that application of inorganic fertilizer combined with organic manure i.e. T_7 (75% RDN + 25% N through FYM +$ZnSO_4$ @ 20 kg/ha) was found better in improving growth, yield attributes and grain and fodder yield of sorghum Proagro-8340 (Hybrid) than rest of the treatments.

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Response of lentil genotypes to seed rate and fertilizer levels

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Field experiment was conducted at Regional Agricultural Research Station, Vijayapura in Northern dry zone of Karnataka on medium black soil to study the response of lentil (*Lens culinaris* Medik) genotypes to seed rate and fertilizer levels during *rabi* 2015–16. The experiment was laid out in split-split plot design with three genotypes as main plot (JL-3, IPL-316 and RVL-31), three seed rates as sub plot (30, 35 and 40 kg/ha) and two fertilizer levels as sub sub plot (25 : 50 : 25 kg and 10 : 30 : 00 kg N, P_2O_5 and K_2O/ha) treatments. The lentil genotype RVL-31 recorded significantly higher grain yield (130.7 kg/ha) and it was on par with genotype JL-3 (121.0 kg/ha). Significantly higher yield was attributed to significantly higher growth and yield parameters, viz. number of plants per m row length at 90 DAS (30.6 and 29.5, respectively), pods per plant (13.65 and 17.20, respectively), seeds per pod (1.06 and 1.07, respectively), and harvest index (19.25% and 16.39%, respectively). Seed rate of 40 kg/ha recorded significantly higher grain yield (243.4 kg/ha), haulm yield (811.3 kg/ha) and harvest index (16.63%) and higher number of plants per m row length and protein yield (36.3 kg/ha).The fertilizer level of 25 : 50 : 25 kg N, P_2O_5 and K_2O/ha recorded significantly higher grain yield (123.2 kg/ha), haulm yield (801.2 kg/ha) and harvest index (15.95%) compared to 10 : 30 : 00 kg N, P_2O_5 and K_2O/ha. The lentil genotype, RVL-31 with 40 kg ha seed rate and fertilizer level of 25 : 50 : 25 kg N : P_2O_5 : K_2O/ha recorded significantly higher grain yield (243.4 kg/ha), net returns (₹ 8,991/ha) and benefit cost ratio (1.70) with better performance of growth and yield parameters.

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Productivity of mango (*Mangifera indica*) as influenced by mango cultivars, cropping system and nutrient management

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Mango (*Mangifera indica* L.) occupies prime place among fruit crops in India. Out of the 7.22 million ha under fruit crops in India, 34.9% area (2.52 Mha) is occupied by mango alone and accounts for 20.7% (18.43 Mt) of the total fruit production (88.98 Mt) (IHD, 2014). Mango, a huge-size woody perennial tree, is usually grown on wider spacing and also at juvenile phase the sparse foliage permits required light for the under storey intercrops that makes the microclimate compatible for inter-cultivation. Intercrops perform differently under different mango cultivars, as they get affected by rooting behaviour of mango and also by canopy spread which affect the light transmission to ground storey intercrop. Owing to heavy feeding nature of mango, inorganic fertilizers are one of the most expensive inputs in orchard management. Supplementing the fertilizer requirement through intervention of legumes and their stover incorporation may help in reducing recommended dose of nutrients, improving the physico-chemical and biological properties of soil, maintaining nutrient balance, increasing nutrient use efficiency besides improving the productivity on sustainable basis (Patil *et al*., 2005). Keeping all these aspects in view, an experiment was conducted to evaluate the effect of intercrops on the comparative performance of mango cultivars and their nutrient requirement under the influence of residue recycling of intercrops and residual effect of nutrients supplied to intercrops.

METHODOLOGY

A field experiment was conducted during the rainy, winter and summer seasons of 2011–12 and 2012–13 at Todapur Research Orchard of Horticulture Division, ICAR-Indian Agricultural Research Institute, New Delhi (28°35′ N, 77°12′ E and 228.6 m above mean sea-level). The experiment was carried out on 3-year-old existing mango orchard planted with spacing of 6 m × 6 m, which gives ample space in between mango plants for growing intercrops. Before the commencement of study, this interspace was not used for growing crops. The experiment was laid out in a split-split-plot design with three replications. Main plots treatments consisted of 4 mango cultivars, viz. 'Pusa Surya', 'Amrapali', 'Mallika' and 'Dashehari', subplots consisted of 4 cropping systems, viz. mango + cowpea (cv. 'Pusa Komal') for green pods– Indian mustard (cv. 'Pusa Vijay'), mango + greengram (cv. 'Pusa Vishal') for grain– Indian mustard, mango + blackgram (cv. 'Azad urd 1') for grain– Indian mustard and sole mango, while sub-subplots treatments comprised 3 levels of nutrient management in mango, viz. Control, 50% recommended dose (RD) of NPK through inorganic + 50% RD of FYM and RD of NPK through inorganic + RD of FYM. Besides natural incorporation of the litter fall of mango, residue/stover/stalks of all the intercrops were incorporated uniformly in the soil after picking of pods/threshing. RD of manure and fertilizer consists of 20 kg FYM, 300 g N, 150 g P_2O_5 and 300 g K_2O/plant during first year of investigation and 30 kg FYM, 400 g N, 200 g P_2O_5 and 400 g K_2O/plant in the succeeding year. The recommended package of practices including irrigation and plant protection measures were followed for intercrops and mango.

Table 1. Effect of mango cultivar, cropping system and nutrient management on fruit yield of mango

Treatment	Fruit yield/ plant (kg)		Fruit yield/ ha (kg)	
	2011–12	2012–13	2011–12	2012–13
Mango cultivar				
'Pusa Surya'	3.29	5.00	913	1388
'Amrapali'	3.35	5.07	929	1407
'Mallika'	2.82	4.65	783	1291
'Dashehari'	3.10	4.86	860	1350
SEm±	0.059	0.045	16.3	12.5
CD (*P*=0.05)	0.203	0.155	56.4	43.2
Cropping system				
Mango + cowpea mustard	3.18	5.08	882	1412
Mango + greengram mustard	3.16	4.97	878	1382
Mango + blackgram mustard	3.14	4.88	872	1356
Sole mango	3.07	4.63	853	1286
SEm±	0.050	0.054	13.9	15.1
CD (*P*=0.05)	NS	0.159	NS	44.1
Nutrient management in mango				
Control	2.91	4.44	808	1232
50% RD of NPK + 50% RD of FYM	3.19	5.04	886	1400
RD of NPK + RD of FYM	3.31	5.20	920	1445
SEm±	0.043	0.047	11.9	12.9
CD (P=0.05)	0.121	0.131	33.7	36.5

RESULTS

Marked variation in fruit yield was recorded among the cultivars. 'Amrapali' with fruit yield/plant of 3.35 and 5.07 kg and fruit yield/ha of 929 and 1,407 kg during 2011–12 and 2012–13 respectively showed supremacy over 'Dashehari' and 'Mallika'. 'Pusa Surya' showed *at par* performance with 'Amrapali'. 'Mallika' was the significantly lowest yielder amongst the four cultivars studied; the yield reduction was by 18.6 and 9.0% compared to 'Amrapali' during respective years of study. The results of the study revealed that the productivity of base crop was appreciably influenced by the different intercrops combination tried in the study. During second year of investigation, mango yields from all the three intercropping system were significantly higher over sole mango. Mean maximum fruit yield of 5.08 kg/plant and 1,412 kg/ha was harvested with cowpea–mustard sequence, closely followed by greengram– mustard. Least fruit yield (4.63 kg/plant and 1,286 kg/ha) was realized with sole plantation of mango. During first year as well; similar yield variation of base crop was recorded though the difference was insignificant. Application of RD of NPK + RD of FYM exhibited significantly higher fruit yield (920 and 1,445 kg/ha) over rest of the treatments. 50% RD of NPK + 50% RD of FYM was found to be second best treatment; which recorded 9.7 and 13.6% higher yield over control (808 and 1,232 kg/ha). Two varying fertility levels resulted in significant yield difference, though the difference was marginal. The increased number of fruits per plant and increased fruit weight in the treatment combination of NPK and FYM; obviously, had favourable effects on culminating higher yield.

CONCLUSION

Based on the study, it is concluded that genetic variability of mango and legume based agri-horticulture system with stover incorporation has potential for improving the yield of mango. Legume based agri-horticulture system has also potential to reduce the recommended dose of inorganic and organic nutrient to the extent of half during juvenile phase of orchard.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Carbon sequestration and preservation capacity as influenced by nitrogen management practices in Trans-Gangetic plains of India

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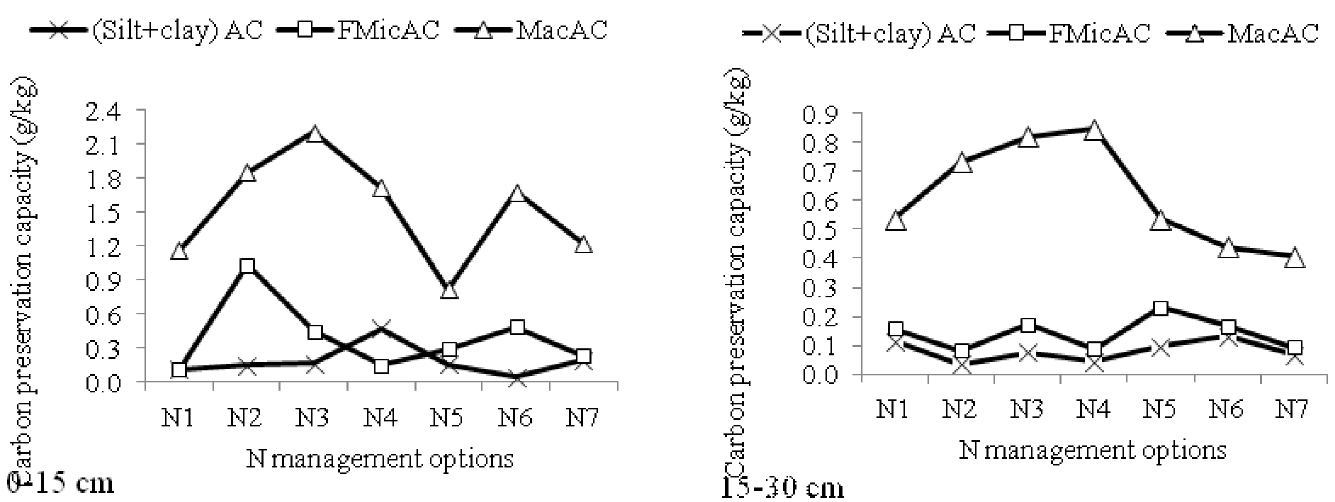
Trans-Gangetic plains of India with repetitive rice–wheat cropping system exploited soil by nutrient mining and imbalanced use of agrochemicals. Carbon and nitrogen management through organic inputs to the soil helps in improving the aggregate stability. Soil aggregates are important agents of soil organic carbon (SOC) retention (Haile *et al.,* 2008). To conserve SOC, it is important to improve our understanding of the interactions between climatic factors, soil properties and cropping sequence. The current study was an attempt to find out the best nitrogen management option for sequestering and preserving SOC for higher system productivity and sustainable soil management.

METHODOLOGY

A field experiment having seven nitrogen management treatments was conducted during 2011–13 at ICAR-Central Soil Salinity Research Institute, Karnal, Haryana, India, with wheat–mungbean–maize cropping system. Wheat and maize was grown as per the treatments, while green gram was sown on residual fertility and incorporated in the plots before sowing of the maize. Initial soil samples upto 30 cm depths indicated that pH_2 ranged 7.17–7.70, EC_2 values varied from



[a]RDF: N=150 kg/ha; P_2O_5 = 60 kg/ha; K_2O = 30 kg/ha
[b]WSA=water stable aggregate; MWD=mean weight diameter; AS=aggregate stability

Fig. 1. Influence of N management optionson carbon preservation capacity of different soil aggregates

Table 1. Effect of N management options on soil carbon pools and aggregation properties under wheat-mungbean-maize cropping system

Treatment	TC (g/kg)	TIC (g/kg)	C stock (Mg/ha)	WSA[b] (%)	MWD[b] (mm)	AS[b]
0-15 cm						
N_1 = 100% RDN[a]+10 t/ha FYM	4.56	0.00	8.85	35.8	0.55	0.29
N_2 = 100% RDN	4.74	0.00	11.1	48.4	0.43	0.23
N_3 = 75% RDN + 25% N through FYM	4.56	0.00	9.85	34.9	0.59	0.27
N_4 = 50% RDN + 50% N through FYM	5.28	0.00	11.9	50.3	0.75	0.33
N_5 = 50% N through FYM	4.38	0.06	10.2	45.8	0.59	0.27
N_6 = 25% N through FYM	5.13	0.09	11.1	34.2	0.60	0.31
N_7 = No Nitrogen	3.78	0.12	8.12	33.2	0.34	0.20
15-30 cm						
N_1 = 100% RDN [a] +10 t/ha FYM	4.44	0.00	6.84	47.3	0.52	0.23
N_2 = 100% RDN	4.56	0.00	9.45	38.7	0.44	0.25
N_3 = 75% RDN + 25% N through FYM	4.38	0.00	7.15	45.5	0.57	0.20
N_4 = 50% RDN + 50% N through FYM	5.15	0.00	12.2	48.5	0.70	0.30
N_5 = 50% N through FYM	4.21	0.07	7.32	46.9	0.42	0.25
N_6 = 25% N through FYM	5.11	0.09	7.10	36.2	0.44	0.21
N_7 = No Nitrogen	3.51	0.15	6.40	31.0	0.38	0.20

[a]RDF: N=150 kg/ha; P_2O_5 = 60 kg/ha; K_2O = 30 kg/ha
[b]WSA=water stable aggregate; MWD=mean weight diameter; AS=aggregate stability

0.16–0.26 dS/m, SOC (%) ranged from 0.33 to 0.63%. Soil samples were collected from 2 depths (0–15 and 15–30 cm) for investigating carbon dynamics and its stocking. Total carbon was analyzed by using CHN Elemental Analyzer (model Vario EL III) and other derived parameters were estimated following standard protocols.The capacity of the different sized soil aggregates to preserve/capture C per unit of the specified size of water stable aggregates are called carbon preservation capacity (CPC) of that particular size fraction and it was calculated as: CPC (g/kg) = (AAC × WSA)/100; where, AAC and WSA denotes aggregate associated carbon and water stable aggregates, respectively. Soil carbon stock was calculated by the formula adopted by Chaudhari *et al.* (2015).

RESULTS

After 2 years of wheat-moong-maize cropping system, total carbon (TC), total inorganic carbon (TIC) and carbon stock estimated under different N management practices indicated the effect of inorganic and organic fertilizer on carbon sequestration (Table 1). Treatment N_4 (50% RDN + 50% N through FYM) showed highest C stocking in both the soil depths, which was higher by 46.6% in 0–15 cm and 90.6% in 15–30 cm over control. Manna *et al.* (2005) observed that the SOC in the unfertilized plot decreased by 15.5–41.5% at three experimental sites compared to initial values, whereas, the treatment receiving NPK and NPK + FYM either maintained or improved it over initial SOC content. Water stable aggregate (WSA), mean weight diameter (MWD) and aggregate stability (AS) differed with varied quantity of FYM addition. Treatment N_4 recorded highest MWD and aggregate stability, possibly due to higher macro-aggregates. The results of the current study revealed higher carbon preservation capacity (CPC) of macro-aggregates, irrespective of the treatment (Fig. 1); this indicated preferential accumulation of C in macro-aggregates due to the fact that organic matter first enters the soil mainly in particulate form. During decomposition this is progressively incorporated into mineral associated pool with a consequent positive effect on stabilization of macro-aggregates resulted its high CPC.

CONCLUSION

The study established that integrated nutrient management by 50% N through inorganic + 50% N through FYM along with full P and K through inorganic enhanced C sequestration in reclaimed-sodic soils of hot semi-arid zone of Indian subcontinent. The above said treatment increased TC content by 39.7 and 46.7%, water stable aggregates by 51.5 and 56.5% and aggregate stability by 65 and 50% over no nitrogen treatment, respectively, in both the soil depths.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Effect of phosphorus levels and bio-organic sources on grain quality, nutrient uptake and economics of wetland rice (*Oryza sativa*)

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Rice (*Oryza sativa* L.) is the staple food crop of not only India but also of the world. Average productivity of rice in country is far below than other rice-growing countries. Improvement in nutrient use efficiency of phosphorous and their by stabilizing yield and farmer's income are the issues of prime concern. Thus, it is necessary to search out ways and means to develop a phosphorus management system by nutrient supply through conjunctive use of chemical fertilizers, organic manure and biofertilizers is essential to produce crops in line with the observed global standards of quantity and quality. Phosphorus solubilizing bacteria (PSB) solubilizes the fixed soil phosphate and increase the efficiency of applied phosphorous resulting in higher rice yield (Gull *et al.*, 2004). Among various organic sources, FYM and use of blue green algae (BGA) in wetland rice are the common practices (Begum *et al.*, 2009). The high cost of chemical fertilizer and low purchasing power of Indian farmers restricts its use in proper quantity, hampering crop production. With a view to, reduce the use of chemical fertilizer by enhancing the use of organic sources of nutrients, viz. FYM, biofertilizers etc. is inevitable. Although, the use of phosphate solubilizing microorganisms, farmyard manure and blue green algae are commonly recommended and found suitable for rice crop under integrated nutrient management strategy. Keeping these facts in to consideration an experiment was conducted to evaluate the comparative performance of phosphorus levels and bio-organic sources on grain quality, uptake of primary nutrients and economics of wetland rice under eastern Uttar Pradesh conditions.

METHODOLOGY

A field experiment was conducted during rainy season of 2013 at Agricultural Research Farm, Institute of Agricultural Sciences, Varanasi to evaluate the influence of phosphorus levels and bio-organic sources on grain quality, nutrient uptake and economics of wetland rice. The soil was sandy clay loam in texture with pH 7.35, Electrical conductivity (dS/m at 25°C) 0.15, organic carbon 0.39%, available N, P, K content in soil was 198.03 kg/ha, 23.7 kg/ha and 188.32 kg/ha respectively. Factorial experiment was laid out in Randomized Complete Block Design assigning four levels of phosphorus, viz. control, 50%, 75% and 100% recommended dose of fertilizers (RDP) and three bio-organic sources, i.e. PSB, PSB + BGA and PSB + BGA + FYM (5 t/ha) replicated thrice. Recommended dose of fertilizers used was N_2-P_2O_5-K_2O (120-60-60 kg/ha). The N, P and K were supplied through urea, diammonium phosphate (DAP) and muriate of potash respectively. Half of the recommended dose of nitrogen and full dose of potassium were applied as basal application and remaining half nitrogen was applied in two equal splits at active tillering and panicle initiation stages uniformly to all the treatments. Variable rates of phosphorus were applied as per treatment. Four week old seedling of rice cv. 'HUR 105' was transplanted on the puddled field keeping two seedlings/hill at a spacing of 20 cm × 15 cm. After 10 days of transplanting, BGA was applied at the rate of 10 kg/ha in their respective treatments. Before transplanting, inoculants suspension of liquid PSB culture (*Bacillus polymyxa*) was prepared with water in ratio of 1 : 10 and seedling roots were dipped in solution for about 30 minutes under shade and transplanted immediately to their respective plots. Well decomposed FYM was applied basally as per treatment. Recommended agronomic practices were followed to raise the experimental crop.

RESULTS

The highest grain yield was recorded with the application of 100% RDP which exhibited significant superiority over control and 50% RDP but observed at par with 75% RDP. Combined application of PSB + BGA + FYM recorded the maximum grain yield which was significantly superior to PSB + BGA and PSB alone. However, difference between PSB + BGA and PSB alone was not significant.

Data revealed that maximum grain protein content and protein yield was recorded with the highest phosphorus level (100% RDP) applied which was significantly superior over its lower phosphorus levels. However, phosphorus levels, i.e. control, 50% RDP and 75% RDP remained statistically at par with each other in case of protein content and protein yield in grain.

Among bio-organics, maximum protein content and protein yield recorded in rice grain with combined use of PSB+BGA+FYM proved significantly higher over use of PSB alone but observed at par with the application of PSB+BGA. Application of PSB + BGA + FYM increased the protein content and protein yield over use of PSB alone. Integration of bio-organic sources might have increased the removal of phosphorus and other nutrient to the plant which ultimately influenced the protein yield favorably. These results confirmed the finding of Dixit and Gupta *et al.* (2005).

Maximum net return (₹ 44,645.29) was recorded with application of 100% RDP while higher benefit: cost ratio (1.20) was obtained with 75% RDP. Among bio-organics, PSB + BGA + FYM recorded maximum net return (₹ 43,085.03/ha) and benefit: cost ratio (1.16). This might be due to favorable effect of FYM which helped in release of nutrients and also accelerated the algal growth to provide atmospheric nitrogen compared to application of PSB + BGA or PSB alone. Findings are in close conformity with Davari and Sharma (2010).

Application of highest phosphorus level (100% RDP) claimed significantly higher uptake of nitrogen, phosphorus and potassium uptake by grain and straw over its lower phosphorus levels (Table 2). The adequate supply of phosphorus played a vital role in removal and translocation of nutrients resulting higher uptake of NPK by rice crop (Tripathi *et al.*, 2007). Among bio-organics, combined use of PSB + BGA + FYM removed higher N, P and K by grain

Table 1. Effect of phosphorus levels and bio-organics on grain yield, protein content, protein yield and economics of rice

Treatments	Grain yield (q/ha)	Grain protein content (%)	Protein yield(kg/ha)	Cost of cultivation (₹/ha)	Net return (₹/ha)	Benefit: cost ratio
P levels (% RDP)						
0	42.59	6.67	284.34	34,373	35,796	1.04
50	45.06	7.21	325.29	35,987	38,272	1.06
75	49.91	7.69	383.71	36,763	43,986	1.20
100	50.97	9.18	471.36	37,678	44,645	1.18
SEm±	0.93	0.35	20.06	–	931	0.04
CD (*P*=0.05)	2.73	1.04	58.72	–	2,720	0.11
Bio-organics						
PSB	45.37	6.94	316.49	35,599	38,601	1.08
PSB+BGA	46.76	7.84	369.65	36,068	40,339	1.12
PSB+BGA+FYM	49.27	8.28	412.45	36,935	43,085	1.16
SEm±	0.81	0.31	17.37	–	806	0.03
CD (*P*=0.05)	2.37	0.90	50.85	–	2,361	NS

RDP, Recommended dose of phosphorus (60 kg/ha); PSB, phosphate solubilizing bacteria; BGA, blue green algae; FYM, farmyard manure @ 5 tonnes/ha

Table 2. Effect of phosphorus levels and bio-organics on nutrient uptake of rice crop

Treatments	Nutrient uptake (kg/ha)					
	Nitrogen		Phosphorus		Potassium	
	Grain	Straw	Grain	Straw	Grain	Straw
P levels (% RDP)						
0	45.51	19.82	6.12	3.06	11.16	69.39
50	52.05	25.87	7.28	4.03	12.06	79.79
75	61.39	32.56	8.37	4.90	14.24	84.02
100	75.42	41.38	11.79	8.98	15.57	96.44
SEm±	3.21	0.84	0.41	0.55	0.54	2.04
CD (P=0.05)	9.40	2.41	1.21	1.60	1.54	5.97
Bio-organics						
PSB	50.64	27.53	6.96	4.20	12.41	76.29
PSB+BGA	59.14	29.84	8.60	5.23	13.12	81.82
PSB+BGA+FYM	65.99	32.36	9.62	6.29	14.24	89.12
SEm±	2.78	0.73	0.36	0.47	0.47	1.77
CD (P=0.05)	8.14	2.14	1.05	1.39	1.38	5.17

RDP, Recommended dose of phosphorus (60 kg/ha); PSB, phosphate solubilizing bacteria; BGA, blue green algae; FYM, farmyard manure @ 5 tonnes/ha and straw. This might be due to increased efficiency and cumulative effect of combined application of bio-organic sources resulting increased uptake of nutrients Yadav *et al.* (2013).

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Effect of cropping systems and nutrient sources on system productivity and system economics of direct seeded *basmati* rice based cropping system

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Rice is one of the most important staple crops feeding more than half of the global population. Rice–wheat cropping system is major cropping system and it is occupying nearly 13.5 million ha of Indo-Gangetic Plains (IGP) of South Asia covering Pakistan, India, Bangladesh and Nepal. The productivity and sustainability of rice-wheat systems are threatened because of inefficient use of inputs (fertilizer, water, labour), increasing scarcity of resources, changing climate, emerging energy crisis and rising fuel prices and rising cost of cultivation (Ladha *et al.*, 2009). In recent years, interest of farmers in direct seeded rice, diversification and integrated nutrient management has increased because of escalation of capital, production costs and scarcity of resources like land, labour and water. Direct seeding of rice, a common practice before 'Green Revolution' in India, is becoming popular once again because of its potential to save water and labour. Productivity of directed seeded rice often reported to be comparable with conventional transplanting method (Gangwar *et al.*, 2008). Integration of inorganic fertilizers and organic manure provides balanced nutrition to crops and minimizes the antagonistic effects resulting from hidden deficiencies and nutrient imbalance. Therefore, it needed to diversify the existing system and reorientation of nutrient management strategy for increasing the productivity on the sustainable basis

METHODOLOGY

The field experiment was conducted during *khaki, rabi* and summer seasons of 2014-15 and 2015-16 at the research farm of ICAR-Indian Agricultural Research Institute, New Delhi, India. Soils are alluvium–derived sandy clay loam in texture. The soil had pH 7.9, organic C 0.49%, available N 209.7 kg/ha, P 15.3 kg/ha, and K 272.4 kg/ha. The experiment was initiated in strip–plot design with three replications. Four cropping systems, *viz*. DSBR (Direct seeded basmati rice)–wheat–fallow, DSBR–wheat–mungbean, DSBR–cabbage–mungbean and DSBR–cabbage–onion were assigned to vertical strips; and 4 nutrient sources, *viz*. control, 100% recommended dose of fertilizers (RDF) through fertilizers, 50% RDF+25% recommended dose of nitrogen (RDN) through leaf compost (LC)+biofertilizers, 50% RDF+25% RDN through vermicompost (VC)+biofertilizers were assigned to horizontal strips. The RDF of rice, wheat, cabbage, mungbean and onion were 120:60:60, 120:60:60, 150:70:70, 15:30:0 and 100:50:50 kg N: P_2O_5:K_2O kg/ha respectively. The vermicompost and leaf compost was applied before sowing/planting of crops based on the nitrogen equivalent basis and requirement of each crop in respective

Table 1. Effect of cropping systems and nutrient sources on system productivity and system economics of direct seeded *basmati* rice based cropping systems

Treatment	System productivity		System economics							
	REY (t/ha)		cost of cultivation (×10^3 ₹/ha)		Gross returns (×10^3 ₹/ha)		Net returns (×10^3 ₹/ha)		B:C ratio	
	2014–15	2015–16	2014–15	2015–16	2014–15	2015–16	2014–15	2015–16	2014–15	2015–16
Cropping systems										
DSBR wheat	5.78	5.95	78.33	83.66	183.67	191.48	105.34	107.82	1.34	1.28
DSBR wheat moonbeam	6.86	7.29	93.77	100.08	213.05	230.27	119.27	130.19	1.27	1.30
DSBR cabbage moonbeam	12.91	13.25	100.58	108.66	326.20	352.07	225.62	243.42	2.24	2.24
DSBR cabbage onion	21.09	20.28	152.41	168.08	519.44	555.03	367.03	386.95	2.40	2.30
SEm±	0.346	0.363			8.182	9.563	8.182	9.563	0.058	0.065
CD (P=0.05)	1.198	1.255			28.31	33.086	28.31	33.086	0.200	0.223
Nutrients sources										
Control	7.18	7.13	77.35	86.21	195.88	208.84	118.53	122.63	1.53	1.42
100% RDF through fertilizers	13.17	13.18	93.98	102.22	348.88	372.47	254.90	270.26	2.71	2.64
50% RDF + 25% RDN-LC + bio.	12.82	12.97	127.64	136.76	340.62	366.87	212.97	230.11	1.66	1.68
50% RDF + 25% RDN-VC + bio.	13.46	13.48	126.12	135.29	356.98	380.67	230.86	245.38	1.83	1.81
SEm±	0.226	0.288			5.702	7.838	5.702	7.838	0.039	0.04
CD (P=0.05)	0.780	0.995			19.729	27.119	19.729	27.119	0.136	0.14

DSBR, Direct seeded rice; RDF, Recommended dose of fertilizers; RDN, Recommended dose of nitrogen; LC, Leaf compost; VC, Vermicompost; Bio = Biofertilizers; REY, Rice equivalent yield

treatments. All the observations were recorded by using standard procedure.

RESULTS

The yield of component crops of the system expressed as rice equivalent yield (REY) under different cropping systems and various nutrient sources has been presented in Table 1. The results pertaining to system productivity (REY) indicated that significantly the highest REY was registered in DSBR–cabbage–onion system (21.09 and 20.28 t/ha during 2014-15 and 2015-16, respectively). DSBR–cabbage–onion system increased the REY to the extent of 2.7 and 2.4 times during 2014-15 and 2015-16, respectively over DSBR–wheat system. Among the nutrient sources, application of 50% RDF+25% RDN-VC+biofertilizer registered significantly the highest REY (13.46 t/ha and 13.48 t/ha) during both the years which was statistically at par with all the nutrient sources during both the years. The application of 50% RDF+25% RDN-VC+biofertilizer increased the REY to the extent of 87.5 and 89.1% during 2014-15 and 2015-16, respectively over control. This might be due to balanced supply of nutrients to the crops throughout the crop growth period as vermicompost undergo decomposition during which series of nutrient transformation takes place and helps in their higher availability to the crops. Critical examination of data revealed that DSBR–cabbage–mungbean and DSBR–cabbage–onion systems obtained significantly the maximum system gross and net returns and B: C ratio during both the years of experimentation (Table 1). This might be due to inclusion of vegetable crops in the cropping systems during both years. Further, application of 50% RDF + 25% RDN-VC+biofertilizer resulted in significantly the maximum system gross returns, whereas, the highest system net returns were obtained with 100% RDF. Integration of vermicompost and leaf compost also increased the cost of treatment, therefore, reduced the system net returns as compared to chemical fertilizers.

CONCLUSION

The investigation clearly brought out the fact that the different rice based cropping systems and nutrient sources have significant effects on system productivity and economics. Vegetable based cropping systems, DSBR–cabbage–onion or DSBR–cabbage–mungbean cropping systems in conjunction with 50% RDF + 25% RDN-VC + biofertilizers give higher system productivity and profitability in terms of rice equivalent yield over other cropping systems.

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Growth and yield of clusterbean varieties as a influenced by foliar application of iron

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Clusterbean, also known as guar, is a arid legume crop that is cultivated mostly in the arid and semi arid areas as it is drought resistant. The word "guar" represents its derivation from sanskrit word "Gauaahar" which means cow fodder or otherwise fodder of the livestock. There is no other legume crop so hardy and drought tolerant as clusterbean, which is especially suited for soils and climate of Rajasthan. The popular guar gum (28 to 32%), which is used in mining, petroleum drilling and textile manufacturing sectors, is obtained from the endosperm of the seed of the plant. Many genotypes for different agro-ecological situations of arid and semi-arid have been released. The newly developed varieties are superior under particular situation.

Average yield of crop in Rajasthan is below potential yield. The low yield of crop is mainly due to cultivation of traditional low yielding varieties without or with little fertilization and lack of other improved agronomic practices. Thus, it offer a great scope for increasing its productivity through selection of suitable varieties and sound crop husbandry practices. Use of recently released high yielding varieties is imperative to meet out our increasing industrial demand. These varieties vary yielding potential under varied climatic conditions, but a variety performing better is selected for the region.

Micronutrients have played vital roles in the growth, yield and quality of legumes crops. Hallock (1978) observed that foliar application of micronutrient is better than soil application for increasing yield. Legume crops required not only adequate macronutrient but also micronutrients for increasing the bacterial activity of nodule. Therefore, an optimum supply of micronutrients under balanced condition is very important for achieving higher productivity. Iron being an essential micronutrient takes active part in the metabolic activities of the plant. It acts as an activator of dehydrogenase, proteolase and peptidases enzymes and involved directly or indirectly in the synthesis of carbohydrates and proteins. Iron being a structural component of porphyrin molecules, cytochromes, heams, hematin, ferrichrome and leg–heamoglobin is involved in oxidation-reduction reactions. Therefore, the present investigation was carried out to identify response of different varieties with foliar application of iron in clusterbean.

METHODOLOGY

The experiment was conducted at the Agronomy farm, Sri Karan Narendra Agriculture University, Jobner in Agroclimatic zone III A (Semi-arid Eastern Plain Zone) of Rajasthan. The soil was loamy sand in texture, alkaline in reaction (pH value 8.2), poor in organic carbon (0.14%) with low available nitrogen (130 kg/ha) and medium in phosphorus and potassium content (18.9 and 175.6 kg/ha) respectively. The Twenty treatment combinations consisting of five clusterbean varieties (RGC-986, RGC-1003, RGC-1033, RGC-1055 and RGC-1066) and four foliar spray treatment of 0.5% $FeSO_4$ (control, branching, flowering and branching + flowering) were tested in randomized block design with three replications. The seed was sown manually on 10 July 2014 maintaining spacing of 30 cm × 10 cm, with 20 kg/ha seed rate.

RESULTS

Growth parameter and yield attributes

Results indicated that variety of RGC-1066 recorded significantly increase plant and remained at par with variety of RGC-1055 over rest of varieties. The variety of RGC-1033 recorded significantly increases the dry matter accumulation, number of seeds per pod and test weight and remained at par with the variety of RGC-1055. The differential behaviour among the varieties could be explained solely by the variation in their genetic make up and their differential behavior under different climatic conditions (Rawat *et al*., 2015).

The result further indicated that application of $FeSO_4$ @ 0.5% at branching + flowering stage significantly increase the plant height, dry matter accumulation, relative growth rate and number of pods per plant and remained at par with the application of $FeSO_4$ @ 0.5% at branching stage over control. Similar result was found in case of leaf area index, crop growth rate, number of seeds per plant and test weight but remained at par with the application of $FeSO_4$ @ 0.5% at flowering stage over rest of varieties. The favourable effect of foliar application of fertilizers might be due to on account of improved photosynthetic efficiency and chlorophyll formation. This might be due to readily available Fe at early and the critical stage of plant growth that facilitated maximum plant growth (Eleyan *et al*., 2014).

CONCLUSION

It was concluded that under prevailing conditions, clusterbean varieties 'RGC-1033'appear suitable for cultivation in semi-arid Rajasthan. However, foliar application of 0.5% $FeSO_4$ at branching stage could be useful for improving highest seed yield. The farmers of the Indian sub-continent are not habituated to use micronutrients as foliar spray on field crop.

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Effect of method and time of nitrogen application on growth and yield of sorghum

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A field experiment on method and time of nitrogen application on sorghum genotypes under rainfed condition was conducted during *kharif* season of 2012–13 at the farm of Sorghum Research Unit (CRS) Dr. PDKV, Akola to find out proper method and time of nitrogen application for enhancing productivity and soil fertility. The experiment was planned in FRBD with the treatments as Factor A: N application methods (5 Nos) as N1: 50% N, at sowing and 50% at 30 DAS, N2: 50% N, at sowing + 25% at 30 DAS +25% at boot-leaf stage (BLS), N3: 25% N, at sowing + 50% at 30 DAS +25% at boot-leaf stage (BLS), N4: 25% N, at sowing + 50% at 30 DAS +15% at BLS 10% at grain filling stage (GFS), N5: 25% N, at sowing + 45% at 30 DAS + 5% foliar spray at 45 DAS +15% at BLS+10% GFS and Factor B two cultivars as G1-CSH 16 and G2-CSV 20. In N application methods the plant height and the yield attributing characters as panicle length (cm), panicle weight (g) and grain weight/panicle were significantly maximum with the application of 50% N at sowing + 25% at 30 DAS +25% at boot-leaf stage (BLS). Fodder and grain yield was significantly maximum with the application of 50% N at sowing + 25% at 30 DAS + 25% at boot-leaf stage (BLS). Among the cultivar the variety CSV 20 recorded significantly maximum plant height, panicle length (cm), panicle weight (g) and fodder yield than hybrid CSH 16. However the hybrid CSH 16 recorded significantly maximum grain yield but it was at par with the variety.

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Response of groundnut to varying levels of sulphur and its sources

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Sulphur is now recognized as the fourth major plant nutrient and integral part of balanced fertilization for oilseeds in general and groundnut in particular. Continuous use of high analysis sulphur devoid fertilizers coupled with intensive cropping using high yielding varieties and reduction in use of organic manures resulted in sulphur deficiency in soils. A number of substances supplying sulphur like gypsum, SSP, elemental sulphur are available in the market. Gypsum is a material huge deposits of which are found in the state of Rajasthan and being excavated at large scale. Thus, it is wise to give a fresh look to sulphur requirement of groundnut and select a relatively cheaper and more effective source for obtaining higher yield and superior quality product.

METHODOLOGY

The study was carried out under loamy sandy soil during *kharif,* 2015 at S.K.N. College of Agriculture, Jobner. The soil of the experimental field was alkaline in reaction, low in organic carbon, available nitrogen and medium in available phosphorus and potassium. The experiment comprising of five levels (15, 30, 45, 60 and 75 kg/ha) and three sources of sulphur (gypsum, elemental sulphur, SSP) thereby making 15 treatment combinations was laid out in randomized block design and replicated thrice. A uniform dose of 20 kg N and 40 kg P_2O_5/ha was applied through urea and DAP, respectively at the time of sowing. Groundnut variety 'RG-382' (Durga) was sown in rows spaced 45 cm apart. The crop was irrigated three times at critical growth stages due to long dry spells.

RESULTS

Results showed that progressive increase in level of sulphur upto 60 kg/ha significantly increased the growth and yield attributing characters of groundnut, viz. dry matter accumulation at most of the stages, number and weight of root nodules/plant, number of pods/plant and seed index over lower levels. It also recorded significantly higher pod (1,892 kg/ha), haulm (3,469 kg/ha) and biological yield (5,361 kg/ha) of groundnut over 45, 30 and 15 kg/ha. However, plant height, CGR and number of kernels/pod were found to increase significantly upto 45 kg S/ha, only. Results further revealed that nitrogen, phosphorus and sulphur concentration in kernel and haulm, protein and oil content in kernel were improved significantly upto 45 kg S/ha. Whereas, enhancement in total nutrient uptake and oil yield was recorded significant upto 60 kg S/ha. Sulphur fertilization at 60 kg/ha also fetched additional net returns of ₹ 6343, 15,867 and 34,062/ha over 45, 30 and 15 kg/ha, respectively with the highest B : C ratio of 1.60. Gypsum proved significantly superior among all the sources of sulphur with respect to growth and yield determining characters of groundnut. It also improved the pod, haulm and biological yield to the extent of 32.0, 32.2 and 32.1 per cent over elemental sulphur. The corresponding increase due to SSP was 16.7, 21.7 and 19.9 per cent that was noted to be the next better source of sulphur fertilization. Remaining at par with each other, gypsum and SSP also recorded significant improvement in number and weight of nodules/plant, pods/plant, kernels/pod, shelling percentage, N, P and S concentration in kernel and haulm and protein and oil content in kernel than elemental sulphur. Significantly higher nitrogen, phosphorus and sulphur uptake, oil yield and net returns were also obtained under gypsum application.

CONCLUSION

Sulphur fertilization at 60 kg/ha was found the most suitable dose for obtaining higher pod yield (1,892 kg/ha), net returns (₹ 55,034/ha) and B : C ratio in groundnut. Similarly, gypsum was observed as the most effective source of sulphur for enhancing productivity (1,872 kg/ha) and getting higher net returns (₹ 55,358/ha). On the basis of production function, application of sulphur at 66.86 kg/ha was worked out to be the optimum dose for groundnut.

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Studies on the effects of super imposition of organic and microbial supplements over recommended dose of fertilizers in wheat (*Triticum aestivum* L.)

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The present study was conducted during *rabi* season 2014-15 at Students Instructional Farm of Chandra Shekhar Azad University of Agriculture & Technology, Kanpur (Uttar Pradesh) with the objectives to find out suitable superimposition nutritional level and to assess economics of different fertility level for wheat crop under irrigated conditions. The treatment consisted seven super imposition doses of vermicompost @ 5 t/ha, compost 10 t/ha, Azotobactor and PSB for seed treatment as individual and in combination over inorganic fertilizers compared with only recommended doses of inorganic fertilizer (control) were laid out in Randomized Block Design replicated three times. The soil of field was sandy loam in texture and normal sown of wheat verity as New Shekhar (K-1006). The superimposition of organic manures, nitrogen supplements over inorganic fertilizers in different treatments exhibited significant response in terms of increasing grain yield from 2.06% to 17.45% compared to control treatment which recorded lowest (3.45 t/ha) grain yield. The combined doses of (RDF + compost 10 ha/ha + Azotobacter and PSB, nutrition recorded highest grain yield (4.05 t/ha) followed by RDF + vermicompost 5 t/ha Azotobacter and PSB by 3.81 t/ha grain yield and significantly at par. On economic parameter, the maximum gross income ₹ 80,900/ha, net income of ₹ 29,132/ha, was also recorded in RDF + Compost @ 10 t/ha + Azo. & PSB beneficial effect of super impost nutrition in wheat crop in normal sown condition.

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Effect of fertility and cow urine levels to growth and yield of Indian mustard

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Oilseeds play a vital role in Indian economy, accounting for 5% of gross national product and 10% of the value of agricultural product.). Among the seven edible oilseeds cultivated in India, rapeseed–mustard (*Brassica* spp.) contributes 28.6% to the total production of oilseeds. The country witnessed yellow revolution through a phenomenal increase in production and productivity of rapeseed and mustard from 2.68 mt and 650 kg/ha in 1985–86 to 6.96 mt and 1,022 kg/ha in 1996–97, respectively. In spite of these achievements, there exists a gap between production potential and actual realization. In India rapeseed-mustard is grown on an area of 5.53 m ha with production and productivity of 6.41 mt and 1,157 kg/ha. In spite of increased production and productivity of rapeseed–mustard in the country, the per capita consumption (8.2 kg/capita/year) of fats and oils is quite low. The requirements of fats and oils will be much higher in view of increasing population and improved and increased standard of living of the people in near future. It has been recognized that N, P and K fertilizers alone are not always sufficient to provide balanced nutrition for optimal yield and quality of mustard (Jain and Sharma, 2000). It has been experimentally found that, in cauliflower cultivation the highest curd yield and the highest benefit cost ratio were observed by application of N through urine.(Khanal *et al*., 2011). Therefore, it seems that cow urine under livestock based integrated farming system has a great potential for use as a bio fertilizer in crop production.

METHODOLOGY

A field experiment was conducted during winter (*rabi*) season of 2013–14 at the IFS block of Agricultural Research Farm, Department of Agronomy, Institute of Agricultural Sciences. The soil of the experimental field was silty clay loam mollisol having having pH 7.8, organic carbon 0.38%, available nitrogen 138.48 kg N/ha, available phosphorus 23.48 kg P/ha, available potassium 172.10 kg K/ha , available sulphur 20.73 (mg/ kg). The experiment consisted of twelve treatments Main plot treatment – Three fertility levels F_1= 50% (Recommended Dose of Fertilizer), F_2=75% (Recommended Dose of Fertiliser), F_3=100% (Recommended Dose of Fertilizer) and Subplots treatment –Four levels of cow urine application (U) U_0= 0 L Urine + 900 L Water/ha , U_1= 300 l Urine + 600 L Water/ha, U_2= 600 L Urine + 300 L Water/ha, U_3= 900 L Urine + 0 L Water/ha. So the total numbers of treatment combinations were twelve. Furrows were opened in each plot at a distance of 40 cm for sowing of mustard variety 'Pro agro 4001' sown at 5 kg/ha. Half of N and full doses of P and K were applied in furrows after mixing with moist soil. The sources of N, P, K and S were Urea, DAP, MOP and elemental sulphur, respectively. The rest half nitrogen was top dressed through urea at one month stage. Cow urine with or without water as per treatment was applied in furrows opened for sowing. Storage of urine was done in plastic container at room temperature. The urea N content of the urine was determined 1 day before application to ascertain the amount of nutrients applied. All the agronomic operations were kept uniform in all the plots. Pendimethalin 30 EC @ 1 kg/ha was applied as pre emergence spray. This was accompanied by one mechanical-cum-manual weeding at 4 week stage of the crop.

RESULTS

The increasing fertility levels up to 100% markedly influenced the growth parameters, viz. plant height, no of green leaf, leaf area index, leaf chlorophyll content in terms of SPAD value, dry matter production as well as phonological events. All the growth attributes improved with application of 100% RDF at most of the growth stages during the experimentation. Increased NPKS levels enhanced the seed and stover yields significantly up to 100% RDF. The highest yields increase were recorded under 100% RDF followed by, 75% RDF and 50% RDF. Higher yields associated with higher levels of fertility were consistently observed because of enhanced growth and yield attributes. The positive response of mustard to applied nutrients up to 100% RDF was also reported by Ghimire and Bana (2009). However, the effect of urine application on growth attributing characters was more pronounced at 900 L /ha followed by 600 L urine/ha (Table 1). The seed yield was increased significantly with increasing levels of urine application up to 900 l/ha. The results are in agreement with the findings of (Mohanty *et al*., 2014). Increasing levels of urine application from 0 to 900 l/ha favorably improved the stover yield. Higher urine levels produced taller plants and increased no of functional leaves/plant, primary and secondary branches/plant and accumulation of dry matter/plant which ultimately resulted into higher stover yield.

CONCLUSION

On the basis of the experimental findings of present investigation following conclusions are drawn: No curtailment in the recommended fertilizer dose (120 kg N +

Table 1. Effect of fertility and cow urine levels on growth and yield of mustard

Treatment	Plant Height* (cm)	Functional leaves/plant**	Leaf Chlorophyll content***(SPAD)	LAI**	Seed yield (kg/ha)	Stover yield (kg/ha)
Fertility level						
50% RDF	139.0	13.73	40.1	3.10	930	2,709
75% RDF	151.1	15.15	43.6	3.52	1,069	2,970
100% RDF	156.7	17.12	44.8	3.70	1,220	3,270
S. Em+	1.51	0.42	0.36	0.08	34.0	111.6
CD (P=0.05)	5.94	1.66	1.41	0.32	133	438.3
Cow urine level (L/ha)						
0	143.8	14.00	41.2	3.10	996	2,710
300	147.6	15.11	42.1	3.37	1,052	2,803
600	150.7	15.87	43.6	3.60	1,115	3,091
900	153.7	16.35	44.5	3.69	1,130	3,327
S. Em+	1.68	0.37	0.48	0.08	12.7	52.0
CD (P=0.05)	4.98	1.10	1.42	0.25	37.6	155.1

*At harvest; **At 60 DAS; ***At 30 DAS

60 kg P_2O_5 + 60 kg K_2O + 40 kg S /ha) to mustard is possible. Cow urine application up to 900 l /ha enhanced the growth, yield and quality of mustard.

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Effect of integrated application of inorganic and organic sources on yield and nutrient uptake by pearlmillet

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Integrated nutrient supply system aimed at sustainable crop production level with minimum deleterious effect of chemical fertilizers on soil health and least disturbance to pearlmillet-mustard ecosystem by orchestrating the combined use of inorganic fertilizers and organic manures. The best of inorganic could be obtained in the presence of adequate organic manure and that maximum pearlmillet and mustard yield could be obtained through complementary use of organics with inorganic fertilizers. This approach restores and sustains soil health and productivity in the long run besides meeting the nutritional deficiencies. The result of the long-term field. Experiment/demonstration at farmers field indicated that the technology of the combined use (15 t FYM/ha/year with recommended dose of NPK) increased the productivity of pearlmillet–wheat, cotton–wheat, cotton–mustard, mustard–sorghum and rice–wheat cropping system.

METHODOLOGY

Field study was conducted at the Crop Research Farm of Rajmata Vijayaraje Scindia Agriculture University, Gwalior (M.P.) in *kharif* season 2014 with pearlmillet as a test crop. The experimental soil having pH (1 : 2) 7.5, electrical conductivity (E.C.) 0.43dS/m, organic carbon (O.C.) 4.53 g/kg, available N (172.96) kg/ha, Olsen-P (11.79) kg/ha, available K (198.24) kg/ha and available S (6.88) mg/kg. The 100% NPK recommended dose of fertilizer for pearlmillet was 80 kg N, 40 kg P_2O_5 and 20 kg K_2O/ha respectively. The experiment consisted of nine treatments replicated three times in a randomized block design, viz. FYM @ 16 t/ha (T_1), N_{40} P_{20} K_{10} + FYM @ 8 t/ha: T_2, N_{20} P_{10} K_5 + FYM @ 12 t/ha: T_3, N_{60} $P_{30}K_{15}$ + FYM @ 4 t/ha: T_4, Vermicompost 5,334 kg/ha: T_5, $N_{40}P_{20}K_{10}$ + Vermicompost @ 2,667 kg/ha: T_6, $N_{20}P_{10}K_5$ + Vermicompost @ 4,000 kg/ha: T_7, $N_{60}P_{30}K_{15}$ + Vermicompost @ 1,334 kg/ha: T_8, $N_{80}P_{40}K_{20}$: T_9. The farmyard manure (FYM) was obtained from small dairy holders. The FYM @ 16 t /ha was incorporated one month before sowing as per treatments. Total N, P, and K contents of the FYM were 0.50, 0.25 and 0.50% respectively. Half of the N and entire dose of P, K were applied at the basal dose and remaining quantity of N was top dressed after 35 days, in the form of urea, di-ammonium phosphate, murate of potash. Grain and straw yields were recorded after harvest of crop. The grain and straw samples were digested in H_2SO_4 for determination of N and di-acid mixture of HNO_3 and $HClO_4$ (2 : 5) for P, K and S estimation. Plant uptake of N, P, K and S were computed by multiplying the yield with the respective nutrient content. After harvest of the crop, the composite surface (0–15 cm) soil samples from each plot of the experimental field were analyzed for pH, EC, OC, available N, P, K by following standard procedures.

RESULTS

The organic carbon of soil increased significantly with the application of FYM and vermicompost along with graded dose of fertilizers (Table 1). The highest build-up of OC in the soil was recorded in 100% NPK, which was at par with 25% vermicompost + 75% NPK and 75% vermicompost +

Table 1. Influence of integrated application of inorganic and organic sources on soil chemical properties of post-harvest soil and yield

Treatment	pH (1:2)	EC (dS/m)	OC (g/kg)	Grain Yield (kg/ha)	Straw Yield (kg/ha)
100% FYM	7.4	0.42	4.24	3170.66	9723
50% FYM + 50% NPK	7.7	0.42	4.36	3549.3	12038
75% FYM +25% NPK	7.7	0.43	4.49	3468.23	12038
25% FYM + 75% NPK	7.5	0.44	4.46	3693.43	12346
100% Vermicompost	7.7	0.42	4.34	3044.73	11575
50% Vermi +50% NPK	7.6	0.45	4.5	4192.46	11266
75% Vermi + 25% NPK	7.5	0.45	4.5	3450.16	10957
25% Vermi + 75% NPK	7.6	0.46	4.59	3774.46	12964
100% NPK	7.4	0.46	4.61	3891.6	14507
CD (P=0.05)	NS	0.016	0.17	646.271	1814.04

Table 2. Influence of integrated application of inorganic and organic sources on nutrient uptake

Treatment	Total nutrient uptake (kg /ha)			(ppm)
	N	P	K	S
100% FYM	64.79	10.05	142.27	8.18
50% FYM +50% NPK	114.89	23.00	199.45	11.63
75% FYM + 25% NPK	97.35	23.47	207.02	11.11
25%FYM + 75% NPK	85.62	72.26	221.03	12.86
100% Vermicompost	84.07	26.09	207.32	10.34
% 50Vermicompost + 50% NPK	116.11	37.83	225.92	15.08
% Vermicompost 75+ 25% NPK	96.1	25.24	213.67	14.85
25% Vermicompost + 75% NPK	137.39	33.29	245.54	19.95
100% NPK	180.78	38.81	303.05	23.06
CD (P=0.05)	27.48	6.79	35.36	2.95

25% NPK. Thus, integrated application of organics with chemical fertilizers (vermicompost + NPK) resulted in significantly higher organic carbon content in soil. The increase in OC content in the manorial treatment combinations is attributed to direct addition of organic manure in the soil which stimulated the growth and activity of microorganisms and also due to better root growth, resulting in the higher production of biomass, crop stubbles and residues. Higher yield in comparison to 100% FYM and 100% vermicompost were recorded with 50% vermicompost + 50% NPK (Table 2). There was a significant response of different treatments as compared to organic sources. Grain yield varied from 3,044.73 to 4,192.46 kg /ha under different treatments which were in T_5 (100% vermicompost) and T_6 (50% vermicompost +50% NPK) respectively. Application of P along with N considerably increased yield of pearlmillet compared to the application of FYM alone. A better supply of phosphorus has been associated with prolific root growth resulting in enhanced water and nutrient absorption. The application of K along with NP significantly increased the grain and straw yield of pearlmillet over FYM and vermicompost alone, emphasizing on the essentiality of balanced fertilization to obtain higher pearlmillet productivity. As K play a number of indispensable roles in a wide range of function. Increasing fertility levels increased the yield of pearlmillet in different combination of NPK + vermicompost. Application of balanced fertilization of N, P and K led to significantly higher NPK uptake in comparison to FYM and vermicompost alone (Table 2). Nutrient uptake was influenced significantly by the application of chemical fertilizers alone or in combination with FYM and vermicompost. The highest total uptake (grain +straw) of NPKS (180, 38.81, 303.05 and 23.06 kg/ha respectively) was recorded with the incorporation of 100% NPK. It is obvious as from inorganic fertilizer release of NPK is faster in the solute form, whereas NPK availability from organics is after its mineralization which depends on soil conditions.

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Nutrient management in Bt cotton under dry farming condition of North Saurashtra agro climatic region

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Cotton 'the king of apparel fibers' is an important cash crop and it supplies a major share of raw material for the textile industry and playing a key role in the economic and social affairs of the world (Anonymous, 2010). It is grown chiefly for its fiber which is used in the manufacture of cloths, making of threads and extraction of oil from cotton seed (Deshmukh *et al.,* 2013). The Cotton (*Gossypium hirsutum* L.) is grown throughout India under both rain fed and irrigated conditions on an area of 9.5 M ha (Yang *et al.,* 2014). India ranks first in area and production but productivity levels of cotton in India (544 kg/ha) are far below the world average (704 kg/ha). For getting higher production, it is essential to evolve and adopt a strategy of nutrient management by using a judicious combination of chemical fertilizers which may not only increase production but also improve soil health for sustaining the productivity. Keeping in view, this experiment was planned to study the effect of nutrient management in *Bt* cotton for sustaining yield under dry farming conditions.

METHODOLODY

A field experiment was conducted during the *kharif* season of 2011 to 2015 at Main dry farming Research Station, Junagadh Agricultural University, Jam Khambhalia. The soil of experimental field was sandy loam in texture having pH 8.30, EC 0.35 dS/m and organic carbon 0.41%. The soil was medium low in available phosphorus (28.60 kg/ha), high in available potash (336.0 kg/ha) and medium in available sulphur (17.8 ppm). The field experiment comprised of nine treatments in randomized block design with three replications. The treatments were 80 kg N/ha, 80 kg N + 20 kg P_2O_5 + 40 kg K_2O + 20 kg S/ha, 80 kg N + 20 kg P_2O_5 + 40 kg K_2 + 40 kg S/ha, 80 kg N + 20 kg P_2O_5 + 80 kg K_2O + 20 kg S/ha, 80 kg N + 20 kg P_2O_5 + 80 kg K_2O + 40 kg S/ha, 80 kg N + 40 kg P_2O_5 + 40 kg K_2O + 20 kg S/ha, 80 kg N + 40 kg P_2O_5 + 40 kg K_2O + 40 kg S/ha, 80 kg N + 40 kg P_2O_5 + 80 kg K_2O + 20 kg S/ha and 80 kg N + 40 kg P_2O_5 + 80 kg K_2O + 40 kg S/ha. The nitrogen was applied in three splits, i.e. 25% as basal, 50% as top dressing at 35–40 days and 25% as top dressing at 60–65 days. The phosphorus, potash and gypsum for sulphur were applied as basal before sowing. Gross and net plot size was 5.4 m × 4.5 m and 4.8 m × 2.7 m, respectively. Cotton BG-II variety G. Cot. Hy.-8 was sown. The total rainfall received during the crop season (June to November) was 880.6, 310.4, 1263.6, 324.7 and 242.0 mm in 24, 14, 33, 19 and 12 rainy days in the year of 2011, 2012, 2013, 2014 and 2015, respectively. During *kharif* 2012

Table 1. Yield attributes, yield and economics of Bt cotton under dry farming condition (pooled data over 3 years)

Treatments	Plant height (cm)	No. of branches/ plant	No. of balls/plant	Seed cotton yield (kg/ha)	Net return (₹/ha)	B : C ratio
80 kg N/ha	86.6	13.13	26.75	1,452	42,063	1.81
80 kg N/ha + 20 kg P_2O_5/ha + 40 kg K_2O/ha + 20 kg S/ha	88.9	13.56	31.60	1,754	52,091	1.94
80 kg N/ha + 20 kg P_2O_5/ha + 40 kg K_2O/ha + 40 kg S/ha	91.0	14.66	29.44	1,751	51,806	1.92
80 kg N/ha + 20 kg P_2O_5/ha + 80 kg K_2O/ha + 20 kg S/ha	88.2	14.52	30.69	1,705	48,918	1.76
80 kg N/ha + 20 kg P_2O_5/ha + 80 kg K_2O/ha + 40 kg S/ha	92.3	15.32	32.32	1,763	51,107	1.81
- 80 kg N/ha + 40 kg P_2O_5/ha + 40 kg K_2O/ha + 20 kg S/ha	91.8	15.18	27.97	1,676	47,695	1.72
80 kg N/ha + 40 kg P_2O_5/ha + 40 kg K_2O/ha + 40 kg S/ha	92.3	15.98	32.44	1,759	50,941	1.81
80 kg N/ha + 40 kg P_2O_5/ha + 80 kg K_2O/ha + 20 kg S/ha	90.1	15.07	29.39	1,696	47,558	1.65
80 kg N/ha + 40 kg P_2O_5/ha + 80 kg K_2O/ha + 40 kg S/ha	97.5	16.59	33.21	1,798	51,565	1.76
S.Em.±	2.7	0.70	2.1	40		
CD at 5%	7.9	2.04	6.1	113		
CV%	4.1	18.41	17.7	6.99		

the experiment was not sown due to very late onset of monsoon (35th MSW) and experimental data of *kharif* 2015 were not included in pooled result due to low yield on account of three week dry spell at establishment and vegetative growth stages. Data on growth, yield performance and economic were recorded and statistically analyzed.

RESULTS

The result presented in table on plant height, number of branches per plant and number of bolls per plant in cotton crop was significantly affected due to different nutritional treatments in pooled results. On the basis of pooled results, maximum values of all the attributes were recorded with application of 80-40-80-40 NPKS kg/ha. The data indicated that seed cotton yield was significantly affected due to different nutritional treatments in pooled results. On the basis of pooled results, maximum seed cotton yield (1,798 kg/ha) was recorded due to application of 80-40-80-40 NPKS kg/ha, which was significantly higher than treatments 80 kg N/ha and 80-40-40-20 NPKS kg/ha and statistically at par with rest of all the treatments. The minimum seed cotton yield (1,452 kg/ha) was recorded under recommended dose of fertilizer, i.e. 80 kg N/ha. The data pertaining to economics of various nutrient management treatments revealed that the higher net realization (₹ 52,091/ha) and cost benefit ratio (1.94) was obtained with application of 80-20-40-20 NPKS kg/ha.

CONCLUSION

On the basis of results obtained in this experiment it can concluded that application of 20 kg P_2O_5, 40 kg K_2O and 20 kg sulphur (150 kg gypsum/ha) along with 80 kg N/ha for obtaining higher yield and net monetary return under rain fed condition of North Saurashtra Agro Climatic Zone (AES-10).

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On farm response of soybean–chickpea cropping system to NPK and sulphur application in western Vidarbha

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Wheat, Chickpea and safflower are most important Rabi crops in the zone. Average fertilizer consumption is 37.85 kg N, 36.50 kg P_2O_5, 6.5 kg K_2O per hectare and sulphur consumption is very meager to minimal which is quite in adequate considering requirement of mono or double crop in a year. Farmer's hesitate to supply recommended dose to the crops because of varied problems and therefore imbalance application of NPK is also commonly observed, keeping this in view the present investigation entitled 'On farm response of soybean–chickpea cropping system to N P K and Sulphur' was conducted in two blocks of Western Vidarbha Zone.

METHODOLOGY

Field experiments were conducted at six locations (four experiments per villages) each year during 2013–14, 2014–15 and 2015–16 respectively with seven treatments, treating location as a replication. Villages were selected in Nandgaon khandeshwar and Morshi block of Amravati district. Treatments consist of no NPK (control), recommended dose of N alone, NP alone, NK alone and NPK (30 : 75 : 30 and 20 : 40 : 20) kg NPK /ha and NPK plus 25 kg sulphur/ha for soybean and chickpea respectively, applied to both the crops on plot size of 20 m × 10 m. The soils of experimental site is mostly medium to deep black cotton and slightly alkaline in reaction , well distributed rainfall ranged between 721 to 1,096 mm was received during the crop growth period . Soybean 'JS 9305' was sown from 15th June to 23th July, Chickpea 'JAKI 9218' was from 28th October to 24th of

Table 1. Mean pooled grain yield (kg/ha), Economics (Rs/ha) & nutrient response (kg/kg) of crops as influenced by various treatments on soybean- chickpea cropping system

Treatment	Soybean Equivalent yield (kg/ha)	System cost of cultivation (₹/ha)	System Net Monetary Returns (₹/ha)	System Net Monetary Returns over control (₹/ha)	Nutrient response (kg/kg)
Control	1,691	31,307	33,166	1,859	–
Rec. N	2,108	33,442	41,300	8,134	9.04
Rec. NP	2,556	39,633	51,842	18,676	9
Rec. NK	2,306	35,415	45,088	11,922	6.04
Rec.NPK	2,992	41,618	64,608	31,442	6.19
Rec.NPK+ Sulphur	3,362	45,191	74,470	41,304	6.93
Farmers practice	2,085	38,062	41,369	8,203	3.6

November both the crops were raised with recommended package of practices except fertilization. NPK was supplied through straight fertilizers and supply of sulphur through bensulf to both the crops as per recommended timing. Life irrigations were given to soybean and chickpea crop as per the recommendation.

RESULTS

Pooled data indicated that the yield of soybean was highest with recommended dose of NPK + Sulphur but treatment NP & NK both alone being at par has increased the yield significantly over control and recommended dose of N alone. But in case of chickpea application of recommended dose of Sulphur NPK + S was found significantly superior over all the treatments. Data on economics of soybean–chickpea sequence as affected by fertilizer application (Table 1) indicated that total per hectare monetary benefit was augmented by ₹ 41,304 per hectare due to fertilization with NPK + Sulphur, and ₹ 31,442 per hectare by application of recommended dose of NPK to both crop over control. Least monetary returns were achieved by only application of recommended Nitrogen application to both the crop over control. Recommended dose of Nitrogen and Phosphorus to soybean as well as chickpea showed more monetary returns (₹ 18,676/ha) than that of application of Recommended dose of Nitrogen and Potash application (₹ 11,922/ha)over control.

CONCLUSION

Soybean and Chickpea in sequence cropping should be fertilized with 30 : 75 : 30 : 25 and 20 : 40 : 20 : 25 kg NPKS/ha respectively for getting maximum production in terms of yield and net monetary returns from the cropping system. And it is widely adapted cropping system in rainfed situation at Amravati district of western Vidarbha of Maharashtra state.

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Effect of fertigation scheduling and fertilizer levels on yield, quality and commercial cane sugar production under subsurface drip fertigated sugarcane

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Field investigation was carried out on sugarcane at Zonal Agricultural Research Station (ZARS), VC, farm Mandya, UAS, GKVK, Bangalore, Karnataka during 2014–15. To study the effect of fertigation levels and fertigation scheduling on yield, quality and commercial cane sugar production of sugarcane under subsurface drip fertigation. Soil of the experimental site was red sandy loam with low OC (0.46%), medium available N (292.5 kg/ha), available P_2O_5 (38.2 kg/ha) and available K_2O (178.3 kg/ha). Experiment was laid out in factorial randomized complete block design, replicated thrice consisting of two factors Factor A fertigation scheduling upto 3.5, 5.0, 6.5, 8.0 and 9.5 months and Factor

B fertigation levels of 75, 100 and 125 per cent RDF with control soil application of 100 per cent RDF with surface irrigation. Out of the recommended dose of fertilizer (250: 100 : 125 kg NPK/ha), 50 percent P was applied as basal dose and remaining P was applied at 105 days after planting (DAP) while earthing up for drip irrigated plots wherein, entire dose of N and K is applied through subsurface drip fertigation at different intervals of 3.5, 5.0, 6.5, 8.0 and 9.5 months with three fertigation levels of 75, 100 and 125 per cent RDF consisting 28, 40, 52, 64 and 76 splits of fertigation respectively, twice in a week and drip irrigation was scheduled for every two days. Soil application of recommended dose of fertilizer, (250 : 100 : 125 kg of NPK/ha) as per package of practice surface irrigation was considered as control plot. Viable and healthy two budded sugarcane sets were planted in a zig-zag manner in paired row method of planting with spacing of (165 + 30) × 30 cm. Co-86032 variety was used for planting. The results of the experiment revealed that fertigation scheduling upto 9.5 months has given on par results on the quality parameters, viz. brix (19.85%), pol (18.92%), purity (95.42%), reducing sugar (3.30%) and CCS (commercial cane sugar production) (13.65%). Similar results was also observed under fertigation levels upto 125 per cent RDF (recommended dose of fertilizer) recorded quality parameters, viz. brix (20.26%), pol (19.34%), purity (95.63%), reducing sugar (3.20%) and CCS production (13.84%) and the interaction effect between fertigation scheduling and fertigation levels also followed the same trend recorded quality parameters, viz. brix (19.80%), pol (18.85%), purity (95.38%), reducing sugar (3.31%) and CCS production (13.60%). In comparison with conventional method of sugarcane cultivation recorded lower quality parameters, viz. brix (19.72%), pol (18.80%), purity (95.16%), reducing sugar (2.82%) and CCS (13.34%). Significantly higher cane yield was observed under fertigation scheduling upto 9.5 months (250 t/ha) and higher cane yield (225 t/ha) under fertigation levels @ 125 per cent RDF. The interaction effect between fertigation scheduling and fertigation levels are significant, the fertigation up to 9.5 months with 125 per cent RDF recorded significantly higher cane yield (255 t/ha) while conventional method of cane cultivation recorded significantly lower cane yield (146 t/ha). This clearly indicates that increment in the fertigation scheduling and fertigation levels does not affect the quality and CCS production of sugarcane under subsurface drip fertigation. However, significantly higher cane yield can be obtained under fertigation scheduling and fertigation levels without affecting the quality and CCS production.

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Effects of moringa *(Moringa oleifera)* leaves and NPK (15 : 15 : 15) fertilizer on yield and protein content of soybean (*Glycine max*) in Obubra, southeastern Nigeria

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Soybean (Glycine max) is an important food and industrial crop in many parts of the world mainly due to its high nutritional value and seed protein content (Tiamigu and Idowu, 2001). Besides its relatively high grain protein content of over 40%, soybean has edible vegetable oil content of 20% which is rich in essential fatty acids and devoid of cholesterol and carbohydrate content of about 5% (Eze *et al*., 2013). Moringa is a fast growing tree plant with a high forage yield which may amount to 120 metric tons dry matter/ha/yr (Makkar and Becker, 1996). Moringa has also been reported to significantly enrich agricultural lands and improve soil fertility if used as green manure, (Fuglie, 2001). In Nigeria soil fertility is the major problem faced by many farmers at all levels of agricultural practices. The continuous use of inorganic fertilizers has been shown to be detrimental to the soil and the environment. The incorporation of Moringa leaves as manure could act as double advantage in improving the soil and increase the protein content of the soybean. In the wake of increasing prices of inorganic fertilizer, there is need to find alternative soil and crop improvement materials. The present study therefore is aimed at evaluating the effect of Moringa leaves on the growth, yield and protein content of soybean.

METHODOLOGY

A field experiment was conducted during the 2014

Table 1. Growth, yield and protein content of soybean as influenced by Moringa leaves and NPK fertilizer

Treatment	Plant height (cm)	Leaves/ plant	Pods/ plant	Grain yield (kg/ha)	Protein content (%)
Moringa (t/ha)					
0	26.81	50.5	64.5	699.2	10.2
5	28.31	52.0	42.2	1,170.4	11.2
10	30.26	56.0	74.9	1,996.0	11.6
15	32.3	62.0	52.7	2,124.8	12.1
CD (P=0.05)	3.12	9.26	10.13	27.27	0.42
NPK (kg/ha)					
0	27.07	48.0	37.8	663.0	10.9
50	28.60	54.0	68.4	1,114.0	11.4
100	30.17	57.3	61.7	2,111.0	12.5
150	31.64	59.0	66.4	2,102.0	12.8
CD (P=0.05)	3.12	9.26	10.13	27.27	0.42
Moringa x NPK	NS	NS	20.27	54.54	NS

cropping season at the Cross River university of technology research farm at Obubra, under rain fed condition. Obubra is located at longitude 08° 16′E and latitude 05° 59′N with an altitude of 184 m above sea level. The experiment was a factorial, laid out in a randomized complete block design with three replicates. Four levels each of Moringa leaves (0 tons/ha, 5 tons/ha, 10 tons/ha and 15 tons/ha) and NPK (15 : 15 : 15) fertilizer (0 kg/ha, 50 kg/ha, 100 kg/ha and, 150 kg/ha), respectively were applied giving a total of fifteen treatment combinations. Data were collected on the growth attributes of plant height and number of leaves from ten plants randomly selected per plot at ten weeks after planting. Data on the yield components such as number of pods and grain yield (kg/ha) were collected at full maturity.

RESULTS

Moringa leaves significantly ($p < 0.05$) increased soybean plant height, number of leaves, pod yield and grain yield. Moringa leaves applied at the rate of 10 t/ha and NPK (15 : 15 : 15) fertilizer at the rate of 100 kg/ha gave the highest plant height of 30.26 cm and 30.17 cm, respectively. The application of Moringa leaves at the rate of 10 t/ha significantly ($p < 0.05$) increased the pod yield (74.9) and grain yield of soybean with the highest grain yield of 2,124.8 kg/ha at the rate of 15 t/ha. NPK application at the rate of 50 kg/ha produced the highest number of pods/plant (68.4) while the highest grain yield of 2,111 kg/ha was recorded at 100 kg/ha application of NPK fertilizer. Moringa leaves applied at the rate of 10 t/ha and NPK (15 : 15 : 15) fertilizer at the rate of 100 kg/ha significantly ($p < 0.05$) increased the protein content of soybean, respectively. The interaction of Moringa leaves and NPK (15 : 15 : 15) fertilizer significantly ($p < 0.05$) influenced the number of pods produced per soybean

Moringa leaves when used as green manure can significantly enrich the soil and lead to increased crop production. When Moringa leaves are applied at the rate of 15 t/ha, the grain yield of soybean obtained is equivalent to the yield obtained when NPK (15 : 15 : 15) fertilizer is applied at the rate of 100 kg/ha. Considering the high cost of inorganic fertilizers viz-à-viz the detrimental effects of inorganic fertilizers on the soil and the environment, the adoption of this practice will go a long way to ensuring good quantity and quality food production that is environmentally friendly and nutritionally safe.

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Augmentation ofzinc content through agronomic practices in wheat crop

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ABSTRACT

Zinc biofortification through agronomic practices in wheat could reduce Zn deficiency in populations particularly women and children that depend on wheat consumption as their staple diet. Twenty five sites were selected for conducting multi-locational field trials on zinc fertilization of wheat crop, in the selected districts, villages and interested farmers after extension survey in Haryana, Uttar Pradesh, Punjab and Himachal Pradesh States having variable soil zinc fertility status, during 2014–15 and 2015–16.Experimental design was randomized complete block design with three replicates. Wheat crop was grown under three different Zn applications rates as follows: (*i*) control (no Zn application), (*ii*) soil Zn application, and (*iii*) foliar Zn application. The soil Zn treatment consisted of 50 kg $ZnSO_4.7H_2O$/ha applied to the soil before sowing of wheat. The foliar Zn treatment, a 0.5% (w/v) aqueous solution of $ZnSO_4.7H_2O$ was realized 2 times, i.e. first at anthesis stage and the second one at early milk stage. Results showed that foliar applications of Zn increased grain Zn concentration by about two-fold as compared with control.

Key words: Wheat crop, agronomic practice, biofortification, foliar application, Zinc

INTRODUCTION

Zinc biofortification is the process by which the nutritional quality of food is improved through agronomic practices, conventional plant breeding, or modern biotechnology. Biofortification differs from conventional fortification in that biofortification aims to increase nutrient levels in crops during plant growth rather than through manual means during processing of the crops. Zn deficiency hasreceived an increasing attention not only by agronomists, nutritionists, medical scientists, but also by social economists.Agronomic fortification is the application of nutrient-rich fertilisers to foliage or soil to increase the micronutrient concentration in edible crop parts and thus increase the intake of essential micronutrients by consumers (Carvalho 2013). It has been recognized as a serious threat to human health, especially to women and child nutritionZinc fertilisation has increased zinc content in the wheat grain (Cakmak 2009; Gomez-Galera 2010; Lyons 2012).Wheat is the second most consumed cereal in Asia after rice. Worldwide, wheat (*Triticumaestivum* L.) represents a main dietary source of calories, proteins and micronutrients for the majority of world'spopulation, especially in the developing world (Zou*et al.*, 2012).

METHODOLOGY

Wheat (*Triticumaestivum* L.) crop (HD 2967) was grown in twenty five different locations across four Northern states of India namely, Uttar Pradesh, Himachal Pradesh, Punjab and Haryana during *rabi* season in the years 2014–15 and 2015–16. Experimental design was randomized complete block design with three replicates. Wheat was grown under three different Zn applications ratesas follows: (*i*) nil (no Zn treatment), (*ii*) soil Zn application, (*iii*) foliar Zn application. The soil Zn treatment consisted of 50 kg $ZnSO_4.7H_2O$/ha applied to the soil before sowing. The foliar Zn treatment, a 0.5% (w/v) aqueous solution of $ZnSO_4.7H_2O$ was sprayed on the standing crop. Foliar Zn applications were realized 2 times: first at anthesis stage and the second one at early milk stage (after 90–95 and 110–115 days of sowing).

Wheat grain samples were carefully and thoroughly washed by tap water and then distilled water before drying at about 65°C. The samples were digested with di-acid HNO_3:$HClO_3$ (9:4 ratio) and the Zn concentration in the digested solution was measured using Atomic Absorption Spectrophotometer (AAS).

RESULTS

During 2014–15, the results showed that wheat yield increased from 0.35% to 9.74% by soil Zn application as compared to control, however increase in wheat yield by foliar application of Zn increased from negligible to 1.50%, as compared to control. The results presented in Graph 1 shows that application of zinc in soil increased grain yield of wheat adequately over control whereas foliar application was almost at par with control. Further in the year 2015-16, the results showed that wheat yield increased from 0.75% to 8.67% by soil Zn application as compared to control; however increase in wheat yield by foliar application of Zn increased from 0.03% to 5.83%, respectively, as compared to control.

The field trials results showed that wheat grain zinc concentration during 2014–15, increased from 0.1% to 6.3% by soil Zn application as compared to control, however increase in grain Zn by foliar application of Zn increased from 47.6% to 93.7%, as compared to control. Further, during 2015–16, wheat grain zinc concentration increased from 3.20% to 10.3%, by soil Zn application as compared to control, however increase in grain Zn by foliar application of Zn increased from 32.4% to 98.8%, as compared to control.

CONCLUSION

In conclusion, foliar Zn application to wheat at two stages of growth, i.e. the booting and milk stages, represents an effective high impact agronomic practice to contribute increase in Zn concentration in wheat grain. Foliar spray Zn significantly increased grain Zn concentrations and this positive impact occurred consistently over a wide range of environments.

ACKNOWLEDGMENTS

We are grateful for the financial support provided by BIRAC, DBT, Bill & Melinda Gates foundation and USAID under Grand Challenges India–2014 to Amity University Uttar Pradesh, Noida.

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Symposium 8
Conservation Agriculture and Smart Mechanization

Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Conservation agriculture in a rice-wheat cropping system on a calcareous soil of eastern Indo-Gangetic Plains: Effect on soil carbon pools

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Rice–wheat is one of the most widely practiced cropping systems in the world, covering an area of 26 million hectares (Mha) spread over the Indo-Gangetic Plains (IGP) of South Asia and China. Sustainability of this important cropping system is however, at stake due to emergence of second generation problems in the post-green revolution era namely, decline in the groundwater table, increased sub-soil compaction, atmospheric pollution, multi-nutrient deficiencies and decline in quantity and quality of soil organic matter (SOM). Zero tillage along with retention of crop residues is an important component of CA not only to increase the SOC content but also to recycle plant nutrients, improve soil aggregation and nutrient storage. Nonetheless, information regarding effects of CA on soil C accumulation and distribution of C pools (both organic and inorganic) is scarce for the calcareous soils of the eastern IGP.

METHODOLOGY

The long-term CA experiment is continuing since 2006 in rice (*Oryza sativa* L.)-wheat (*Triticum aestivum* L.) system at the experimental farm of Borlaug Institute for South Asia (CIMMYT), Samastipur, Bihar, India (25°59′ N, 85°41′ E and 53.0 m above MSL) having sub-tropical hot and humid climate. The soil is clay loam in texture and highly calcareous in nature having higher contents of inorganic C, i.e. carbonates of Ca and Mg. The treatments were: conventional-till transplanted rice followed by conventional-till wheat (CTR-CTW), CTR followed by zero-till wheat (CTR-ZTW), ZT direct dry-seeded rice followed by CTW (ZTDSR-CTW), ZTDSR followed by wheat both on permanent raised beds with residue retention (PBDSR-PBW+R), ZTDSR followed by ZTW without residue retention (ZTDSR-ZTW), and ZTDSR-ZTW with residue retention (ZTDSR-ZTW+R). After completion of six cropping cycles soil samples were collected from 0 to 15 cm layer during May 2012, and analyzed for total C using CHN analyzer (EuroVector Instruments, EA 3000, Italy). Total soil inorganic C (SIC) was measured titrimetrically by digesting the soil with dilute HCl and then back titrating the excess HCl with dilute NaOH. Total soil organic carbon (SOC) concentrations were then computed by subtracting total SIC from total C concentrations. Different fractions of SOC with varying lability were estimated following Chan *et al*. (2001) using 5, 10, and 20 mL of concentrated (18.0 mol/L) H_2SO_4 and $K_2Cr_2O_7$ solution.

RESULTS

Total SOC concentration increased significantly under all ZTDSR plots over CTR-CTW plots (Fig. 1). Increases in SOC in the 0–15 cm soil layer were nearly 13, 12, 20 and 11% under ZTDSR-CTW, ZTDSR-ZTW, ZTDSR-ZTW+R and PBDSR-PBW+R, respectively, compared with the CTR-CTW. Plots under ZTDSR-ZTW+R had 7.0 and 7.6% higher total SOC concentration in the 0–15 cm soil layer than ZTDSR-ZTW and PBDSR-PBW+R plots, respectively. Under double ZT, reduction in the tillage intensity resulted into less disruption of soil aggregates and consequently greater physical protection of SOC inside macro aggregates, thus resulting in an increase in SOC. A further increase in total SOC under double ZT with residue retention plots might be due to the fresh organic matter input which led to the formation of particulate organic matter which is not subjected to rapid oxidation and loss. Although same amount of residue was supplied to both under ZTDSR-ZTW+R and PBDSR-PBW+R plots, periodical reshaping of beds and relatively higher exposed surface area under bed planting resulted into loss of SOC under the later. On the other hand, total SIC concentration was highest under CTR-CTW (44.2 g/kg) which got decreased considerably due to double ZT, as implied from total SIC values under CTR-ZTW (42.5 g/kg), ZTDSR-CTW (41.7 g/kg) and ZTDSR-ZTW (40.6 g/kg). Double ZT and double residue retention in ZTDSR-ZTW+R ultimately resulted in 10.9% less total SIC than CTR-CTW plots (Fig.1). Plots with PBDSR-PBW+R registered 6.3% decrease in total SIC concentration compared to CTR-CTW. An attempt was also made to quantify labile and recalcitrant pools of SOC as affected by CA practices. Non-labile SOC was the largest pool of total SOC, followed by very labile, labile and less labile pools. Averaged across treatments, non-labile, less labile, labile and very labile pools contributed 77.0, 4.0, 7.0, and 12.0%of total SOC, respectively in the 0-15 cm soil layer. Conservation agriculture practices had

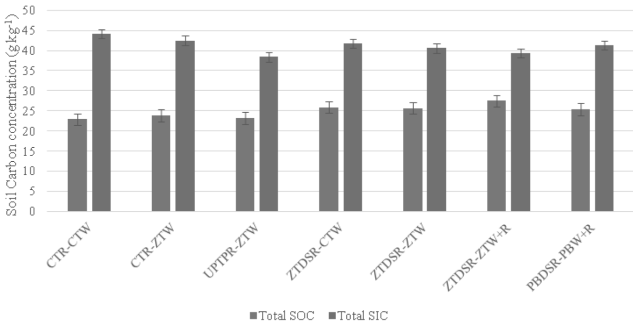

Fig. 1. Effect of continuous CA practices (6 years) in rice–wheat cropping system on total SOC and SIC of surface soil (0–15 cm) on a Calciorthent. Error bars represent least significant difference at 5% significance level

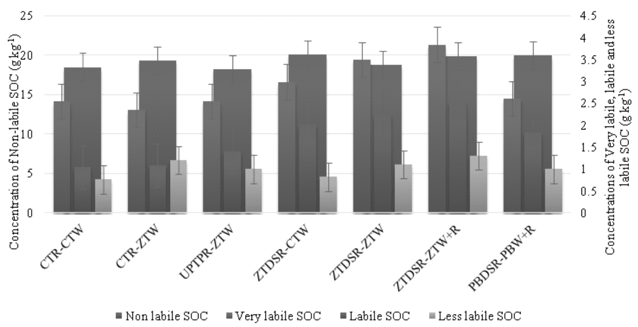

Fig. 2. SOC fractions as affected by continuous conventional vis-à-vis CA practices in rice–wheat cropping system on a Calciorthent. Error bar represents least significant difference at 5% significance level.

greater impact on the very labile SOC, which increased significantly with the adoption of ZT in only rice (ZTDSR-CTW) or in both crops (ZTDSR-ZTW), as compared to CTR-CTW. Residue retention (ZTDSR-ZTW+R) resulted in a significant additional increase in very labile C concentration over ZTDSR-ZTW plots. Under ZTDSR-ZTW+R, a 50% increase in very labile SOC concentration was observed over CTR-CTW (Fig. 2). Labile pool of SOC followed similar pattern with relatively smaller treatment differences. Less labile and non-labile SOC were maximum and significantly higher under ZTDSR-ZTW+R compared with CTR-CTW. Walkley-Black SOC, which is the summation of very labile, labile and less labile pools, showed similar pattern of changes due to CA as in case of very labile pool. Significant increase in Walkley-Black SOC was found under all ZTDSR treatments as compared to CTR treatments.

CONCLUSION

Double ZT (ZTDSR-ZTW) significantly increased total SOC concentration over CTR-CTW, but not total SIC concentration. Reduction in tillage intensity coupled with residue retention additively increased SOC under ZTDSR-ZTW+R, in turn achieving highest total SOC concentration in the soil**.** Interestingly, ZTDSR-ZTW+R plots had 14.5 and 4.2% less total SIC concentration than CTR-CTW and ZTDSR-ZTW plots, respectively in the surface layer. Double ZT stabilized or sequestered the organic C that has been added to soil over the past six years, mainly through cereal residue retention. Increased biomass production and SOC accumulation under the CA practice (ZTDSR-ZTW+R) of the eastern IGP could provide a sustainable rice-wheat cropping system without impairing soil health.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Conservation agriculture as a climate change adaptation and mitigation strategy

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The growing threat of food insecurity and poverty in India is further exacerbated by the risk of climate change and a moderate increase in temperature will have significant impact on rice, wheat and maize yields. The impact may be further worsening by increasing water scarcity, frequent floods and droughts and declining soil carbon content. Climate models project that global surface air temperature may increase by 4.0–5.8°C in the next few decades. Rainfall patterns in India would change with the western and central areas witnessing as many as 15 more dry days each year, whereas the northern and northwestern areas could have 5 to 10 more days of rainfall annually. Thus, dry areas are expected to get drier and wet areas wetter. With a 1°C rise in temperature there would be at least 10% increase in irrigation water demand and in arid and semi-arid regions of Asia. Given these deleterious impacts of climate change on food security, adaptation of agriculture to climate change is not a choice, but a compulsion. The conservation agriculture (CA) is identified as most suitable strategy amongst the adaptation and mitigation options for climate change impact in crop production. CA helps in adaptation to climate change through retaining more soil moisture by increasing infiltration rate, decreasing penetration resistance and bulk density compared to conventional tillage practices. The retention of residue helps in decreasing canopy temperature and reducing heat stress in crops raised under CA compared to conventional tillage. Crop rotation reduces the pest and weed infestations and legumes inclusion adds nitrogen through biological fixation. On an average, by adopting of zero tillage in rice-wheat system of the IGP, farmers could save 36 L diesel ha^{-1} equivalent to a reduction in 93 kg CO_2 emission/ha/yr. Puddled and transplanted rice increase CH_4 emission whereas zero tillage Direct Seeded Rice (DSR) reduces CH_4 emission effectively. Thus, the conservation agriculture contributes to build climate resilient agricultural system through i) increased yield and farm and farm income, ii) adaptation to heat and water stresses, and iii) reduction in Green House Gas (GHGs) emissions.

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Effect of solar dimming on growth and yield of wheat (*Triticum aestivum*) in Delhi NCR region

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Solar radiation is the most important factor for many plant physiological and bio-chemical processes for regulating the growth and development of plants. Apart from global warming, global dimming has received prominent attention due to climatic and environmental implications. As a consequence of increase in aerosol content and air pollutants, light dimming or reduction in global radiation (i.e. the sum of the direct solar irradiation and the diffuse or sky radiation scattered by the atmosphere) has become major challenge for crop production. Reports show that decline in solar radiation affects agricultural productivity in some parts of the world such as China (Yang *et al.*, 2013) and India (Kumari and Goswami, 2010). Keeping in view the importance of radiation dimming present study was conducted to study the growth pattern of wheat crop under reduced solar radiation.

METHODOLOGY

A field experiment was conducted with three wheat cultivars (HD 2967, WR 544 and PBW 502) under five solar radiation treatments, i.e. R_1 (no shading), R_2 (20% shading), R_3 (35% shading), R_4 (50% shading) and R_5 (75% shading) at the farm of ICAR-Indian Agricultural Research Institute, New Delhi during *rabi* season of 2014–15 and 2015–16. In this experiment split plot design was followed with three replications in 5 m × 3 m plots. Different plant parameters like plant height and internode distance were measured at different days after sowing (DAS) throughout the crop growth period. Plant biomass was also measured at regular intervals during entire growing seasons. At the time of harvesting final biomass and grain yield were also measured. Data were analysed using SAS software.

RESULTS

Plant height increased with the reduction in solar radiation. The highest plant height (97.67 cm) was observed in R_5 at 110 DAS followed by, 96.94 cm in R_4, 96.78 cm in R_3, 95.23 cm in R_2 and 94.78 cm in R_1. In case of cultivars, HD 2967 showed the highest plant height of 102.89 cm, followed by WR 544 (97.198 cm) and PBW 502 (89.89 cm) at 110 DAS. Similar result was found for year 2015–16 that plant height was the highest (103.70 cm) in R_5 compare to other treatments. Internode length (cm) of first, second, third, fourth and fifth internode from top to bottom in wheat crop was significantly influenced by the various levels of reduced radiation with maximum difference in second internode than compare to other internodes. The highest (14.50 cm), second internode distance was observed in R_5 followed by R_4 (13.20 cm), R_3 (12.50 cm), R_2 (11.40 cm) and R_1 (10.60 cm) during *rabi* 2014–15. Similar results were obtained during 2015–16. In case of cultivars, the reason might be difference in their genetic makeup. During the *rabi* seasons (2014–15 and 2015–16) internode distance increased with reduced radiation level. Plant biomass was also measured at different growth stage and showed significant reduction due to reduced solar radiation in all treatments during *rabi* 2014–15 and 2015–16. Crop produced highest biomass (14.21 t/ha) in R_1 followed by R_2 (11.56 t/ha), R_3 (8.88 t/ha), R_4 (7.34 t/ha) and R_5 (5.19 t/ha) at 140 DAS during *rabi* 2014–15. Similar findings were observed during *rabi* 2015–16. The grain yield, final biomass and harvest index were significantly reduced under R_5 than R_4, R_3, R_2 and R_1 conditions. During 2014–15, among the different treatments final biomass was the lowest in R_5 (5.19 t/ha). Cultivars also showed significant difference in biomass. Harvest index was significantly decreased under reduced solar radiation. Harvest index was the lowest in R_5 (17.61%), followed by R_4 (20.35%) and R_3 (28.04%) and highest under open condition (33.33%). During 2014–15, the interaction between reduced solar radiation and cultivars was non-significant. During 2015–16, similar significant result was found for final biomass, grain yield and harvest index. Final biomass was observed be the lowest under R_5 (4.22 t/ha). Grain yield was also significantly reduced under R_5 (0.51 t/ha) and R_4 (1.14 t/ha) due to crop lodging.

CONCLUSION

Thus, the present study clearly showed significant difference in the crop growth and development of wheat crop under reduced solar radiation. Plant height and internode length were increased with the reduction in solar radiation. Both parameters were significantly higher in severe shading condition than compare to mild shading. Final biomass and grain yield were significantly decreased with shading during *rabi* seasons 2014–15 and 2015–16. Among the different parameters significant changes were observed in plant height, biomass, yield and harvest index. These difference were mainly attributed to the micro-meteorological changes within plant canopy.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Effect of anti-transpirants and straw mulch on growth and productivity of soybean

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Soil moisture is one of the most limiting factors for crop production. It is lost as evaporation from soil surface and as transpiration from the plant surfaces. Reduction of transpiration and evaporation is needed for maintaining favorable water balance in the plants under limiting water conditions. Straw mulching helps in conserving the soil moisture and reduces soil temperature by modifying the hydrothermal regime (Aulakh *et al.,* 2012). So an experiment was planned with an objective to study the effect of anti-transpirants and straw mulch on growth and productivity of soybean.

METHODOLOGY

A field experiment was conducted during *kharif* 2012 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 382.5 mm rainfall (26 rainy days) was received during the crop growing season. The experiment was laid out in factorial experiment in randomized complete block design with three replications. The treatments included mulching levels (straw mulch @ 5 t/ha after sowing and without mulch) and foliar application of anti-transpirants [Magnesium carbonate 5%, Glycerol 5%, Sodium carbonate 2%, Potassium nitrate 1% and Control (water spray)] at flowering. The soybean variety SL 744 was sown on 7 June 2012 in rows 45 cm apart using a seed rate of 75 kg/ha. Nutrients, viz. 30 kg nitrogen and 60 kg P_2O_5 per ha were applied entirely as basal dose to the crop. Each plot measured

Table 1. Effect of mulch and anti-transpirants on growth, yield attribute and yield and economics of soybean

Treatment	Plant height (cm)	Pods/plant	Straw yield (kg/ha)	Seed yield (kg/ha)	Gross returns (₹/ha)	Net returns (₹/ha)	B:C
Mulch							
Straw mulch @ 5 t/ha	77.4	64.3	3,633	1,666	37,333	9,278	1.35
Control (no mulch)	68.9	60.1	3,205	1,516	33,973	8,918	1.38
CD (P=0.05)	6.03	NS	359	100	2,251	NS	NS
Anti-transpirants							
Magnesium carbonate 5%	74.1	62.0	3,467	1,532	34,325	3,825	1.12
Glycerol 5%	68.2	57.5	3,342	1,518	34,014	4,977	1.17
Sodium carbonate 2%	73.3	63.9	3,250	1,601	35,881	7,719	1.27
Potassium nitrate 1%	72.4	64.7	3,398	1,648	36,918	13,756	1.59
Control	77.9	62.8	3,638	1,657	37,216	15,214	1.69
CD (P=0.05)	NS	NS	NS	NS	NS	3,559	0.13

6.0 m × 3.6 m. The crop was harvested on 29 October 2012. Data on plant height and pods per plant were recorded at harvest from randomly selected five plants from each plot. Biological yield and seed yield was recorded on a plot basis and then converted into kg/ha. Net returns as well as benefit:cost (B:C) ratio were also worked out. Data were subjected to analysis of variance (ANOVA) as per the standard procedure.

RESULTS

Application of straw mulch @ 5 t/ha after sowing recorded the highest plant height, pod/plant, straw yield and seed yield of soybean (Table 1). Straw mulch recorded 9.9% higher seed yield over no mulch. Similarly, application of straw mulching improved growth parameters and seed yield of soybean (Sekhon *et al.,* 2005). Straw mulch also gave significantly higher gross returns as compared to control (no mulch). However, net returns and B : C ratio were not significantly influenced by mulch.

Application of different anti-transpirants had non-significant effects on plant height, pods/plant, straw yield and seed yield of soybean. The interaction effects of mulches and anti-transpirants were non-significant for seed yield. Use of anti-transpirants was not economical over control.

CONCLUSION

Application of straw mulch @ 5 t/ha after sowing provides higher seed yield of soybean over no mulch.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Productivity and profitability of pearlmillet as influenced by planting and nitrogen management practices under conservation agriculture

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Pearlmillet holds a place of pride in the rural economy of the country as the pearlmillet covers an area of 7.1 million hectares and produces 9.1 million tonnes of grains with the productivity level of 1,272 kg/ha. Due to soil and climatic adversities, the crop suffers from several biotic and abiotic stresses, particularly moisture stress, resulting in poor and unpredictable crop yields. Conservation agriculture (CA) has emerged as a major way forwards from the existing unsustainable mode of crop production (Sharma and Behera, 2007). CA practices (zero-tillage + mulching) are the viable approach to retain and maintain soil moisture and essential plant nutrients under semi-arid dryland situations. However, some factors like N management may hinder the production in residue-based zero-till farming systems because of lesser N availability due to slower soil N mineralization, and greater immobilization, denitrification and NH_3 volatilization compared with conventional-till systems (Patra *et al*., 2004). Therefore, proper nutrient management schedules under CA systems are yet to be developed. The crop and livestock component of intensive farming systems of rainfed areas compete for crop residues, as either soil cover or feed resources. Due to less biomass productivity and competing uses of crop residues, the scope of using crop residues for conservation agriculture is limited in dryland ecosystems. High density planting is the other technology which can solve the problem of mulching material availability for adoption of CA in rainfed farming systems. Therefore, the present research work "Planting and nitrogen management in pearlmillet under conservation agriculture based pearlmillet–mustard cropping system" was undertaken.

METHODOLOGY

Field experiment entitled "Planting and nitrogen management in pearlmillet under conservation agriculture based pearlmillet-mustard cropping system'' was conducted at experimental farm of Department of Agronomy, Indian Agricultural Research Institute, New Delhi during *kharif* season 2015. The field had an even topography and good drainage system. Soil of the experimental site was sandy loam in texture, poor in organic carbon concentration, available N and medium in available P and K. Soil was slightly alkaline in reaction with pH 7.5. The experiment was conducted in fixed layout of split-plot design, replicated thrice. The field experiment comprised of three main plot treatments of planting density, i.e. normal distance sowing(0.45 × 0.10 m) (D_1), high density sowing (0.22 × 0.10 m) *fb* alternate row harvesting for fodder at 35 DAS (D_2) and high density sowing (0.22 × 0.10 m) *fb* alternate row harvesting for fodder at 45 DAS (D_3) and five sub plot treatments of nitrogen management, i.e. control (N_1), 60 kg N/ha as basal (100% RDN) (N_2), 30 kg N/ha as basal + 30 kg N/ha as side dressing (N_3), 75 kg N/ha as basal (125% RDN) (N_4), and 37.5 kg N/ha as basal + 37.5 kg N/ha as side dressing (N_5). Pearlmillet variety 'Pusa Composite-443' was sown by happy seeder @ 4 kg seed/ha in normal distance plot and @ 8 kg seed/ha in high density plots. Urea was drilled in bands 5 cm below the surface during pearlmillet sowing. Side-dressing of urea was done at 30 DAS as per treatments. Growth parameteras, yield attributes and other biometrics observations were undertaken as per requirements for validation of findings. Soil and plant analysis were made following standard procedures.

RESULTS

High density sowing *fb* alternate row harvesting for fodder at 45 DAS treatment noted significantly higher green forage yield, green forage equalent yield and production efficiency over high density sowing *fb* alternate row harvesting for fodder at 35 DAS and normal distance sowing. Increase in forage yield with delayed harvesting has been mainly due to taller plants and thicker stem. Among N management treatments, the highest green forage yield, green forage equalent yield and production efficiency were obtained in 75 kg N/ha as basal (125% RDN) treatment. Normal planting density brought about significant improvement in grain and stover yield of pearlmillet over higher planting density *fb* alternate row harvesting at 35 DAS and higher planting density *fb* alternate row harvesting at 45 DAS. Application of 37.5 kg N/ha as basal + 37.5 kg N/ha as side dressing and 75 kg N/ha as basal (125% RDN) to pearlmillet significantly

Table 1. Effect of planting density and nitrogen management on yield and economics of pearlmillet

Treatment	Green fodder yield (t/ha)	Grain yield (t/ha)	Stover yield (t/ha)	Green fodder equivalent yield (t/ha)	Production efficiency (kg/ha/day)	B:C ratio	Monetary efficiency (₹/ha/day)
Planting density							
D_1	–	2.57	8.86	–	32.07	2.10	577.7
D_2	9.84	2.35	7.80	1.38	46.64	2.36	692.2
D_3	12.53	2.11	6.99	1.77	48.51	2.27	672.1
SEm±	0.05	0.03	0.19	0.01	0.48	0.04	11.22
CD (P=0.05)	0.28	0.13	0.75	0.06	1.88	0.15	44.07
Nitrogen management							
N_1	9.46	1.81	6.45	1.33	33.72	1.71	475.0
N_2	12.06	2.34	7.68	1.69	43.37	2.26	649.6
N_3	10.79	2.42	7.78	1.51	42.88	2.22	645.4
N_4	12.50	2.53	8.74	1.76	46.35	2.54	738.1
N_5	11.10	2.61	8.78	1.56	45.69	2.49	728.5
SEm±	0.21	0.03	0.31	0.028	0.53	0.06	18.13
CD (P=0.05)	0.64	0.10	0.91	0.084	1.55	0.18	52.91

enhanced the grain yield and stover yield over 30 kg N/ha as basal + 30 kg N/ha as side dressing, 60 kg N/ha as basal (100% RDN) and control treatments. The economic analysis exhibited the highest B-C ratio and monetary efficiency under high density sowing *fb* alternate row harvesting for fodder at 35 DAS. Application of 75 kg N/ha as basal treatment recorded significantly higher B-C ratio and monetary efficiency as compared to all other nitrogen management treatments and control except 37.5 kg N/ha as basal + 37.5 kg N/ha as side dressing.

CONCLUSION

On the basis of experimental results, it can be concluded that high density sowing *fb* alternate row harvesting for fodder at *35 DAS* is a suitable practice to get higher forage yield and can be a sustainable alternative of forage shortage under CA. For getting higher yield with more profit under conservation agriculture especially during initial 2–3 years, pearlmillet should be fertilized with 75 kg N/ha (125% RDN) as basal.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Increasing the possibility of double cropping by mitigating water and nutrient stress through Conservation Agriculture in rainfed Alfisols

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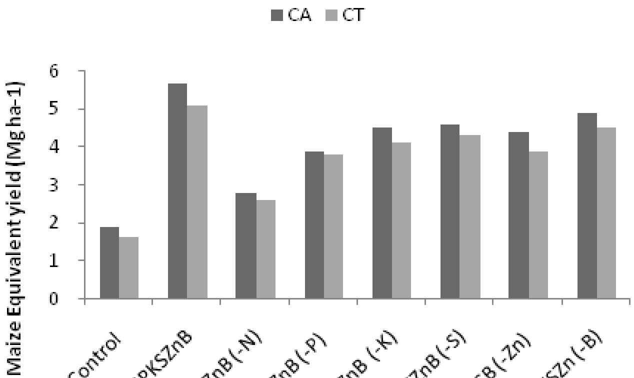
Land degradation, low soil fertility, erratic rainfall are the prime constraints for low agricultural production in the semi-arid region. In Alfisols regions of southern India, most of the cultivated areas produce a single crop in rainy (*kharif*) season and 25–30% rainfall goes unutilized in post rainy (*rabi*) season which remains fallow. In these areas, drought hardy crop like horsegram can be cultivated in sequence of *kharif* crop by practicing effective soil moisture conservation measures or conservation agriculture (CA). CA can play a major role in stabilizing production in rainfed regions by mitigating water and nutrient stress through adoption of reduced tillage, crop rotations and residue retention. By practicing CA, residual moisture and nutrients can be effectively utilized and net productivity and profitability can be increased by increasing cropping intensity. Reddy and Willey (1985) reported a reasonable yield of horsegram after an early pearlmillet crop in Alfisols. Several successful case studies on CA were reported in irrigated systems (Aulakh *et al.,* 2012), but very limited efforts were made in rainfed production systems. In this background, an attempt was made to find out the impact of CA on system productivity, nutrient use efficiency and profitability in maize-horsegram cropping sequence in rainfed Alfisol.

METHODOLOGY

A field experiment was initiated in June, 2010 at Gunegal Research Farm (17°, 40′, 40.4″ N latitude and 78°, 39′, 55.7″ E longitude and at a mean sea level of 626 m) of Central Research Institute for Dryland Agriculture (CRIDA), Hyderabad. These sandy loam soils are slightly acidic in reaction, low in soil organic carbon, medium available nutrients (N, P and K). Among micronutrient Zn was deficient (0.48 mg/kg). Experiment was laid out in split plot design consisting 2 tillage treatments (conservation= zero tillage and residue retention (CA) and conventional= 2 ploughing, complete removal of removal (CT)) as main plot and nutrient management (control, NPKSZnB, N, P, K, S, Zn, B omission) as sub plot. Each treatment was implemented in triplicate.



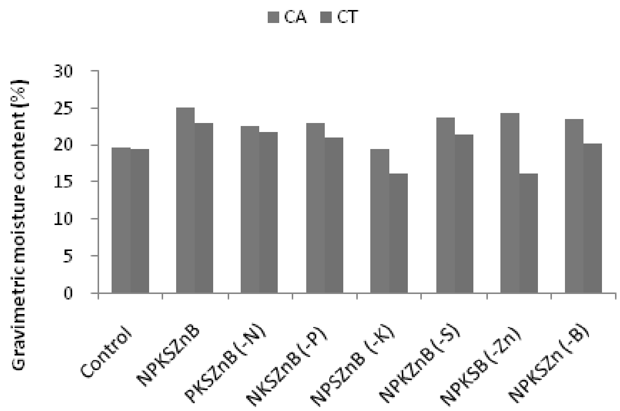


Fig. 1. Maize Equivalent Yield (Mg/ha) and moisture content (%) of soil at 70 DAS of horsegram crop influenced by CA and balanced fertilization

Plot dimension was 5 × 4 m. Chemical fertilizers as N, P, K, S, Zn and B were applied in the form of urea (46% N), diammonium phosphate (DAP) (18% N and 46% P_2O_5), muriate of potash (MOP) (60% K_2O), single super phosphate (SSP), Zinc sulfate (21% Zn) and Borax respectively. Hybrid maize (DHM 117) was grown in rainy season (June-October) following 60 × 25 cm spacing and horsegram (CRIDA 18R) was sown just after the harvesting of maize.

RESULTS

Pooled data showed that tillage did not significantly influence cob length, cob girth, cob weight and grain weight per cob, but significantly higher number of grains per cob (382) and 100 grain weight (29.9 g) of maize was observed in CA compared to CT. Grain yield of maize was on par in both the tillage treatments. Significantly higher stover yield (5.8 Mg/ha) was observed in CT but higher harvest index (35.7%) was obtained in CA. Higher grain (4.3 Mg/ha), stover yield (6.0 Mg/ha) and harvest index (41.7%) was observed in balanced fertilization treatment. Agronomic efficiency (AE) of N, P, K in CA was 22.1, 55.3 and 26.6 kg yield increase per kg of fertilizer nutrients applied compared to 18.8, 40.7, 24.1 kg yield increase per kg of fertilizer nutrients applied respectively in CT due better soil water nutrient interaction (Aulakh *et al*., 2012). Higher grain (0.39 Mg/ha), straw (1.21 Mg/ha) yield and harvest index (23.4%) of horsegram was observed in CA. Higher maize equivalent yield (Mg/ha) was found in CA (4.1) compared to CT (Fig. 1a). Higher grain yield of horsegram in CA was due to 2.8% higher soil moisture compared to CT during flowering and grain filling stage of horsegram which helped better grain filling of horsegram (Kassam *et al.,* 2014). Significantly higher gross return (Rs. 37308 ha^{-1}), net return (Rs. 29375 ha^{-1}) and B:C ratio (2.25) was found in CA compared to CT. Though in terms of *kharif* crop yield (maize), there was not much effect of CA, but CA influenced significantly in *rabi* horsegram yield. That ultimately improved the returns and B:C ratio. Tillage systems did not have much influence on soil pH, EC and other macro and micro nutrients, but significantly higher buildup of available K was observed in CA. However in most of the nutrient omission treatments, depletion of that particular nutrient was observed. Significantly higher available N (207 kg/ha) and K (180 kg/ha) was observed in balanced fertilization and N omission treatment respectively. There was a slight improvement in soil organic carbon in CA with balanced fertilization (5.4 g/kg).

CONCLUSION

Effect of CA is more pronounced in sequence crop (horsegram) grown in *rabi* season. In less rainfall year, it can minimize the effect of moisture stress of hosegram and sustain the crop for several more weeks. CA improved the SOC and available nutrient status, particularly K in the soil. Thus, CA with improved nutrient management can improve soil health, nutrient use efficiency and increase net primary productivity and profitability in rainfed region.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Long term conservation agriculture in maize based cropping systems under semi-arid agro-ecosystem: crop productivity, profitability and soil health

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The diversification of rice-wheat (RW) systems with maize-based systems and alternate soil and crop management practices could help in enhancing the system productivity,profitability, sustain soil health and environmental quality, and save irrigation water and labour costs (Aulakh and Grant, 2008), provide palatable fodder and meeting increased demand of maize grains from piggery and poultry industries (Singh *et al.*, 2016).As a result, productivity of different cropping systems is showing either static or declining trends (Parihar *et al*., 2016). Maize, an important crop for food and nutritional security in India, is grown in diverse ecologies and seasons on an area of 8.67 m ha. In the previous decade (2003–04 to 2012–13), the maize area expanded by 1.8% and production increased by 4.9% showing productivity growth at 2.6% per annum in India. In the past, maize was evaluated as an alternate crop to rice with conventional management practices in RW systems but it was not proved economical due to its lower yield and market price. However, in recent years with the introduction of single cross high yielding maize hybrids provided genotypic options for crop diversification in RW systems. In the northwestern Indo-Gangetic plains (IGP) maize is commonly grown in rotation with wheat, chickpea, mustard and winter maize. Another option to improve soil health and increase farmer's profits lies in the integration of short-duration legumes for grain and green manuring (e.g. mungbean and *Sesbania*) in a cereal-based cropping systems. In this backdrop, the objectives of present study were to determine the long term effects of different tillage practices and intensive maize based crop rotations on system productivity, profitability and soil health of north-western IGP.

METHODOLOGY

A long-term field experiment established in June 2008 under three main-plot treatments consisting tillage and crop establishment (TCE) practices [zero tillage (ZT), permanent bed (PB) and conventional tillage (CT)] and four intensified maize-based systems [maize–wheat–mungbean (MWMb); maize–chickpea–sesbaina (MCS); maize–mustard–mungbean (MMuMb); maize–maize–sesbania (MMS)] in sub-plots.The Crop establishment in CT involved one ploughing each with disc harrow followed by spring-tyne cultivator and rotavator. In ZT, different crops were direct drilled using ZT planter with inverted 'T' tynes. In the first year (July 2008), raised beds were fresh whereas in subsequent seasons they were kept as permanent beds (PB). The width of the beds (mid-furrow to mid-furrow) was 67 cm, with 37cm wide flat tops, and 15 cm furrow depth. Reshaping of PB was done at the end of every cropping cycle in one-go simultaneous while planting using raised bed multi-crop planter. To measure the crop productivity, the grain/seed yields of wheat, mustard and chickpea were estimated from 2×4 m^2 (8m^2) harvested area. The maize cobs were harvested from 10.72 m^2 area (central 4 rows constituting 4m length with row spacing 67 cm) and threshed by maize plot sheller to estimate the grain yield. Seed yield of summer mungbean were estimated from 8 m^2 area.To compare the productivity of different crops and system productivity of the cropping systems, the yield of non-maize crops was converted into maize equivalent yield (t/ha) as per the standard formula.

RESULTS

In a 7-year study significant ($P<0.05$) improvement in system productivity, and net returns (by 1.1-20.9, 8.9-45.1 and 3.6-16.6, 13.3-34.2%, respectively) was observed with ZT and PB compared to the CT plots(Fig. 1). In the initial two years, higher system productivity (maize equivalent yield) and net returns were recorded in PB, while from third year onward ZT registered maximum productivity. Significant ($P<0.05$) tillage by cropping system interactions were observed for soil organic carbon (SOC) content. The soil organic carbon (SOC) was maximum in PB-MCS plots at 0-15 cm and 15-30 cm soil depths.However, the SOC content of all the tillage and cropping systems plots were statistically at par for 30-45 cm depth (Fig. 2).

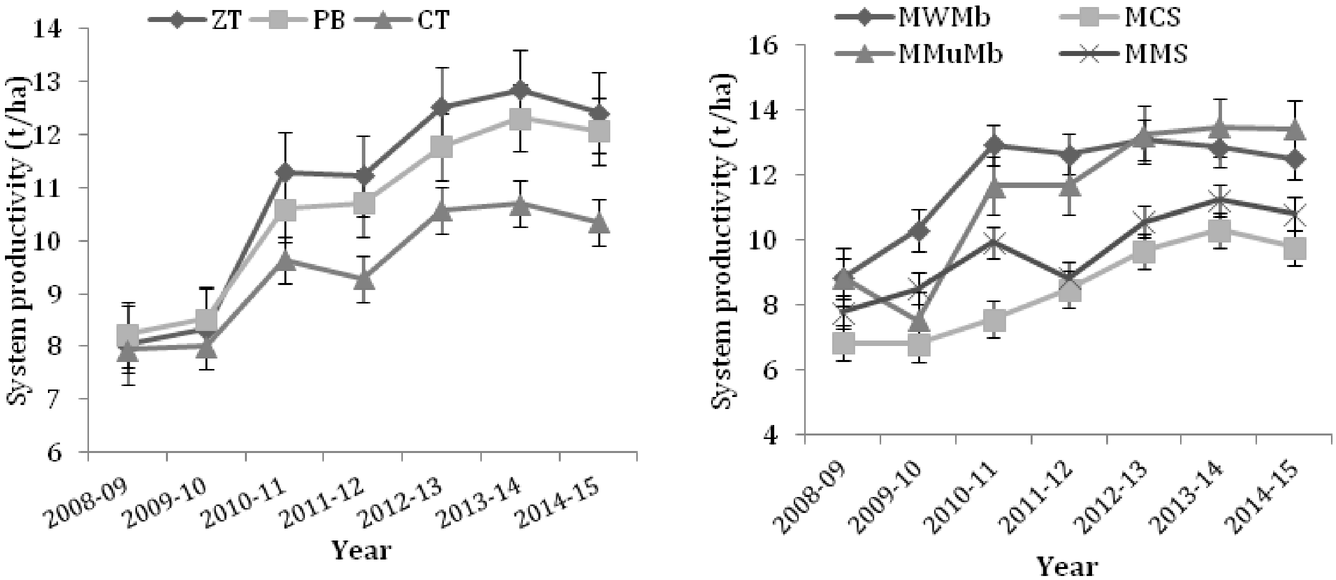

Fig. 1. Long term effect ofdifferent tillage practices and diversified cropping systems onsystem productivity.CT=Conventional tillage, PB=Permanent bed, ZT=Zero tillage, MWMb=Maize-Wheat-Mungbean, MCS=Maize-Chickpea-Sesbaina, MMuMb=Maize-Mustard-Mungbean, MMS=Maize-Maize-Sesbania.

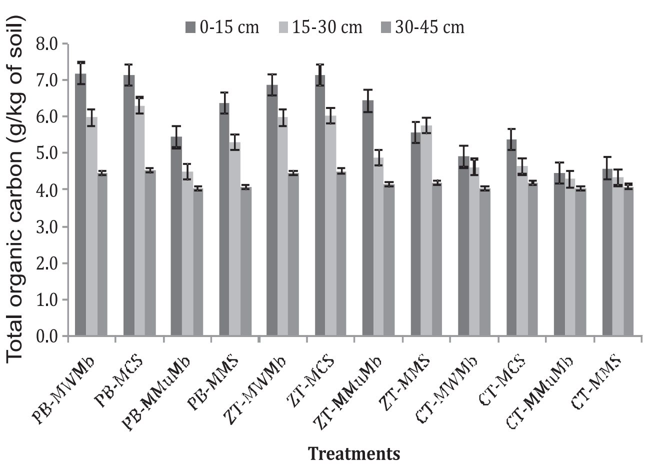

Fig. 2. Interaction effect of long term tillage practices and diversified cropping systems on total soil organic carbon content.CT=Conventional tillage, PB=Permanent bed, ZT=Zero tillage, MWMb=Maize–Wheat–Mungbean, MCS=Maize–Chickpea–Sesbaina, MMuMb=Maize–Mustard–Mungbean, MMS=Maize–Maize–Sesbania.

CONCLUSION

Our study reveals that under the multiple challenges sustainable intensification of maize systems (MMuMb and MWMb) using CA based management options have potential for meeting future food needs, income security and sustainability of natural resources in North Western India.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Slow release nitrogen fertilizer in conservation agriculture for enhancingcrop health, yield and soil properties in intensified maize systems

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The Conservation agriculture (CA) practices are proving as the best alternative for resource degrading tillage intensive cropping systems in Indo-gangetic plains and elsewhere. Most of the nitrogen nutrient applied in the crops by top-dressing lies on the crop residues and get lost by volatilization and immobilization results in poor nutrient use efficiency. At the same time, this may results in more negative environmental footprints of crop production. Thus, under CA proper nutrients management especially alteration in traditional N management practices may not only further enhance its adoption at large scale but also it can make CA as more eco-friendly agriculture practice (Jat *et al*., 2015). The application of coated N fertilizer could be better options for enhancing N-use efficiency (Jat *et al*., 2011) under such situations. In order to explore the feasibility of one time application of such coated nitrogen fertilizer like *neem* or sulphur coated urea under CA, this experiment was started in July 2012 for intensified maize-based systems.

METHODOLOGY

A field study was conducted on during 2012–16 as a long-term experiment at New Delhi. The soil of the experimental site was sandy loam in texture with neutral pH having low N, medium P and high K availability. The treatments consisted of two cropping systems: maize–mustard–mungbean (MMuMb) and maize–wheat–mungbean (MWMb) in main-plots; two residue management practices of with (WR) and without residue (WoR) in sub-plots and four N management practices of control, prilled urea (PU), sulphur coated urea (SCU) and neem coated urea (NCU) in sub-sub plots arranged in split-split plot design and replicated thrice. The crop health, yield and soil parameters were studied in these intensified irrigated maize base cropping systems.

RESULTS

The combined analysis of four years data revealed that the one-time *neem* coated urea (NCU) application was beneficial under CA. The application of residue (WR) also yielded better over no residue (WoR) application in maize. In third year, the system productivity was significantly higher with application of either sulphur or *neem* coated urea in intensified maize systems. The SCU or NCU lead to enchantment in system productivity by 12 or 10% over conventional prilled urea application. The application of residue lead to significant enhancement in system productivity by 910 kg/ha over WoR (Fig. 1). The maize-mustard-mungbean (MMuMb) system yielded significantly higher over maize–wheat–mungbean (MWMb) by 5.7%. Significant residue* N application interactions were found where the coated fertilizer application resulted in significantly higher yield in WR while under WoR the prilled urea performed on par with coated fertilizers.This was probably due to better moisture regimes with residue retention which lead more vigorous crop growth. After a dry spell of 10 days in maize, the residue application lead to depletion in canopy temperature by more than 3.5 °C compared to less than 2.5°C in WoR in most of the cases found in our study.

The nitrogen-use efficiency (NUE) was higher under MWMb system over MMuMb and it increased by NCU and SCU application over PU application. Moreover, under the residue retention, decrease in NUE was observed which was the highest with conventional PU application. The retention of residue leads to decrease in penetration resistance after

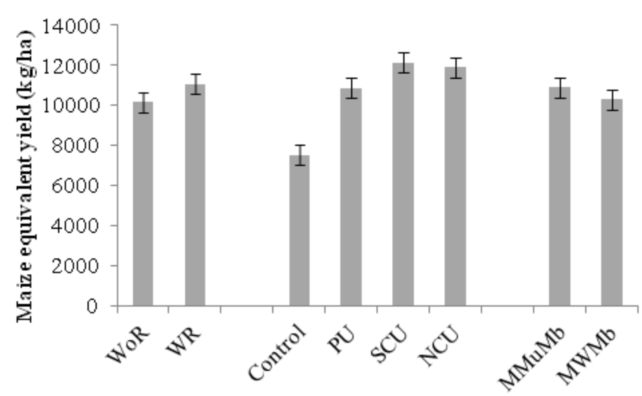

Fig. 1. Effect of coated fertilizer application on system productivity of intensified maize systems under different residue management scenario in third year.

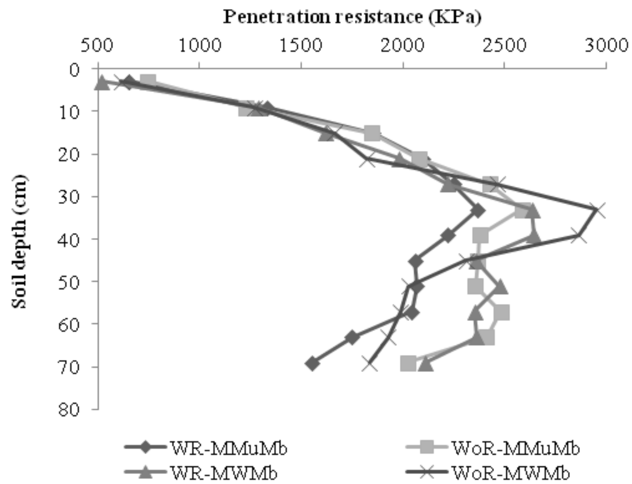

Fig. 2. Effect of coated fertilizer application on penetration resistance after three years in intensified maize systems under different residue management scenario after three years

three years of experimentation as compared to no residue application (Fig. 2). The residue application lead decrease in penetration resistance might be due to enhanced soil organic carbon (Parihar *et al*., 2016) which leads to decrease in soil bulk density.

CONCLUSION

Based on our study, it was concluded that the application of neem/sulphur coated fertilizer found to be effective for enhancing yield, crop health and soil physical properties under conservation agriculture in intensified maize systems.

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Symposium 9

Innovation Systems and Last Mile Delivery

Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Role of front line demonstrations in last mile delivery of technologies: A case of groundnut–wheat cropping systems in Mid-Western Plain Zone of Uttar Pradesh

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Groundnut (*Arachis hypogaea* L.) is the most important oilseed crop of the country. It is mainly grown in Gujarat, Andhra Pradesh, Tamil Nadu, Maharashtra, Karnataka, Madhya Pradesh, Uttar Pradesh, Orissa, Rajasthan and Punjab. Uttar Pradesh accounts for 10.85% and 11.19% of area and production, respectively in the country with the average yield of 1,149 kg/ha which is equivalent to the national average (1,117 kg/ha). Budaun district has the sizeable area (728 ha) under groundnut cultivation but the productivity level is very-very low (749 kg/ha) during 2010–11. The groundnut production scenario in the country has undergone a sea change. The main contributors to such transformations have been (*i*) availability of improved oilseeds production technology and its adoption, (*ii*) expansion of cultivated area, (*iii*) price support policy and (*iv*) institutional support, particularly establishment of technology mission on oilseeds in 1986 (Hegde, 2004). The improved technology packages were also found to be financially attractive. Yet, adoption levels for several components of the improved technology were low, emphasizing the need for better dissemination (Kiresur *et al.*, 2001). Several biotic, abiotic and socio-economic constraints inhibit exploitation of the yield potential and these needs to be addressed. The state-wise yields obtained both under improved technology and farmers' practice ranges from 12 to 110% between states and the national average being 36%. The additional production that can be attained by exploiting the yield gap at national level is about 2 million tonnes (Kumar and Chauhan, 2005).Therefore, keeping the above point in view, the FLDs on groundnut using integrated crop management technology was started with the objectives of showing the productive potentials of the new production technologies under real farm situation over the locally cultivated groundnut crop.

METHODOLOGY

The present study was carried out by the Krishi VigyanKendra, Ujhani (Budaun) under Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut during *kharif* seasons from 2008 to 2013 (6 years) at the farmer's fields of different villages ofBudaun district in Mid-Western Plain Zone of Uttar Pradesh.In total 78 frontline demonstrations in 30ha area in different villages were conducted. In general, soils of the area under study were sandy loam in texture and medium to low in fertility status.The technologies demonstrated as Integrated Crop Management (ICM) practices comprised under FLDs, viz. use of improved variety (TG 26) at the rate of 80 kg/ ha, seed treatment with carbendazim @ 2 g per kg seed, balanced nutrient application (N : P: K @ 46 : 60 : 30 kg/ha with 20 kg $ZnSO_4$ and 10 kg S/ha), line sowing, timely weed management by pre emergence use of pendimethalin @ 3.0 litre per hectare and control of groundnut tikka disease by propiconazole @ 500 ml/ha and termite management with chloropyriphos at the rate of 3 litres per hectare.In case of farmers practice plots, existing practices being used by farmers were followed and included variety kaushal at the rate of 80 kg/ha, application of N : P : K @ 41 : 46 : 00 kg/ha, line sowing, manual weeding at 20–25 DAS and termite control by chloropyriphos at the rate of 2 litres per hectare. The FLDs were conducted to study the gaps between the potential yield and demonstration yield, extension gap and technology index. The technology gap, extension gap and technology index were calculated using the formulae given by (Samui *et al.*, 2000). The satisfaction level of participating as well as neighbouring farmers' for the performance of improved variety demonstrated was also assessed. The data collected were tabulated and statistically analyzed to interpret the results. The economic-parameters (gross return, net return and C : B ratio) were worked out on the basis of prevailing market prices of inputs and Minimum Support Prices of outputs.

RESULTS

The data (Table 1) indicated that the frontline demonstration has given a good impact over the farming

Table 1. Yield performance of groundnut under FLDs at farmers' field

Year	No. of demo.	Area (ha)	Yield (kg/ha)		% yield increase over FP	Technology gap (kg/ha)	Extension gap (kg/ha)	Technology index (%)
			Demons tration	Farmers practice				
2008	11	5	1,529	1,240	23.31	271	289	15.06
2009	13	5	1,358	1,100	23.45	442	258	24.56
2010	13	5	1,384	1,216	13.82	416	168	23.11
2011	13	5	1,412	1,229	14.89	388	183	21.56
2012	13	5	1,463	1,247	17.32	337	216	18.72
2013	15	5	1,492	1,263	18.13	308	229	17.11
Mean	78	30	1,440	1,216	18.49	360	224	20.02

community of Budaun district as they were motivated by the new agricultural technologies applied in the demonstrations. Results of FLDs showed that the ICM practices, produced on an average 1,440 kg/ha groundnut yield, which was 18.49% higher compared to prevailing farmers practice (1,216 kg/ha). The technology gap observed may be attributed tothe dissimilarity in the soil fertility status and weather conditions. Hence, variety wise location specific recommendation appears to be necessary to minimize the technology gap for yield level in different situations. This varies from 271 to 442 kg/ha in the demonstration period.The extension gaps ranged from 168 to 289 kg/ha during the period of demonstration emphasized the need to educate the farmers through various means for the adoption of improved agricultural production technologies to reverse this trend of wide extension gap. More and more use of latest production technologies with high yielding varieties will subsequently change this alarming trend of galloping extension gap. The new technologies will eventually lead to the farmers to discontinuance of old varieties with the new technology.The technology index shows the feasibility of the evolved technology at the farmer's fields. The lower the value of technology index means more is the feasibility of the technology. The results (Table 1) showed that maximum technology index value 24.56% was noticed in the year 2009 followed by 23.11% (2010) whereas, minimum value of technology index of 15.06% in the year 2008, it may be due to uneven and erratic rainfall and vagaries of weather conditions in the area. The economics (Cost of cultivation, gross and net return) of groundnut under front line demonstrations were estimated and the results have been indicated that frontline demonstrations recorded higher average cost of cultivation (₹ 13,523/ha), gross returns (₹ 40,732/ha) and net return (₹ 27,209/ha) with higher cost: benefit ratio (2.98) compared to farmers practice (₹ 11,952/ha, ₹ 34,492/ha, ₹ 22,540/ha and 2.85, respectively). The results suggest that higher profitability and economic viability of groundnut demonstrations under local agro-ecological situation. This might be due to higher production under FLDs as compared to the prevailing farmers practice in all the three years.

CONCLUSION

It may be concluded that the frontline demonstrations on integrated crop management technology in groundnut crop has been found more productive, profitable and feasible in Mid-Western Plain Zone of Uttar Pradesh as compared to prevailing farmers practice under real farm situations. Farmers were motivated by results of demonstrations of integrated crop management practices in groundnut and they would adopt these technologies in the coming years.This will substantially increase the incomeas well as the livelihood of the farming community.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Mobile soil testing using proximal sensor technology are key to contributing to last-mile delivery problems on soil nutrient management

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Farmers in developing countries are generally confronted with significant yield gaps, i.e. their crop yields are lower than what is potentially possible. It is often stated that field-specific nutrient management advice based on routine soil testshelps to reduce the yield gap (Tittonell *et al*., 2008). Moreover it also contributes to more efficient use of scarce nutrient resources. So, if agricultural productivity, farming profitability and food and nutrition security are to be enhanced, constraints on the access to affordable soil testing and soil nutrient management advice should be resolved. Numerous studies have shown the perspectives of proximal sensing methods like infrared spectroscopy for affordable and precise soil testing. Generally, equipment for proximal soil sensing is robust, in principle making soil testing in the field possible. Yet, in practice such reliable mobile soil tests are still not available. This gap between potential of the methodology and implementation in practice is a typical example of a Last-mile delivery problem. Here, we present a workflow that overcomes the above-described Last-mile delivery problem by setting up a global soil spectral database andcombining this with real-time big data analysis, resulting in soil tests and subsequent soil nutrient management advice. While we are active worldwide, we show here our first results of rolling out our developed soil tests in East African countries (Anonymous, 2016)

METHODOLOGY

We defined 6 work packages to develop affordable and precise mobile soil testing:

1. Sensor selection: developing near-infrared (NIR), mid-infrared (MIR) and XRF spectroscopy sensors based on robustness, precision and repeatability.
2. Calibration database: defining optimal sample locations and defining standardized sampling, pretreatment (e.g. soil drying and unbiased subsampling), storing and transportation protocols.
3. Reference methods: selecting wet-chemical reference soil testing methods and implementing these at a single soil reference laboratory.
4. Building predictionmodels: developing multivariate NIR, MIR and XRF soil spectral prediction models and evaluation of prediction model performances.
5. Fertilizer recommendations: setting up a universal soil nutrient management advice framework, focusing on field-specific optimal soil fertility and crop yield.
6. Information transfer: developing communication methods to farmers and their advisors.

RESULTS

Mid 2016, ~12,000 locations were identified for the collection of calibration samples in 15 countries all over the world, ~5,500 samples from 10 countries were collected and shipped to the soil reference laboratory in the Netherlands, and ~4,500 samples were tested on >80 soil characteristics. Currently 60 of these soil characteristics are under study for prediction by soil sensing.These prediction models are integrated into a fully automated, continuously available prediction engine. The following soil testing concepts have now been developed:

1. A mobile or stationary laboratory based on MIR and XRF spectroscopy is implemented in a country or region when >10 relevant soil parameters have an R^2 of prediction is >0.9. By the end of 2016 we expect to have laboratories implemented in Burundi, Ivory Coast, Kenya, Namibia, the Netherlands, Philippines, Tanzania, Uganda, Ukraine, northern USA and Zambia.
2. A handheld scanner combining NIR spectroscopy and EC (electrical conductivity) measurements.This mobile phone-operated scanner has become operational recently in Kenya and soon in more East African countries.

Both soil testing concepts transfer spectral and field-specificdata via the mobile network or internet. Data analysis occurs fully automated, and analytical results and management recommendations are returnedin real-time. Implementations of these soil testing concepts are carried out by SoilCares partners including advisors or suppliers. The recommendation schemes are tuned together with the partners as function of, e.g. local conditions, available fertilizers and yield levels. Strategies like integrated soil fertility management, organic farming, balanced approach or soil restorations can be incorporated.

CONCLUSION

The perspectives of the soil testing concepts of SoilCares using sensor technology are quite promising for efficient Last-mile delivery of routine soil testing and soil nutrient management advice. We foresee a vital role for partners with an existing (business) relationship with local farmers.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Phule PVC Bhat Lavani choukat: A low cost precision agricultural tool in paddy transplanting

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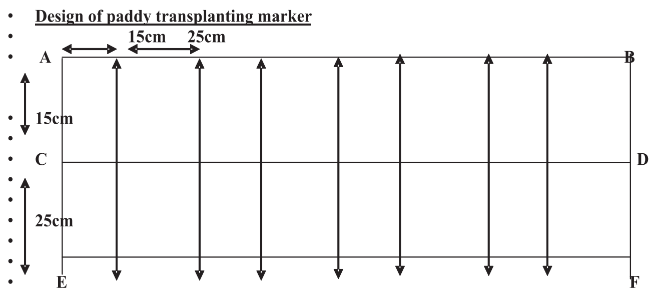
Rice is the staple food of more than 50 percent population of the world. About 90 percent rice area exists in Asia (Das, 2012). The average rice yield in India is only 2.09 t/ha, as compared to 6.58 t/ha in Japan and world average of 3.91 t/ ha (Shivay *et al*., 2007). In Maharashtra rice is grown over an area of 14.99 lakh hectares with an annual rice production of 32.37 lakh tones and average productivity of the state is 2.01 t/ha ranks 13th place in rice production in country. The gap can shorten by only adopting modern rice production technology of fourfold, i.e. 'Charsutri Technology'. This envisages the use of Urea–Dap briquette as slow releasing fertilizers for better fertilizer use efficiency (70%) and increasing in yield (20%). The success of this technology is relies spaced transplanting at a spacing of 15×25 cm^2 with rope and marker guided tool. But during the peak period due to non availability of labours especially male labours makes the failure of the technology.

In paddy cultivation transplanting is very drudgeries operation in overall paddy cultivation processes and 22.3 percent of total time is spent in this operation (Singh and Gite, 2012). From these about 50 percent would be women against 42% at present. In addition, the migration from rural to urban areas in Asia has decreased substantially the labour resource in agriculture. In addition to the adoption of high-yielding and early maturing rice varieties, the application of combinations of existing technologies would save time, land and water for intensification of rice production in the future. Keeping this in view, the present experiment was conducted to compare economic cost and quantum of drudgery with conventional and improved method of paddy transplanting (Mondal and Basu, 2009) This research was aimed to know the cost cutting on labour and fertilizer without reduction in production potential by using low cost precision implement against the conventional and previous improved methods for their physiological fatigue, human drudgery and ergonomical evaluation of both the methods. The experiment was planned with following objectives to develop manually operated paddy transplanting marker for maintaining proper plant geometry of paddy crop. To conduct the performance evaluation of the developed paddy transplanting marker in comparison with conventional method. To compare the yield and cost economics of paddy transplanting marker with conventional methods.

METHODOLOGY

A field experiment was conducted during *kharif* 2014 at Zonal Agricultural Research Station, Western Ghat Zone, Igatpuri., Dist. Nasik (MS) in randomized block design with three treatments replicated on 30 farmers field. The low cost precision farming Phule PVC Bhat lavani Chokat (Paddy transplanting marker frame) was designed and developed technically for spaced transplanting. An on station and on farm ergonomic evaluation was conducted at 5 locations and 30 farmers field with the design of the frame is as follows

The treatments are comprised of 1.Conventional method of transplanting. 2. Rope and marker method and 3. Phule PVC Bhat lavani choukat were undertaken. The data on ergonomics study including, Body mass Index (BMI),



Discomfort scale, Time of operation, Area covered with implement were collected and all the relevant data were statistically analyzed.

RESULTS

The results of 12 Male and 18 female farmers were under study. The results revealed that The BMI was ranged from 17.33 to 28.88.The area covered in a stipulated period of 30 min time has ranged from 22 to 29 m^2 area. Table 1 shows that labour requirement were lowered down than rope method but higher than conventional with less reliance on male labours. The ergonomics study shows that the discomfort scale of this implement has ranged from 1 to 2 having no to low discomfort. The Table 1 indicates that the plant population in the PVC bhat lavani choukat and rope method are remains the same but 32.5% more seedlings with higher seed rate was recorded in conventional method. The 31.25% and 38.88% more no of tillers were recorded in rope and PVC chokat transplanting over conventional method. The direct effect of PVC bhat lavani chokat on reduction in seed rate and improvement in tillers over conventional method is statistically significant. Similar results were observed by Wang ZaiMan and *et al.* (2010). The major aspect of labour saving was quantitatively reduced in PVC Bhat lavani choukat over the rope method is 33.33% especially two male labours. There is less labour required in conventional method over PVC chokat on contrary to loss of seed and fertilizers. Overall the PVC bhat lavani choukat has improved the yield by 35.48 and 12.89% over conventional and rope method respectively due to higher productive tillers over other treatment. The Table 2 indicates that the projected saving for Maharashtra is likely to be labour saving of 51.29 crores and additional income of 322.6 crores from additional yield due to improved method of technology. The cost of frame is ₹ 275 per unit.

Table 1. Comparative labour required, labour saving, no.of plants/m^2 and yield (t/ha)

Sr. No.	Particular	Labour required/ha	Labour saving/ha	No.of plants/m^2	No.of plants/m^2	Yield (t/ha)	Per cent yield increase
1	Conventional method (Farmers practice)	24	0%	195	11	3.1	100% (base fig.)
2	Rope and marker method	36	+9 (133.33%)	147	16	3.8	122.58%
3	Phule Bhat Lavani Choukat	27	100% (base fig.)	147	18	4.1	135.48%

Table 2. Projected cost saving in Maharashtra paddy growers

Sr. No.	Particular	Labour required/ha	Labour cost saving	Additional yield (t)
1	Conventional Method (Farmers practice)	24	–	–
2	Roap and Marker method	36	–	–
3	Phule Bhat Lavani Choukat	27	51.29/- crores	129040/-322.6 Crores additional returns (Avg rate: ₹ 2,500 per t)

CONCLUSION

This is a resource conservation technology which saves seed rate, fertilizers and labour. Easy to adopt the improved charsutri technology of spaced planting and use of briquette. Save fertilizers than conventional method saves the seed quantity can be used from single to multi persons easily. The choukat is light in weight and can be transported to any corner of the field easily. Very low in cost and can be made locally. The Phule PVC bhat lavani choukat (Paddy transplanting marker) will be beneficial to small and marginal farmers for successful implementation of improved charsutri rice production technology with labour saving and increase in yield. The use of this frame will enable the in national goal of food security as well as pollution control and climate change effects.

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Symposium 10

Livelihood Security and Farmers Prosperity

Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Root growth and cane yield of ratoon sugarcane under the combined effect of stubble shaving, off-barring, root pruning and placement of basal dose of fertilisers with surface retention of trash

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Despite of well established rooting system, the sugarcane ratoon yields are less (20–25%) than main planted crop of sugarcane. This is mainly due to lack of machinery for proper placement of fertilisers and poor acquisition and utilization of nutrients by the older roots. Therefore, practices should aim at inducing fresh finer roots particularly at the initial stages of ratoon cycle to match the water and nutrient demands of large number of emerging tillers. The options lie in terms of pruning to induce fresh slush of roots, in addition to surface retention of trash to act as mulch for better hydro-thermal regimes and placement of fertilisers closer to newer roots. However, farmers usually burn the trash because of constraints in fertiliser placement and other intercultural operations. To resolve these issues, recently a multi-purpose machine was fabricated (Choudhary *et al.,* 2016) that performs four operations i.e. stubble shaving, off-barring, root pruning and placement of basal dose of fertilisers (SORF) with surface retention of chopped trash in a single pass. Accordingly, its impact was assessed on the root architecture and yield response of ratoon sugarcane.

METHODOLOGY

A field experiment was conducted with ratoon sugarcane during April 2015 to March 2016 at ICAR-NIASM, Baramati, Maharashtra on black silty clay soil with pH 7.81 and 6.7 g/kg organic carbon. Four treatments: no-trash without fertilizer nitrogen (T_1); burning of left over trash and broadcasting of basal fertiliser doses (conventional practice: T_2); chopping and surface retention of trash and thereafter drilling of basal fertiliser doses with machine (T_3) and chopping and surface retention of trash and use of multi-purpose machine for stubble shaving, off-barring, root pruning and placement (15 cm) of basal doses of fertilisers (T_4) were accommodated in a RCBD with four replications. Half of the recommended N, P and K applied as basal at the beginning of ratoon while remaining half doses applied at 135 days after the ratoon crop initiation (DARI). Under fertilizer placement treatments, 75% N was applied as basal. A minirhizotron technique was used for periodic monitoring of the rooting patterns. Standard access tubes of 1.8 m length were installed and *in-situ* root images representing 0.2 m soil depth were captured using a Root Scanner CI-600. The images were analyzed for root length (L) with the RootSnap! Software.

RESULTS

The maximum root density (L_A) was monitored in surface 0.4 m soil having 75–85% roots (Fig. 1). The growth rate of roots varied during the crop cycle and the maximum was recorded between 26 to 55 DARI. The L_A in surface 0.2 m soil was comparatively higher with SORF than the other treatments (Fig. 1). Severe water stress conditions after 55 DARI caused stagnation in L_A or even decline due to root decay in the surface 0.2 m soil until 101 DARI especially in T_1 and T_2, though root density substantially improved in deeper layers. This indicated that under water deficit conditions, root explored greater soil volume in deeper layers. On the contrary, the roots continued to grow in T_3 and T_4 treatments as indicated by substantial improvement in L_A from 55 to 101 DARI. This was obviously the impact of better maintenance of hydro-thermal regimes with surface retention of trash. At 144 DARI, the L_A was significantly higher in T_2, T_3 and T_4 over T_1 treatment even down to 0.6 m soil. Band placement of the 75% dose of N as basal along with adoption of SORF techniques (T_4) further improved root growth and the L_A was considerably higher than conventional practice (T_2) in surface 0.4 m soil at 222 DARI. The effects of different trash and SORF techniques also reflected in cane yield production as the cane yield was improved by 13 and 28% with T_3 and T_4 treatments over conventional practice, respectively (Fig. 2).

CONCLUSION

It is concluded that surface retention of chopped trash mitigated the short-term water stress effect through sustained root growth. Drilling of the 75% dose of N as basal along

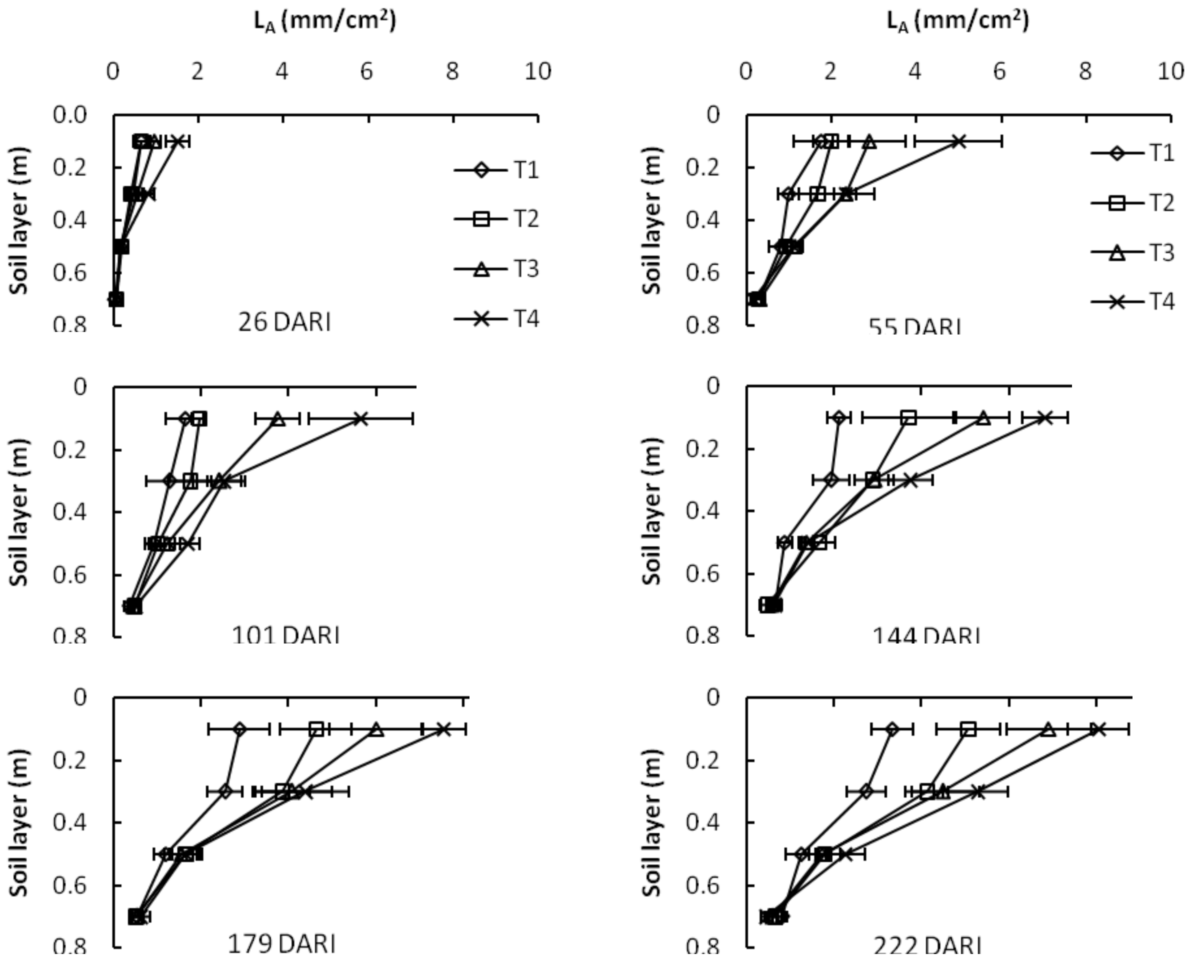

Fig. 1. Periodic root density (L_A) of ratoon sugarcane under no-trash without fertiliser nitrogen (T_1); burning of left over trash and broadcasting of basal fertiliser doses (conventional practice: T_2); chopping and surface retention of trash and thereafter drilling of basal fertiliser doses with machine (T_3) and chopping and surface retention of trash and use of multi-purpose machine for stubble shaving, off-barring, root pruning and placement (15 cm) of basal doses of fertilisers (T_4).

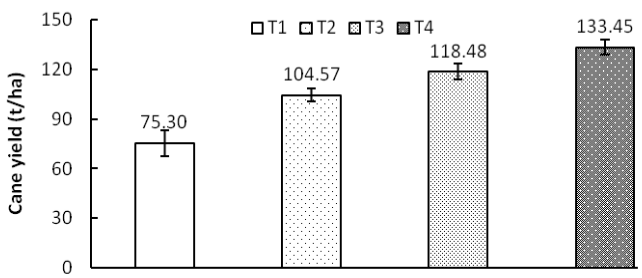

Fig. 2. Cane yield of ratoon sugarcane as affected by no-trash without fertiliser nitrogen (T_1); burning of left over trash and broadcasting of basal fertiliser doses (conventional practice: T_2); chopping and surface retention of trash and thereafter drilling of basal fertiliser doses with machine (T_3) and chopping and surface retention of trash and use of multi-purpose machine for stubble shaving, off-barring, root pruning and placement (15 cm) of basal doses of fertilisers (T_4).

with adoption of SORF techniques of ratoon management lead to substantial improvements in the root growth and cane yields.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Consumption pattern of foods in India with a special focus on value-added foods

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India has a huge potential in value-addition as it tops the production of many food crops, fruits and vegetables and milk. Its annual food grains production is 260 million tons and fruits and vegetables production is 227 million tons. India is the top producer of many such agricultural products and occupies a very important place in the world's food production basket.The Indian food processing industry is one of the largest industries in India. It accounts for 32 per cent of the country's total food market. Value-adding is the process of changing a raw commodity to a high quality end product by adding time, place and/ or form utility in order to meet the tastes/preferences of consumers. It is like producing according to the need of the consumer and then delivering it. There are two types of processing; commodity-based and value-added processing. Commodity processing is just the primary processing. Example, processing of raw food grains like rice, wheat, maize etc. Value-added processing is secondary and tertiary processing. Example processing of milk products.Increasing the profitability of farm products are possible by capturing or creating value to those products.Capturing value relates to capturing some of the value that is added to a product by processing, distribution and marketing. Developing differentiated products is creating value. The product difference may be real or perceived. Example branded products or products with special certification or products produced by using special methods such as organic or environmentally friendly practices. The benefits of adding value to agricultural products include higher returns, the opportunity to open new markets, reducing the glut in the market and availability of off-season products, extending the marketing season of the products, creating new recognition for the farm, increased ability to capture a percentage of the farm-to-retail price spread, market shares and branding etc. There is a link between food industry, value addition and consumption pattern. Now we are seeing the major change in consumption pattern; it is being shifted awaytowards processed foods. This paper deals about the change in consumption pattern, trend in consumption of various groups of commodities etc. The analysis of food consumption pattern and expenditure on food inIndia is of greater interest, because, it helps to understand the future of consumption habits in India. And, it concludes that in India, the increase in the number of educated nuclear families, growing disposable incomes, change in lifestyles and foodhabits, rapid urbanizationand working women and increased awareness about different value added products have led to the emergence and growth of processed foods in the form of convenient foods, ready-to-eat foods, ready-to-cook foods, healthy breakfast cereals, etc. in the pastdecade. Besides that, policy makers and administrators alsoshould promote food processing industries so that the demand and supply of such products will be met equally.The potentialIndia has in terms of its diversified climate in producing a variety of crops has to be utilized properly to achieve a robust economy.

Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Vulnerability of agriculture to climate change: policy imperatives

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In view of the inevitable impacts of climate shocks on the food and rural/agrarian livelihood security there has been an increasing emphasis towards adaptation. The process of adaptation intends to soften the harm and vulnerability associated with the climatic changes through modification in the operations, practices and structures by the human and society so as to enhance their resilience. Besides in comparison to the mitigation-abridging measures, adaptation strategies found to manifests in a lesser time. Adaptation majorly falls under planned and autonomous category. While the former comprise conscious policy actions in realization of the climate changes that are likely to exacerbate vulnerability, the latter is a more reactive approach, i.e. involves strategies (majorly short term adjustments) adopted by an entity independently in response to present and future risks.

The concept of adaptation has been linked to the process of development since developmental interventions are believed to alter the adaptive capacity. Most of the adaptation strategies coincide with the existing developmental initiatives aiming livelihood diversification, natural resource conservation & management, risk financing, production and crop productivity enhancement, food security, etc. This necessitates the need to address adaptation and rural development in an integrated manner, so as to achieve climate resilient development. Also as pointed by FAO; 'In order for climate change adaptation and mitigation to be sustainable and applicable on a wide scale, it must be incorporated, integrated or mainstreamed into the policy apparatus of governments'. This process of achieving climate compatible planning involves either integrating climate change considerations in the development planning from the beginning or transforming the existing programmatic interventions. Major advantage under this approach is that no new policies, programmes and institutions need to be formed separately, due to strong interconnection between adaptation and development.

Mainstreaming in India is still at an incipient stage. Off late there has been increasing consensus towards mainstreaming climate change adaptation into the decision making framework. In recognition of the increasing vulnerability to climate change and its socio-economic ramifications/ impacts, Mainstreaming climate change adaptation into developmental planning has emerged as a forefront agenda and a challenge in front of the Indian policy makers. Such a strategy has been mooted as adaptation and development processes are intertwined. Before analyzing the approach to meld climate change adaptation with developmental decisions, it is pre-requisite to assess and review the programmatic interventions prevailing in the current developmental agenda aimed exclusively at enhancing the resilience or adaptive capacity of the agricultural system.

It was observed that the Indian Government is operationalizing a number of developmental programmes/ schemes across different ministries/ departments with the objective of outcome oriented holistic development of the targeted section or region. In this milieu, the paper attempts to schematize a *thematic/need* based convergence of the on-going developmental programmes/ schemes identified across more than twenty different ministries which explicitly or implicitly shield against the maleficent effects and helps the vulnerable section to mitigate the climate change. Such a cross cutting convergence of different programmes will ensure mainstreaming the developmental agenda as per the relevance of the program to climate change adaptation. The study also envisages sensitizing the Indian policy makers towards the program duplication issue and in ensuring effective utilization of the available financial resources thereby being more prudent, target, action and outcome oriented in their approach towards enhancing the resilience of Indian agriculture/vulnerable section or region or society. Hence, coherent policies aligning with the developmental agenda is of paramount importance

Symposium 11

Emerging Challenges for Agronomic Education

Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Redefining Agronomy and its pertinence in context to current agricultural education

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Indian agriculture contributes to about 8% in global agricultural gross domestic product (GDP) to support 18% of world population on only 11.3% of world's arable land and 2.3% of geographical area. Attainment of food security has been the major objective of Indian agriculturists since independence. No doubt, India achieved this goal successfully by adopting green revolution technologies. The country has achieved more than five-fold increase (50–265 million tonnes) in food grain production, against a three and half fold increase in human population (360–1,250 million) with per capita availability of food grains from 395 g/day in 1950 to 450 g/day in 2012. The gross irrigated area also increased from 22.5 to 91.5 million hectares by this time. Likewise, fertilizer consumption increased many folds since independence. Consequently, India emerged as the second largest producer of food in world and has all the potential of becoming world leader if the emerging challenges of agriculture are addressed through reorientation of agricultural education in general and Agronomy education in particular. Crop husbandry has also witnessed the dynamic evolution accordingly but academically and for all operational purposes the science and academics of Agronomy remained much static as it ought not to be. In this paper, therefore, authors have argued for revisiting the academic and functional parlance of Agronomy in context to dysfunctional consequences of modern agricultural technologies.

CHALLENGES OF MODERN AGRICULTURE

Green revolution technologies (GRTs) on one hand though made India as a food secure nation, on the other hand, are blamed for causing serious damages to the farm production resources. The degradation of natural resources like land and water has now become the key constraint in augmenting agricultural production. The yield plateaus and new generation problems of soils are considered as the silent ill effects of over exploiting the resources. The soil has become sick for sustaining the food production and the environment turned unsafe for human health. The widely emerging problems in agriculture have been empirically documented and discussed at several forum. Some of the prominent among them are delineated as below which shall guide for better understanding and making mindset accordingly in achieving our future goal.

- The soil quality is poor with multiple nutrient deficiencies and low organic carbon content due to intensive cultivation and use of fertilizers in indiscriminate quantities.
- The water table is very critical in most of the irrigated lands, and water quality is also deteriorating due to leaching of salts and pollutants.
- The over exploitation of irrigation water lowered the depth of water table.
- The indiscriminate use of insecticides created resurgence with no satisfactory control of pests, for instance, *Helicoverpa armigera* on cotton and pigeon pea and created tolerance to chemical toxicity of the herbicide isoproturon to the weed *Phalaris minor* in wheat and butachlor to wrinkle grass in rice.
- Chemical residues in food increased the incidence of many diseases/disorders among the farmers in particular and consumers in general.

Apart from the above, there is a growing concern about the consequences of climate change for food security as projections indicate that the demand for food grains would increase the 345 million tonnes (mt) by 2030, means the food grain production has to be increased at the rate of 5.5 mt annually. There are several other examples that the modern technology is challenged and demand a change as well as upgradation of human intelligence to search alternate options keeping all the issues in mind. In view of the above, there is need for re-inventing the Agronomy education as Agronomy-a prime discipline has been known for the contributions it made to the cause of science and society. Principally authors feel that there is need to redefine Agronomy which reflects the discipline as a whole in real sense that may help in developing competent resource persons in a perfect position to foster the next generation of leaders and professionals needed to address these challenges.

DEFINITION OF AGRONOMY: EXISTING TRENDS

The word Agronomy is derived from two Greek words *agros* meaning 'field' and *nomos* meaning 'to manage'. Literally, Agronomy means the 'art of managing field'. Whereas technically, it means the 'science and economics of crop production by management of farm land". Many scientists defined Agronomy as that branch of agricultural sciences dealing with the principles and practices of crop production and field management. Wikipedia provided a nice reminder of what Agronomy is all about: 'Agronomy is the science and technology of producing and using plants for food, fuel, fibre, and land reclamation. Agronomy has come to encompass work in the areas of plant genetics, plant physiology, meteorology, and soil science. It is the application of a combination of sciences like biology, chemistry, economics, ecology, earth science and genetics' (https://en.wikipedia.org/wiki/Agronomy). Merriam-webster also provided the full definition of Agronomy as 'a branch of agriculture dealing with field-crop production and soil management' (http://www.merriam-webster.com/dictionary/Agronomy?&toperStarEhJUS=1). Norman (1980) has defined Agronomy as 'The science of manipulating the crop environment complex with dual aims of improving agricultural productivity and gaining a degree of understanding of the process involved'. Jain (2008) attempted to define Agronomy as 'Sustainable management of natural resources and increased efficiency of production inputs'.

SHIFTING THE PARADIGM FROM 'CROP PRODUCTION' TO 'CROP MANAGEMENT'

Considering the above emerging issues arising in modern agriculture in last few decades, Tripathi (2003) made maiden attempt first time by defining Agronomy as 'branch of agricultural science which deals with the principles and practices of crop production for obtaining maximum economical production from a particular field in one agriculture year without impairing the fertility of soil'. Jain (2008) further suggested that Agronomy is no more only a science of 'Crop Production' but it is a science of 'Crop Management'. However, elaborations of various possible academic dimensions of crop management in his above proposal were silent. As, building theory or definition of any subject mainly have the antecedents of dynamism of related events, documenting their records, establishing the empirical relations among them, therefore, in the context of above delineated facts of modern agriculture, the hitherto defined Agronomy as the 'Science of crop production' may be re-structured as "Agronomy is that branch of agricultural science which deals with the principles and practices of crop management for obtaining maximum economical production from a particular field in one agriculture year without impairing the fertility of soil and adversely affecting the eco-system".

Author, therefore, hold a strong conviction that this modern definition of Agronomy shall fulfil the holistic aim of any agronomist in present changing scenario. Principles of Agronomy deal with scientific facts in relation to environment in which crops are grown. Knowledge of such basic principles helps in modifying the controllable environmental factors of crop production for realising the production potentials of crops. Sound knowledge of agronomic principles and practices aids the agronomists in realizing maximum yields at minimum cost in one agriculture year without degrading the soil fertility and environment.

CONCLUSION

Among all the branches of agriculture, Agronomy occupies a pivotal position and is regarded as the mother or primary branch. Agronomy is an integrated and applied aspect of different disciplines of pure sciences. Agronomy has three clear branches namely, (*i*) Crop Science, (*ii*) Soil Science, and (*iii*) Environmental Science that deals only with applied aspects, i.e. Soil-Crop-Environmental relationship. Sound knowledge of agronomic principles and knowledge of the way to perform the operations of the farm in a skillful manner help the agricultural scientists in realizing maximum yields at relatively lower cost without deteriorating the soil fertility and endangering the environment. The modern definition of Agronomy includes all the important aspects of crop management through which agronomists/students could attain better comprehension in wider perspective so that goal of Agronomy may achieved in real sense into current context.

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New Paradigms in Agronomic Research

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Effect of planting methods and forage crops combination on fodder productivity and economics

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The poor feed quality and dry season feed shortage are the serious limitations for livestock production in rainfed areas and farmers maintain a large herd of animals to compensate for the low productivity of the livestock, which adds to the pressure on land and fodder resources (Pathak, 2005). *Cenchrusciliaris* and *Dichanthiumanulatum* are potential fast growing range grasses and having good regeneration capacity and can withstand moisture stress for fairly long time. *Desmanthus, Siratro* and *Stylosanthes* are legume fodder species which give nutritious fodder and could be grown under rainfed situations. High productive, more palatable, perennial and persistent legumes like *Stylosanthes* and *Desmanthus* are thought to be the best suitable to overcome protein deficiency. Keeping the above points in view, the present study was undertaken to develop appropriate fodder production technology under rainfed conditions through moisture conservation.

METHODOLOGY

The present investigation was conducted at the AICRP on Forage Crops, Department of Agronomy, JNKVV, Jabalpur during 2009–13. The experiment was laid out in factorial randomized block design with comprising eight treatments of 2009–13 to study the effect of planting methods and forage crop combinations on fodder productivity through moisture conservation. There were four combinations of grasses with legume, viz. *Cenchrus ciliaris* + *Desmanthus virgatus, Cenchrus ciliaris* + *Stylosanthes seabrana, Dichanthium annulatum* + *Desmanthus virgatus*, *Dichanthium annulatum* + *Stylosanthes seabrana*in 1 : 1 proportion planted with two moisture conservation techniques, viz. ridges and furrows and flat bed. Therefore, eight treatment combinations replicated three times in a factorial randomized block design (FRBD). The grasses were established by planting seedlings at a spacing of 90 cm × 45 cm and legumes sown in between the two rows of grass, i.e. 1 : 1 proportion of 45 cm spacing maintained in between two rows.

RESULTS

This experiment has been started during *kharif* 2009–10 for evaluating the effect of planting methods and grasses + legume combination on fodder productivity through moisture conservation. The results indicate that the combinations

Table 1. Effect of planting methods and forage crop combination on yield and economics (Mean of three years: 2010–11, 2011–12 and 2012–13)

Treatment	Green fodder yield (t/ha)	Dry matter yield (t/ha)	Crud protein yield t/ha)	Gross monetary returns (₹/ha)	Net monetary returns (₹/ha)
Ridge and furrow – *Cenchrusciliaris* + *Desmenthus*	43.24	14.30	1.60	45,735	35,424
Ridge and furrow – *Cenchrusciliaris* + *Stylo*	35.64	11.20	1.16	39,748	29,418
Ridge and furrow – *Dichanthiumannulatum* + *Desmenthus*	51.10	16.62	1.71	54,727	44,427
Ridge and furrow – *Dichanthiumannulatum* + *Stylo*	35.12	11.99	1.12	37,918	27,608
Flate bed - *Cenchrusciliaris* + *Desmenthus*	41.66	13.60	1.54	44,909	34,599
Flate bed - *Cenchrusciliaris* + *Stylo*	29.42	9.46	0.96	31,671	21,352
Flate bed - *Dichanthiumannulatum* + *Desmenthus*	40.95	14.47	1.56	43,667	32,497
Flate bed - *Dichanthiumannulatum* + *Stylo*	26.76	9.64	0.87	30,070	20,020
CD (P=0.05)					
M	2.343	1.862	0.663		
C	2.136	1.540	0.464		
MX C	1.776	1.523	0.34		

Dichanthium annulatum + *Desmanthus virgatus* recorded highest Green fodder, dry matter and crude protein, i.e. 511, 166.2 and 17.1 q/ha, respectively closely followed by *Cenchrus ciliaris* + *Desmanthus virgatus* with ridge and furrow method, which obtained 432.4, 143 and 16 q/ha of green fodder, dry matter and crude protein yield, respectively. In regard of economics, gross monetary returns, net monetary returns were also recorded maximum in T_3- *Dichanthium annulatum* + *Desmanthus virgatus* raised in ridge and furrow method which gave ₹ 54,727/ha and ₹ 44,427/ha/year.

CONCLUSION

The combination of *Dichanthium annulatum* + *Desmanthus virgatus* planted with ridge and furrow method gave highest green fodder (51.1 t/ha/yr), dry matter (16.62 t/ha/yr) and crude protein yield (1.71 t/ha).

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Response of summer sesamum (*Sesamum indicum*) to nipping and spacings

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The present investigation was conducted at College of Agriculture, Pune during summer season 2011. The experiment was laid out in a Factorial Randomized Block Design (FRBD) with nine treatments in three replications. The treatments comprised three nippings, viz. 20 DAS, 30 DAS and 40 DAS with three spacings, i.e. 30 cm × 15 cm, 45 cm × 10 cm and 60 cm × 7.5 cm with same plant density maintained in net plot. The results indicated that nipping done at 30 DAS showed higher number of capsules/plant, dry matter/plant and the yield parameters such as weight of capsules/plant (28.86 g), number of capsules/plant (95.45), seed weight/plant (15.66 g) and test weight (3.33 g) resulting in higher seed yield (1,216.02 kg/ha) and straw yield (2,249.65 kg/ha). Spacing showed significant effect on sesamum in respect of number of capsules/plant, dry matter/plant and the yield parameters such as weight of capsules/plant (27.52 g), number of capsules/plant (94.80), seed weight/plant (14.63 g) and test weight (3.1 g) resulting in higher seed yield (1,108.35 kg/ha) and straw yield (1,957.01 kg/ha). The combined effect of nipping at 30 DAS with 45 cm × 10 cm spacing were found significant which ultimately gave higher income as compared to the other treatment combinations. This treatment combination showed following higher characters like number of branches/plant, number of capsules/plant, dry matter/plant. and the yield parameters such as weight of capsules/plant (29.47 g), number of capsules/plant (101.53) and seed weight/plant (15.88 g) resulting in higher seed yield (1,224.84 kg/ha) and straw yield (2,265.95 kg/ha). It also registered higher gross monetary returns (₹ 73,490.40/ha), net monetary returns (₹ 39,620.4/ha). Therefore, from the above experiment, it can be concluded that nipping at 30 DAS with the 45 cm × 10 cm spacing gave higher productivity of summer sesamum.

Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Prediction of solubility of metals in metal contaminated soils

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ABSTRACT

The accumulation of heavy metals in soil from different sources (e.g. atmospheric deposition, agricultural practices, urban industrial activities, and sewage sludge applications) is of great concern because of the transferring of potentially toxic metals to human and animal food chain. Once these potentially toxic metals are taken up by plants, they can enter the food chain and may be taken up by humans and animals leading to adverse health effect. Hence, the risk associated with build-up of metals and metalloids in soils and their content in edible portions of plants (human food chain) is of utmost importance. Again, risk assessment of metal contaminated soil depends on how precisely one can predict the solubility of metals in soils. This study was undertaken to predict the free ion activity of Zn, Cu, Mn, Ni, Pb and Cd in metal contaminated soils as a function of pH, extractable metals and soil organic carbon content. For this purpose, twenty five surface soil (0-15 cm) samples were collected from agricultural lands of various locations receiving sewage, sludge, municipality waste and industrial effluents for longer periods. Four soil samples were also collected from agricultural land which has been under intensive cropping and receiving irrigation through tube well water. Soil samples were varied widely in respect of physicochemical properties including metal content. Total Zn, Cu, Mn, Ni, Pb and Cd in experimental soils ranged from 30.2 to 28,662, 24.6 to 2,305, 152 to 1,868, 14.4 to 1,513, 8.39 to 3,793 and 0.22 to 352 mg/kg of soil, respectively. Free metal ion activity, viz. pZn^{2+}, pCu^{2+}, pMn^{2+}, pNi^{2+}, pCd^{2+} and pPb^{2+} as estimated by Baker soil test ranged from 5.2 to 12.1, 8.26 to 15, 4.89 to 7.98, 7.69 to 14.4, 7.36 to 13 and 6 to 14.2 respectively. Free metal ion activity were also estimated following speciation of solution data as extracted by porous *Rhizon* samplers installed within the rhizosphere of the growing plant using version 7 of the 'Windermere Humic Aqueous Model (WHAM-VII). In soils under spinach crop, free metalion activity, viz. pZn^{2+}, pCu^{2+}, pMn^{2+}, pNi^{2+}, pCd^{2+} and pPb^{2+} as estimates by WHAM-VII was 6.79 ± 0.53, 9.99 ± 0.87, 7.96 ± 0.51, 7.65 ± 0.54, 10.3 ± 0.50 and 8.74 ± 0.85 respectively. Solubility model as a function of pH, organic carbon and EDTA extractable metals could explain the variation in pZn^{2+}, pCu^{2+}, pMn^{2+}, pNi^{2+}, pCd^{2+} and $pPb^{2+}$to the extent of 82, 40, 30, 41, 52 and 56%, respectively in case of Baker soil test. Predictability of the solubility model based on pH, organic carbon and EDTA, DTPA or $CaCl_2$ extractable metal was superior in case of *Rhizon* extracted soil solution compared to that based on Baker soil test solution.

Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Yield and yield attributes of safflower cultivars as affected by sowing dates

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Safflower [*Carthamus tinctorius* (L.) Moench] is a very useful oilseed crop for rainfed or dryland areas. Generally it is known as Kusum or Kardi. Safflower is a member of the family Compositae and originally grown for the flowers that were used in making red and yellow dyes. Planting date is very important in agricultural production management decisions, especially at region having environmental restrictions such as sooner or later coldness or serves (Emami *et al.*, 2011). Cultivar selection is also a key management component in any cropping system even more critical in sowing date for crop production (Soleymani *et al.*, 2011). All the varieties may not be suitable for timely as well as the late sowing. The differences in production of timely sown and late sown crops may be attributed to the unfavourable temperature prevailing at different growth stages, such as low temperature at the time of germination which may delay crop emergence. It was reported that the sowing date and cultivars of safflower vary depending on ecological conditions (Daltalab *et. al.* 2013). Therefore, in order to obtain safflower with high yield and quality, it is essential to determine the suitable growth conditions and cultivation techniques. So the aim of this study was to evaluate the 'Yield and yield attributes of safflower cultivars as affected by sowing dates'.

METHODOLGY

An experiment was conducted during the year 2013–14 under All India Coordinated Research Project on safflower, at RVSKVV, College of Agriculture, Indore (Madhya Pradesh). A set of 9 treatment combinations comprising 3 dates of sowing (1^{st} November, 15^{th} November, 30^{th} November) as main plots and 3 cultivars (A-1, NARI-6, NARI-57) as subplots laid out in split plot design with 4 replication. The soil of experimental field was a typical medium black soil (vertisol), soil pH 8.2, EC (0.432 ds/m), low in organic (0.36%), medium in available Nitrogen (235 kg/ha) and available phosphorus (14.9 kg/ha but high in available potash (411 kg/ha). Seeds were used with 20 kg/ha With Planting geometry (R × P) 45 × 20 cm. The recommended dose of fertilizer (60 N + 40 P_2O_5 + 20 K_2O kg/ha) was applied in safflower. Harvest operation done manually. Studied attributes that selected using 5 plants randomized in each plot. The data was analyzed by the method of "Analysis of Variance" as described by Panse and Sukhatme 1985.

RESULTS

The data showed in Table 1, indicated that the Sowing date and cultivars had significant effect on yield and yield attributing characters. It was observed that sowing of safflower on 1^{st} November recorded significantly higher Yield attributing characters viz. number of capitula/plant (26.21), weight of capitula (78.60 g/plant), Number of seeds/ capitula (22.21), 100 seed weight (6.20 g) as compared to 15^{th} November and 30^{th} November respectively. Increase in different yield attributing characters in 1^{st} November sowing might be due to more availability of favorable environmental condition at the vegetative and reproductive phase of the crop and might be due to better uptake of nutrients and translocation of photosynthates during the reproductive phase of the crop, thus increasing the size and weight of seeds. Similar result was found by Emami *et al.*, 2011 and Odivi *et al.*, 2013 reported that delay in sowing resulted generally decrease in the yield attributes. Among the cultivars of safflower, A-1 had significantly higher yield attributing characters, viz. capitula/plant (27.21), weight of capitula (96.72 g/plant), and 100 seed weight (6.55 g) over NARI-57 and NARI-6. The variation in these yield attributing parameters of the cultivars might be related to inherent differences and high vigour in these cultivars. Similar results were reported by Ali Reza Badri *et al.*, 2011.

The data presented in Table 1, indicated that highest seed yield (1,701 kg/ha), straw yield (5,683 kg/ ha) and oil yield (484 kg/ha) was obtained under 1^{st} November sown crop, which was significantly higher over 15^{th} November and 30^{th} November sown crop. The positive effect of date of sowing on straw yield may be due to the pronounced growth during early stages of crop. Similar result was noted by Odivi *et al.*, 2013. Among the cultivars of safflower, A-1 gave the highest seed yield (1,700 kg/ha), straw yield (5,535 kg/ha) and oil yield (416 kg/ha) as compared to NARI-57 and NARI-6. Similar results were reported by Muralidharudu *et al.*, 1989, Hulihalli *et al.*, 1997. The findings are in close confirmity with Sheykhlou *et al.* (2012).

Table 1. Mean comparison for experimental characteristics

Treatments		Number of capitula/ plant	Weight of capitula (g/plant)	Number of seeds/capitula	100-seed weight (g)	Seed yield (kg/ha)	Straw yield (kg/ha)	Oil yield (kg/ha)
Sowing dates	1 November	26.21	78.60	22.21	6.20	1701	5683	484
	15 November	23.92	69.27	20.25	5.49	1314	4787	345
	30 November	20.79	58.83	19.54	5.22	1041	4260	248
	SEm	0.48	2.01	0.21	0.05	11.58	48.55	3.00
	CD (P=0.05)	1.65	6.97	0.74	0.18	40.07	168.02	10.38
	A-1	27.21	96.72	19.67	6.55	1700	5535	416
Cultivars	NARI-6	19.25	52.48	21.92	4.80	1022	4429	276
	NARI-57	24.46	57.51	20.42	5.56	1333	4767	384
	SEm	0.33	1.28	0.18	0.05	8.37	34.56	2.32
	CD (P=0.05)	0.99	3.79	0.52	0.15	24.87	102.67	6.90

CONCLUSION

The experiment was conducted at different cultivar at different sowing date. The results indicated significant differences among different sowing dates and cultivars for seed yield, straw yield and oil yield with the highest from crop grown on 1st November. This is probably due to different moisture and temperature conditions at sowing and seed development stage. As a result of this study, it was concluded that sowing date affected seed and oil yield of safflower. Delayed sowing date decreased seed and oil yield per unit of area. By planting safflower earlier, plants are able to get the full benefit of soil moisture and nutrients during the extended growing season, allowing more total seeds capitula-1 to form because of sufficient time to fill. Consequently, among the cultivars, A-1 proved to be the most suitable in the maximum seed and oil yield. Therefore, it can be recommended to cultivate safflower cultivar A-1 sown in 1st November for higher seed and oil yield in safflower production in Madhya Pradesh.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Planting geometry influence on yield and economics of baby corn (*Zea mays*) varieties

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Among the different kinds of corn, baby corn is a delicious and nutritive vegetable and is consumed as a natural food. It is a specialty corn that provides carbohydrates, proteins, fats, sugars, minerals and vitamins in palatable and digestible form.The earliness facilitates crop diversification, increases overall cropping intensity in a year and enhances profitability.Identification of high yielding variety is the most vital agronomic input as the entire cob is harvested as one baby corn. Slender and upright varieties that can easily fit in narrow row spacing and can yield number of cobs per plant is suitable for the cultivation of baby corn. However, the full potentiality of a variety could be exploited only when they grow under optimum planting geometry (Shobhana *et al*., 2012). Hence, the present investigation was taken up to study the influence of planting geometry on yield and economics of baby corn varieties.

Table 1. Yield and economics of baby corn varieties as influenced by planting geometries

Treatment	Cob yield (kg/ha)	Corn yield (kg/ha)	Cost of cultivation (₹/ha)	Gross returns (₹/ha)	Net returns (₹/ha)	B:C ratio
Variety (V)						
'30V92'	4,310	1,774	43,621	1,13,083	69,463	2.58
'Seed Tech-740'	4,112	1,637	38,373	1,07,037	68,665	2.78
'VL-42'	5,997	2,421	46,003	1,53,953	1,07,951	3.34
CD (P=0.05)	130	84	–	–	2,831	–
Planting geometry (P)						
45 cm × 15 cm	5,296	2,193	43,165	1,33,754	94,389	3.17
45 × 20 cm	4,497	1,799	42,071	1,16,097	74,026	2.75
60 × 10 cm	5,005	1,980	43,355	1,31,102	87,748	3.01
60 cm × 15 cm	4,426	1,768	42,071	1,14,010	71,939	2.69
CD (P=0.05)	135	89	–	–	2,847	–

METHODOLOGY

A field experiment was conducted during *rabi* 2014–15 at the College farm, College of Agriculture, Rajendranagar, Hyderabad, Telangana. The experiment was laid out in a randomized block design with factorial concept. Three varieties ('30V92', 'Seed Tech-740' and 'VL-42') along with four planting geometries (45 cm × 15 cm, 45 × 20 cm, 60 × 10 cm and 60 cm × 15 cm) were accommodated and replicated thrice. Tassels were removed from all the plants as and when emerged. The cobs were harvested at green stage within 2–3 days of silking. Harvesting of 30V92 and Seed Tech-740 started at 76 and 75 DAS respectively and finished in 3 pickings whereas for VL-42 harvesting started at 55 DAS and finished in 5 pickings. Observations were analysed by standard statistical procedure.

RESULTS

Cob and corn yield differed significantly among the three varieties. Higher yields were observed in 'VL-42' followed by '30V92' and 'Seed Tech-740'. The increase in corn yield in VL-42 over 30V92 and Seed Tech-740 was 36 and 27% respectively. Variation in yield among the varieties was due to significant differences in the number of cobs/plant. 'VL-42' had significantly higher number of cobs/plant (3) which resulted in higher yield. The cost of cultivation was highest for 'VL-42' followed by '30V92' whereas it was lowest for 'Seed Tech-740'. Gross returns were higher in 'VL-42' followed by '30V92' and 'Seed Tech-740'. Net returns were significantly higher in 'VL-42' but 'Seed Tech-740' gave lower net returns which were on par with '30V92'. Benefit cost ratio was highest in 'VL-42' followed by 'Seed Tech-740' whereas lowest benefit-cost ratio was observed in '30V92'.Varying planting geometry showed marked differences in yield of baby corn. Planting geometry of 45 cm × 15 cm with 1, 48,148 plants/ha gave significantly higher cob and corn yield followed by 60 × 10 cm with 1,66,666 plants/ha. The lower yield was observed with 60 cm × 15 cm which was on par with 45 × 20 cm with the same plant population of 1,11,111/ha. The increase in plant density from 1,48,148 /ha to 1,66,666 /ha drastically decreased the cob and corn weight/plant because of acute competition for growth factors that even increased plant population could not compensate the loss in cob and corn yield. Net returns were significantly higher with the planting geometry 45 cm × 15 cm whereas 60 cm × 15 cm gave significantly lower net returns. Maximum benefit-cost ratio was recorded with 45 cm × 15 cm whereas it was minimum with 60 cm × 15 cm. Significantly higher net returns and benefit-cost ratio with the planting geometry of 45 cm × 15 cm having plant population of 1, 48,148/ha was due to higher cob yield than other planting geometries.

CONCLUSION

The results showed that higher cob, corn yield and net returns were obtained from 'VL-42' with a spacing of 45 cm × 15 cm whereas significantly lower net returns were obtained from 'Seed Tech-740' with the planting geometry of 60 cm × 15 cm. Thus, baby corn variety 'VL-42' under optimum planting geometry of 45 cm × 15 cm is a viable option for crop diversification in peri-urban areas.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Influence of weather parameters on fresh fruit bunch yield of oil palm (*Elaeis guineensis* Jacq.)

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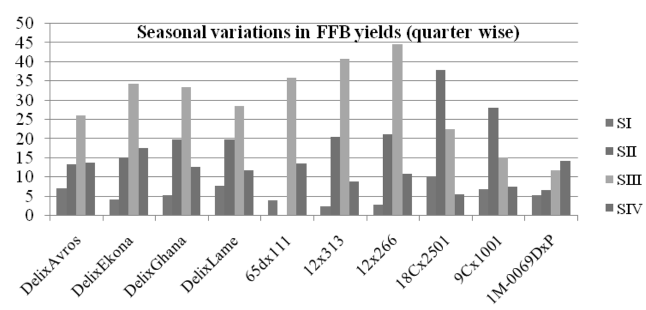
Oil palm is a viable option for meeting vegetable oil demand of India as well as the world due to its high oil yield potential (up to 11–18 t oil per ha) and continuous yielding nature for about 25–30 years. In India, oil palm is generally grown under irrigated conditions except in few pockets of Kerala, Andaman and north eastern states where it is grown as a rainfed crop. This being a humid tropical crop requires high amounts of water, temperature and relative humidity. Even under irrigated conditions, the fresh fruit bunch (FFB) yield appears to get influenced by prevailing climatic conditions as there are variations in FFB number and weight in different seasons of the year. Further, the recorded yields were found lower in the years when normal or even above normal rainfall was received. In order to understand the impact of rainfall and temperature on FFB yield, the FFB yield data recorded in a genetics trial with ten tenera hybrids was analysed and conclusions were drawn. The objectives were: to establish the influence of weather parameters on FFB yield of oil palm under irrigated conditions and to find out the reasons for seasonal variation in FFB yields of oil palm.

METHODOLOGY

The data on fresh fruit bunch (FFB) yield of 10 oil palm tenera hybrids (Deli × Avros, Deli × Ekona, Deli × Ghana, Deli × Lame, 65D × 111, 12 × 313, 12 × 266, 18C × 2501, 9C × 1001 and 1M-0069 D × P) planted in the year 2000 under irrigated conditions at ICAR-IIOPR was analysed for a period of 6 years (2004–09) and it was correlated with the weather parameters of the location. The quarter wise yield pattern was analysed to check whether there is any correlation between weather parameters and yield under irrigated conditions. Then Pearson's correlation coefficients were calculated for FFB yield with rainfall and maximum temperature existed in the current month, 12, 18, 24, 36 and 48 months before harvest of FFB.

RESULTS

In general, FFB yields were found higher (29.2 kg/palm on average) during third quarter of the year (July–September) when the rainfall received was high as it coincides with the south west monsoon period. Very low yields (5.6 kg) were recorded in the first quarter of the year (January to March) irrespective of the cross combination when the maximum temperature was low compared to other three quarters (Fig. 1). Water stress declines FFB yield through inflorescence abortion and a lower sex ratio, both leading to lower bunch number (Corley and Tinker, 2003; Turner, 1976). This indicates that even under irrigated conditions rainfall has got a positive impact on FFB yield of oil palm. In Malaysia 12–24% variation in oil yield of oil palm was attributed to rainfall (Chow Chee Sing, 1992). Correlations with weather data revealed that rainfall and maximum temperature prevailing at 24 months before harvest have got a high degree of correlation with FFB yields (Table 1 and 2). Female sex ratio is very important in oil palm for harvesting high FFB yields. Broekmans (1957) reported that the sex differentiation takes place 18 to 24 months before harvest. Sex ratio is reported to be highly correlated with environmental factors especially water, sunshine and other good growing conditions (Williams and Thomas, 1970). The weather conditions which affect earlier phases of inflorescence and flowering which coincides with flower primordial differentiation are reflected in the yields only 18-24 months afterwards. Turner (1976) reported that the reduction in bunch number probably could be due to the inflorescences primordium which tends to differentiate into male inflorescences at 20-24 months before harvest, as male



[SI: First quarter (Jan–Mar), SII: Second quarter (Apr-Jun), SIII: Third quarter (Jul–Sep), SIV: Fourth quarter (Oct–Dec)]

Fig. 1. Fresh fruit bunch yields in different seasons

Table 1. Pearson's correlation coefficients between rainfall and FFB yield

Particular	Deli × Avros	Deli × E kona	Deli × Ghana	Deli × Lame	65d × 111	12 × 313	12 × 266	18C × 2501	9C × 1001	1M-0069 D × P
Monthly RF	0.539	0.605	0.606	0.515	0.616	0.534	0.695	0.156	0.157	0.664
12 Months before RF	0.377	0.584	0.544	0.484	0.633	0.453	0.642	0.054	0.113	0.627
18 Months before RF	–0.352	–0.454	–0.489	–0.321	–0.510	–0.289	–0.584	–0.071	–0.131	–0.451
24 Months before RF	0.585	0.685	0.638	0.566	0.730	0.632	0.720	0.166	0.276	0.718
36 Months before RF	0.370	0.573	0.521	0.450	0.585	0.347	0.600	–0.033	0.040	0.562
48 Months before	0.487	0.651	0.600	0.597	0.705	0.541	0.710	0.009	0.133	0.701

Table 2. Pearson correlation coefficients between Max T and FFB yield

Particular	Deli × Avros	Deli × E kona	Deli × Ghana	Deli × Lame	65d × 111	12 × 313	12 × 266	18C × 2501	9C × 1001	1M-0069 D × P
Monthly av	0.158	–0.311	0.437	0.352	0.379	0.345	0.365	0.831	0.876	0.144
24 months before	0.773	0.777	0.771	0.820	0.801	0.812	0.803	0.573	0.726	0.786
36 Months before	–0.034	0.3772	0.388	0.429	0.308	0.432	0.404	0.703	0.742	0.177
48 Months before	–0.194	0.079	0.197	–0.102	0.340	0.365	0.442	0.697	0.778	0.034

inflorescences require less nutrition to develop.

CONCLUSION

The FFB yield of oil palm is higher during south west monsoon period coinciding with the third quarter of the year (July–Sep). Fresh fruit bunch yield of oil palm is influenced by rainfall and maximum temperature even under irrigated conditions. The weather conditions especially rainfall and temperature prevailing at 24 months before harvest of FFBs are influencing the yield as the sex differentiation takes place at this stage and thereby affecting the yield.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

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 to 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 1,000-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; 1,000-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, 1,000-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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Effect of date of sowing, varieties and stage of harvesting on yield and quality of barley (*Hordeum vulgare*) fodder

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The field experiment was carried out during 2013–15 at Research Farm of Forage Research and Management Centre, National Dairy Research Institute (NDRI), Karnal to assess the yield and quality of barley fodder. The experiment was laid out in split-plot design with four treatment of date of sowing (21st October, 31st October, 10th November and 20th November) in main plots, three varieties (RD-2552, RD-2035 and RD-2715) in sub plots and three stage of harvesting (45 DAS, 55 DAS and 65 DAS) in sub-sub plots with three replications in total 108 numbers of plots. The results were revealed on the basis of pooled data for two years. The highest green fodder yield (17.60 t/ha) and dry matter yield (2.06 t/ ha) was obtained from variety RD 2715 sown on 10th November at the harvesting of 65 DAS (days after sowing). The variety RD 2715 produced higher fodder yield, i.e. 10.5% over to variety RD 2035 and 15.34% over to variety RD 2552. The variety RD 2552 produced green fodder yield of 14.90 t/ha and highest grain yield (3.66 t/ha) and straw yield (5.01 t/ha) when sown at first date of sowing, i.e. 21st October with harvesting of 45 DAS for green fodder purpose all three varieties differed significantly with the RD 2035 variety. Sowing between 21st October to 10th November was found to be the ideal time for dual purpose barley for production of higher fodder, grain and straw. The performance of variety RD 2552 in terms of green fodder as well as grain production was found to be superior to other varieties. Harvesting of crop at 65 DAS resulted in highest green fodder yield, dry matter yield, plant height, ADF, NDF and hemicelluloses while harvesting at 45 DAS showed highest grain yield, straw yield test weight, leaf: stem ratio, crude protein and ether extract. Harvesting barley for fodder and leaving for the re-growth for grain production will help in getting green fodder during the period of fodder scarcity and increasing the productivity without sacrificing its grain yield.

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Performance of lentil (*Lens culinaris*) varieties as affected by different seed rates under rice (*Oryza sativa*) *utera* conditions

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In Assam, winter rice (*Oryza sativa* L.) is the main crop occupying about 19 lakh ha (2014–15). Out of it, 50% area is medium land, 35% is low land and 15% is very low land. The medium and low land situations have both medium and heavy textured soil while very low lands are mostly heavy textured soil. In medium and low land situations, about 10 lakh ha have medium textured soil which are suitable for *rabi* pulses. Out of this 10 lakh ha, about 6.5 lakh ha remain fallow during *rabi* season. At the same time, the domestic pulse production can meet only 32% of the pulse requirement (3.78 lakh t) of the state. Therefore, horizontal expansion is one of the viable strategies for increasing pulse production.

As the Assamese people consume maximum of lentil (*Lens culinaris* Medik.), the state has to put emphasis on its production. This crop is a viable option for cultivation in medium textured medium rice-fallows. Gupta and Bhowmick (2005) from West Bengal, India and Islam *et al*. (2015) from Bangladesh reported lentil's suitability and scope for growing in rice-fallows both under sequential cropping and *utera* cultivation. Lentil varieties show wide variation with respect to their productivity and adaptability under rice *utera* conditions. In such situation, another important factor governing success of a relay crop is plant stand per unit area. So, the present investigation was planned and executed to find out suitable lentil variety with optimum seed rate for rice relay cropping system.

METHODOLOGY

The field trial was conducted at Shillongani, Assam during *rabi* 2012–13, 2013–14 and 2014–15. The rice variety 'Ranjit' was transplanted in second week of the July and harvested (at 30 cm above ground level) in fourth week of November. There were 3 varieties of lentil, viz.'HUL57', 'KLS 218' and 'PL 406' and two seed rates (37.5 and 45 kg/ha). For a pure crop of lentil, the state recommendation of seed rate is 30 kg/ha. The combination of variety and seed rate were tested in a randomized block design with 4 replications. The *Rhizobium* and PSB(each @ 50 g/kg seed) inoculated seeds were broadcast 12–17 days after 50% flowering of rice crop (in second week of November) when soil was in moist conditions (at or just above field capacity; field capacity of the concerned soil was 23.60%). Plant stand was recorded at 30 days after sowing(DAS), soil moisture at 30, 60 and 90 DAS and soil microbial population (fungi & bacteria) was determined at lentil sowing and harvest. The generated technology then tested in farmer's fields through Krishi Vigyan Kendra (KVK) in 4 districts (Nagaon, Jorhat, Darrang and Chirrang) of Assam against farmer's practice during *rabi* 2015–16.

RESULTS

Pooled analysis showed that the highest grain yield was recorded under lentil variety 'HUL 57' (Table 1). This might be attributed to better adaptability of this variety in rice-*utera* conditions as reflected by considerably higher plant stand in comparison to the other two varieties. The seed rate of 45 kg/ha (805.44 kg/ha) accrued in significantly higher grain yield than 37.5 kg/ha (587.62 kg/ha). The variety 'HUL 57' when sown using a seed rate of 45 kg/ha (897.57 kg/ha) significantly out yielded all other treatment combinations.In all the years, soil moisture conservation was better under 'HUL 57' grown with 45 kg/ha seed rate. Higher plant stand

Table 1. Grain yield (kg/ha) (pooled data of 3 years)

Variety	Seed rate (kg/ha)		Mean
	37.5	45.0	
PL 406	512.64	731.39	622.01
HUL 57	659.03	897.57	778.30
KLS 218	591.18	787.36	689.27
Mean	587.62	805.44	
CD (P= 0.05)	Variety	31.3	
	Seed rate	25.56	
	Interaction	44.27	

Table 2. Economics of different treatment combinations

Treatment	GR (₹)	Cost (₹)	NR (₹)	B:C
PL 406 (37.5)*	33322	14237	19085	1.34
PL 406(45)	45540	15062	30478	2.02
HUL 57 (37.5)	42837	14237	26600	2.00
HUL 57 (45)	58342	15062	43280	2.87
KLS 218 (37.5)	38427	14237	24190	1.69
KLS 218 (45)	51178	15062	36116	2.39

*Figures in parentheses alongside variety represent seed rate.

and better soil moisture conservation under this treatment combination led to considerable increase in soil microbial (both fungi and bacteria) population at harvest. The highest net return (₹ 43,280) and benefit : cost ratio (2.87) were also recorded under thiscombination (Table 2). This technology under on-farm testing through KVK resulted in 40–50% yield increase over farmer's practice (local variety with 30 kg/ha seed rate).

CONCLUSION

There is a vast scope for lentil cultivation in medium textured winter rice lands of Assam. The lentil variety 'HUL 57' with 45 kg/ha seed rate maintains or improves soil environment and at the same time ensures higher productivity showing its better adaptability under rice-*utera* conditions along with positioning itself in aneconomically advantageous state.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Use of plant growth regulators for enhanced growth and yield of sugarcane (*Saccharum* species hybrid complex)

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Sugarcane is one of the most important field crops grown in the tropics and sub-tropics. The productivity of sugarcane in sub-tropical region is far below as compared to tropical region. Extremes of climate and use of sub-optimal agro-technologies are mainly responsible for low sugarcane productivity in sub-tropical India, where 60–70% of millable canes are comprised of tillers, whereas in tropical parts of the country only 20–30% of millable canes are formed from tillers. This may be one of the major reasons for lower yield under sub-tropical regions than the tropical part of the country. Higher sugarcane yield can be achieved by increasing the number of mother shoots instead of tillers (Chand *et al.,* 2011) and higher mother shoots can be achievable by increasing the germination percentage. Almubarak *et al.* (2012) achieved highest cane height with the application of gibbrellic acid. In the light of above, the present study was undertaken to find out the suitability of plant growth regulators for enhancing the germination, growth and yield of sugarcane in sub-tropical condition.

METHODOLOGY

A field experiment was conducted during the spring season of 2015–16 at Sugarcane Research Institute farm, Pusa, Bihar. The soil was sandy loam, having 8.2 pH, 0.48% OC, 25.8% free $CaCO_3$, 1.48 g/cc bulk density and low in available N (221 kg/ha), medium in available P (10 kg/ha) and low in available K (105 kg/ha). Eight treatments, viz. T_1, Conventional planting/farmers practice (03-bud setts); T_2, Planting of setts after overnight soaking in water; T_3, Planting of setts after overnight soaking in 50 ppm ethephon solution; T_4, Planting of setts after overnight soaking in 100 ppm ethephon solution; T_5, T_1+ GA_3 spray @ 35 ppm at 90, 120 and 150 DAP; T_6, T_2 + GA_3 spray @ 35 ppm at 90, 120 and 150 DAP; T_7, T_3 + GA_3 spray @ 35 ppm at 90, 120 and 150 DAP; and T_8, T_4 + GA_3 spray @ 35 ppm at 90, 120 and 150 DAP were arranged in randomized block design with 3 replications. The crop was uniformly fertilized with 150 kg N, 37.1 kg P and 49.8 kg K/ha. Half of the recommended dose of nitrogen and full dose of phosphorus and potassium was applied basal and remaining half of the nitrogen was applied in two equal splits after first irrigation and at the time of earthing up. Sugarcane variety 'BO 153' was planted on 01 April 2015 with a row spacing of 90 cm. Germination count was recorded from 20 DAP to 50 DAP. Plant population was counted at 120 DAP. Whole cane samples were taken at the time of harvest and analysed for sucrose (%) juice (Spencer and Meade, 1955). The total amount of rainfall received during the crop season was 899 mm. Sugarcane was harvested on 10 February 2016.

RESULTS

The different treatments had significant impact on germination, plant population, millable canes and cane yield while, the effect on plant height and sucrose content juice were non-significant (Table 1). Results clearly showed that highest germination percentage at 20, 30, 40 and 50 DAP were recorded from planting of setts after overnight soaking in 50 ppm ethephon solution which was significantly higher over conventional planting/farmers practice (3-bud setts) and planting of setts after overnight soaking in water except at 30 DAP, where planting of setts after overnight soaking in water was statistically comparable to plating of setts after overnight soaking in 50 ppm ethephon solution (Table 1). It was due to favourable condition for germination under ethephon treatment. Planting of setts after overnight soaking in 50 ppm ethephon solution + GA_3 spray @ 35 ppm at 90, 120 and 150 DAP recorded significantly higher plant population (228,700/ha) of sugarcane than conventional planting/farmers practice + GA_3 spray @ 35 ppm at 90, 120 and 150 DAP (162,300/ha) and conventional planting/farmers practice (159,500/ha) but remained at par with others. However, the mean plant height in different treatments ranged from 272 to 320 cm. Highest millable canes (156,600/ha) were recoded with the planting of setts after overnight soaking in 50 ppm ethephon solution + GA_3 spray @ 35 ppm at 90, 120 and 150 DAP, being significantly higher over planting of setts after overnight soaking in water + GA_3 spray @ 35 ppm at 90, 120 and 150 DAP, planting of setts after overnight soaking in water, conventional planting + GA_3 spray @ 35 ppm at 90, 120 and 150 DAP and conventional planning/farmers practice, but it remained statistically at par with rest of the treatments. The improvement in millable canes with

Table 1. Effect of plant growth regulators on growth, yield and quality of sugarcane

Treatment		Germination (%)				Plant population ($\times 10^3$/ha)	Plant height (cm) at harvest	Millable canes ($\times 10^3$/ha)	Cane yield (t/ha)	Sucrose (%)
		20 DAP	30 DAP	40 DAP	50 DAP	120 DAP				
T_1	Conventional planting/ Farmers practice (3-bud setts)	3.2	15.7	20.0	29.0	159.5	272	118.6	80.5	17.01
T_2	Planting of setts after overnight soaking in water	9.8	20.0	23.7	37.0	197.2	275	128.6	88.2	17.07
T_3	Planting of setts after overnight soaking in 50 ppm ethephon solution	13.5	22.8	28.5	50.1	220.3	290	147.2	91.3	17.58
T_4	Planting of setts after overnight soaking in 100 ppm ethephon solution	11.1	21.5	26.3	45.0	220.0	281	145.0	90.9	16.81
T_5	T1+GA3 spray @ 35 ppm at 90, 120 and 150 DAP	3.1	16.0	20.6	28.6	162.3	278	120.8	87.2	17.00
T_6	T2+GA3 spray @ 35 ppm at 90, 120 and 150 DAP	9.8	20.8	23.9	36.4	201.6	288	130.3	95.7	17.11
T_7	T3+GA3 spray @ 35 ppm at 90, 120 and 150 DAP	13.4	19.4	27.1	45.7	228.7	320	156.6	103.2	16.98
T_8	T4+GA3 spray @ 35 ppm at 90, 120 and 150 DAP	12.7	21.5	26.9	45.3	227.5	308	149.1	99.4	16.90
SEm±		0.76	1.40	1.50	2.60	11.48	13.5	7.80	3.95	0.38
CD (P=0.05)		2.3	4.3	4.6	8.1	34.8	NS	23.9	12.0	NS

ethephon treatment was mainly due to variation in germination and plant population. Similarly, the higher cane yield (103.2 t/ha) was produced with the planting of setts after overnight soaking in 50 ppm ethephon solution combined with GA_3 spray @ 35 ppm at 90, 120 and 150 DAP was statistically at par with planting of setts after overnight soaking in 100 ppm ethephon solution + GA_3 spray @ 35 ppm at 90, 120 and 150 DAP, planting of setts after overnight soaking in water + GA_3 spray @ 35 ppm at 90, 120 and 150 DAP and planting of setts after overnight soaking in 50 ppm ethephon solution, but was significantly superior over others. The magnitude of significant increase in cane yield with planting of setts after overnight soaking in 50 ppm ethephon solution + GA_3 spray @ 35 ppm at 90, 120 and 150 DAP was 28.2% over the conventional planting/farmers practice. Increase in cane yield might be owing to improvement in growth and yield attributes, which might have increased tonnage. However, the mean sucrose content in juice ranged from 16.81 to 17.58%.

CONCLUSION

The results showed that planting of setts after overnight soaking in 50 ppm ethephon solution + GA_3 spray @ 35 ppm at 90, 120 and 150 DAP may be used for getting higher growth and yield of sugarcane in the region.

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Influence of time of planting and method of curing on quality parameters and nutrient uptake in oriental tobacco (*Nicotiana tabacum*)

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Tobacco is an important non-food commercial crop and plays a major role in world's economy. It is valued in the world trade mainly for leaf. In the face of mounting evidence on the health hazards of tobacco the consumption is not reduced and it is one of the important sources to country's economy. In recent past due to increased awareness and ill effects of smoking the consumer's preference has been shifted towards soft blended light type of cigarettes. Oriental tobacco is one such type of tobacco which is used as important component of the world's premium blended cigarettes characterised with small, aromatic, flavourful, readily combustible and has good filling properties. Oriental tobacco is a low input requiring, labour intensive and remunerative crop under rainfed conditions. As the crop is grown under rainfed conditions, time of planting with suitable method of curing plays a significant role to get good yield and better quality of leaf. The lowest nicotine content and highest total sugars were recorded in the tobacco planted during October first fortnight which was comparable with the crop planted during October second fortnight. The highest nicotine and lowest amount of total sugars were found in the crop planted during November second fortnight. Curing of primed leaves under 25% ventilated polyhouse curing method recorded the highest amount of total sugars and lowest nicotine content. Open rack sun curing method recorded the highest nicotine content and lowest total sugars. Among the treatmental combinations the highest amount of total sugars and lowest nicotine content was recorded in the crop planted during October first fortnight cured with 25% ventilated polyhouse curing which were comparable with planting of crop during October second fortnight curing under same method. Potassium being an important parameter in improving the burning quality of leaf its content in leaf plays a major role in promoting fire holding capacity of tobacco leaf. The highest potassium content was found in the crop planted during second fortnight of October cured under 25% ventilated polyhouse curing method. The lowest potassium content was found in the crop planted during second fortnight of November cured under Open rack curing method. The planting time significantly influences the nutrient uptake in oriental tobacco. The highest nitrogen, phosphorus and potassium uptake was observed in the crop planted during second fortnight of October which was higher than the other dates of planting. The lowest nutrient uptake was observed in the crop planted during second fortnight of November is due to lower dry matter per unit area coupled with lower nutrient content. The study revealed that planting of oriental tobacco during October second fortnight with 25% ventilated polyhouse curing has resulted in superior quality and higher net returns.

Table 1. Total nitrogen, phosphorus and potassium uptake (kg/ha) at harvest by oriental tobacco as influenced by time of planting

Time of planting	Crop uptake (kg/ha)		
	Nitrogen	Phosphorus	Potassium
I FN Oct	75.7	17.0	57.2
II FN Oct	87.9	19.5	64.0
I FN Nov	56.1	12.1	27.2
II FN Nov	48.2	10.6	20.9

Table 2. Influence of time of planting and method of curing on nicotine content, total sugars and potassium content (%) in Oriental tobacco

Treatment	Nicotine content	Total sugars	Potassium content
Time of planting			
I FN Oct	0.83	20.01	0.94
II FN Oct	0.90	19.52	1.04
I FN Nov	1.22	16.60	0.75
II FN Nov	1.63	14.84	0.60
SEm±	0.32	0.170	0.012
CD (P=0.05)	0.10	0.51	0.03
Curing			
Open sun	1.25	16.19	0.79
25% vent.	0.99	19.55	0.88
50% vent.	1.22	17.49	0.84
SEm±	0.028	0.120	0.010
Time of planting × Curing			
CD (P=0.05)	0.08	0.34	0.03
SEm±	0.056	0.230	0.020
CD (P=0.05)	0.19	0.81	0.07

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Effect of NAA, 2-4-D and KNO_3 on flower drop, fruit setting and yield of Soybean (*Glycine max* L.) under mid hill conditions of Uttarakhand

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Soybean (*Glycine max* L.) is the leading oil seed crop of the world in terms of both area and production. In the recent years, Soybean has become an important crop in India since it yields oil, protein and also other industrial products yielding crop. Growth regulators are reported to have an effect on morphological parameters of soybean (Senthil, 2003). Yield potential of pulses is greatly affected by non-leaf synchronous habit, flower drop, nodule disintegration at the time of flowering, heavy senescence at the time of pod development, excessive vegetative growth in response to excessive irrigation and less fruit setting in lower branches of the plant (Sinha, 1974; Chaturvedi *et al.*, 1980). Growth regulators are effective in several crops and found to balance the source and sink relationship, leading to increase in the yield of crops (Cheema *et al.*, 1987). Plant growth regulators are found to enhance growth and physiological activity of the plant (Reena *et al.*, 1998).

Exogenous application of growth regulators is one approach to improve crop productivity (Pando and Srivastava, 1985). Plant growth regulators play an important role in circumventing limitation to improve production. According to Basole *et al.* (2003) the yield of soybean can be enhanced through physiological growth manipulation by way of foliar application of growth regulators like NAA and nutrients like KNO_3, $ZnSO_4$. The foliar application of nutrients and hormones to certain extent can help in making available the required nutrients to crop for optimum growth and productivity under adverse conditions of soil. The pulse and oil seed crop yields are very poor and this discourages the wide cultivation of it. The plant normally produces large number of flowers but most of them abscise and fruit setting is controlled by many factors. So the use of growth regulators proved better to increase the yield. In the present experiment the effect of growth regulators NAA, 2, 4-D and nutrient KNO_3 were investigated on flower drop ,fruit setting and yield of Soybean (*Glycine max* L.) under mid hill conditions Uttarakhand during kharif season 2015 .

METHODOLOGY

The pot experiment was conducted to see the effect of growth regulators on flower drop, fruit setting, and yield of Soybean (*Glycine max* L.) under mid hill conditions Uttarakhand during kharif season 2015. The pot experiment was laid out in Complete Randomized Design with three replication. The experimental variable consisted of ten treatments having one main crop of Soybean as control (T_1- control, T_2- NAA-10 ppm, T_3- NAA-20 ppm, T_4- NAA-30 ppm, T_5- 2-4-D-10 ppm, T_6- 2-4-D-20 ppm, T_7- 2-4-D-30 ppm, T_8- KNO_3-100 ppm, T_9- KNO_3-200 ppm, T_{10}- KNO_3-300 ppm. The pot soil in the ratio of 20 : 40 : 40 was fertilized with nutrients like N : P : K. The variety Pant Soybean-1092 (*Glycine max L.*) was used in this experiment. The plant was sprayed with different concentrations of growth regulators about one week earlier to bud initiation. The second spraying was done at the stage of 50 per cent flowering. The number of flowers/plant were counted after 5 days of first and second spray of bio regulators.

The yield and yield contributing characters were recorded after harvesting of the crop. Samples comprising of 1,000-grains were drawn irrespective of shape and size from the produce of each pot and weight. Weight of 1,000-grains was recorded. The total seed yield was separately weighted (g/plant) to obtain the grain yield per plant.

RESULTS

Table 1 shows that early flowering was achieved by the application of growth regulators. The treatment 20 ppm (T_3) of NAA hastened the flowering effectively as compared to other treatments followed by 10 (T_2) and 30 ppm (T_4) of NAA. These NAA treatments were in turn followed by 2, 4-D-20 (T_6), 10 (T_5) and 30 ppm (T_7) and KNO_3-200 (T_9), 100 (T_8) and 300 ppm (T_{10}). Maximum days to 50 and 100 per cent flowering were observed in control. Upadhyay, (2002) observed the same findings with the application of NAA @ 20 ppm which showed significant early flowering over control. Earliness of flowering is desirable feature to escape lower temperature at the time of maximum flowering. The results are supported by Leport *et al.* (1999) who suggested that early flowering would benefit yield if flowers were fertile, leading to early pod development and seed filling and thus, avoiding terminal soil moisture stress as in the case of chilling tolerant genotypes.

Table 1. Effect of NAA, 2-4-D and KNO_3 on flowering, fruit setting and yield of Soybean

Treatment	Days to 50% flowering	Days to 100% flowering	Number of flowers at 50% flowering	Number of flowers at 100% flowering	Number of shed flowers at 100% flowering	Test weight (g/plant)	Grain yield (g/plant)	Biological yield (g/plant)
T_1 (Control)	53.67	60.11	35.0	55.8	27.0	131.81	12.21	35.62
T_2 (NAA 10 ppm)	50.38	55.55	44.2	77.0	16.0	168.91	22.67	48.37
T_3 (NAA 20 ppm)	49.00	54.00	49.0	85.6	11.7	176.77	24.84	50.70
T_4 (NAA 30 ppm)	50.90	56.00	42.2	75.5	19.0	166.47	21.62	45.28
T_5 (2, 4-D 10 ppm)	51.21	56.08	40.4	72.6	18.1	164.87	20.33	42.96
T_6 (2, 4-D 20 ppm)	51.00	55.90	41.3	75.0	17.6	165.19	21.19	45.12
T_7 (2, 4-D 30 ppm)	51.66	57.33	40.0	70..0	19.5	161.37	19.20	41.43
T_8 (KNO_3 100 ppm)	52.00	58.66	39.5	65.0	23.8	145.69	15.63	40.69
T_9 (KNO_3 200 ppm)	51.00	57.30	39.9	69.0	23.0	148.69	18.62	42.82
T_{10} (KNO_3 300ppm)	52.50	59.00	39.1	63.0	21.2	143.57	14.60	38.41
CD at 5%	0.77	0.97	0.6	1.8	0.7	1.152	0.47	0.51

It is revealed from the Table 1, that number of flowers at 50 and 100 per cent flowering increased significantly by the application of growth regulators and KNO_3 as compared to control. Highest numbers of flowers were observed in pots treated with NAA 20 ppm (T_3) at 50 and 100 per cent flowering, respectively, while lowest numbers of flowers were obtained with control at 50 and 100 per cent flowering respectively. With respect to increase in number of flowers per plant, highest number were obtained in NAA treatments followed by 2, 4-D and KNO_3 treatments. They found that the foliar application of NAA (20 ppm) had significantly increased the total number of flowers formed per plant (75%) as compared to unsprayed plants.

Number of shed flowers at 100 per cent flowering were minimum in pots treated with NAA 20 ppm followed by 10 ppm of NAA (Table 2). Number of shed flowers were same in treatments NAA with 30 ppm concentration and 2, 4-D with 30 ppm concentration. Maximum flowers shedding were observed in control. Similar results were recorded by Upadhyay, 1994 that NAA prevents flower drop by preventing the formation of the abscission layer. Effectiveness of NAA to check the flower drop may be due to creation of favorable balance of endogenous hormone relative to flowering which inhibits abscission accelerating enzymes like cellulases, succinic dehdrogenases, RNAase, Malic dehydrogenases etc, Auxin induced nucleic acid synthesis to create better reproductive structure (Moore, 1980 and Addicot, 1977)

It is evident from the observations presented in the table 1 that the marked improvement was brought towards the test weight of soybean due to influence of growth regulators. The significantly highest 1,000-grain weight was recorded in the concentration of NAA 20 ppm followed by its remaining concentrations of 10 and 30 ppm which in turn were followed by all the concentration of 2, 4-D and KNO_3. Among treatment, lowest test weight was observed in control.

Economic yield markedly increased with the treatments of growth regulators (Table 1). The significantly highest grain yield was recorded in NAA 20 ppm while lowest was observed in control. The significantly highest grain yield were recorded in NAA (20, 10 and 30 ppm) followed by 2, 4-D (20,10 and 30 ppm) and KNO_3 (200, 100 and 300 ppm) treatments, respectively.

It is evident from the mean values in table- 1 that marked improvement was brought towards biological yield of Soybean due to influence of growth regulators. Maximum biological yield was obtained in pot treated with NAA concentration of 20 ppm followed by 10 and 30 ppm concentration of the same growth regulator which in turn were followed by 2,4-D (20, 10 and 30 ppm) and KNO_3 (200, 100 and 300 ppm) respectively. Minimum biological yield was observed in control. Thus form the above observations it appears that highest biological yield was recorded with all NAA treatments followed by 2,4-D treatments and KNO_3 Treatments.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Performance of maize hybrids under different planting methods

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Maize (*Zea mays* L) is one of the most versatile cereal crop having wider adaptability under diverse soil and climatic conditions. Maize is cultivated in all seasons, viz. *kharif, rabi* and spring. Today, it has become one of the leading food grain crop in many parts of the world, not only in tropical and subtropical areas but also in temperate and high hill ecologies (Kumar *et al.,* 2015). Replacement of common maize by quality protein maize (QPM) is the most effective and attractive measure to meet quality protein needs and to raise the human and nutritional status. QPM production in zero-tillage would help India become both 'Food secure' and 'Nutrition secure' (Jat *et al.,* 2007).

Interventions in the form of resource conservation technologies like zero-tillage and furrow irrigated raised bed system coupled with crop diversification by including maize in place of rice may be a viable option. Replacement of rice with less water requiring crops such as maize in the rice-wheat system and identiûcation of effective strategies for alternate tillage systems will promote sustainable cropping systems in the Indo-Gangetic Plain (Jat *et al*., 2013). In Haryana, a number of hybrids are available for cultivation and their suitability to different establishment methods, residue load and weed management practices may vary. So the present experiment was planned to evaluate the performance of different maize hybrids including QPM under different planting methods.

METHODOLOGY

To study the performance of different maize hybrids under different planting methods a field experiment was conducted at Regional Research Station, Uchani, Karnal of CCS Haryana Agricultural University, Hisar, Haryana (India) during *kharif* 2015. The experiment was laid out in split plot design with three replications. Main plot treatments comprised of four planting methods, viz. raised bed with residue, raised bed without residue, zero tillage with residue and zero tillage without residue. Three maize hybrids, viz. HQPM-1, HM-4 and HM-10 in combination with two weed control treatments, viz. atrazine 750 g/ha (pre-emergence) *fb* 1 hand weeding at 30 days after sowing (DAS) and unweeded check were arranged in sub-plots. The soil of the experimental field was clay loam in texture, medium in organic carbon, low in available nitrogen and medium in available phosphorus and available potassium and slightly alkaline in reaction (pH 8.4). Sowing in raised bed was done with bed planter, beds were first made with one pass of bed planter and then sowing of maize crop was accomplished with one row per bed (75 cm wide) on top of the beds. Sowing in zero-till plots was done with seed drill keeping row to row spacing of 75 × 20 cm in maize crop. On well prepared field, seeds of the maize hybrid, HQPM-1, HM-4 and HM-10 @ 20 kg/ha were sown by seed drill as per crop geometry on June 25, 2015. Harvesting of maize was done on September 29, 2015 from each plot manually and separately.

RESULTS

The results revealed that maize hybrids HM-10 recorded higher plant height, which were significantly superior to HM-4 and HQPM-1 at harvest. Higher leaf area index (LAI) at 60 DAS was recorded under HM-10 as compared to HM-4 and HQPM-1. Crop growth rate (CGR) at 60 DAS was recorded under HM-10 than HQPM-1 and HM-4. HM-10 recorded higher plant dry matter accumulation at harvest, which were significantly superior to HQPM-1 and HM-4.

The hybrid HM-4 provided maximum 100-grains weight and grain yield as compared to HM-10 and HQPM-1. It may be due to varietal variation in growth parameters and yield attributes of maize hybrids (Jat *et al*., 2007). However, among various planting methods zero tillage with residue recorded highest plant height, LAI, CGR, plant dry matter accumulation, 100-grains weight and grain yield under different maize hybrids.

CONCLUSION

It may be concluded that hybrid HM-4 provided maximum 100-grains weight and grain yield, while hybrid HM-10 recorded higher plant height, LAI, CGR and plant dry matter accumulation. Maize hybrids under different planting methods resulted in similar growth parameters. Zero-tillage (ZT) was found superior to raised bed due to better growth parameters (plant height, LAI, CGR, plant dry matter accumulation) and yield attributes (100-grains weight). ZT gave grain yield at par with raised bed. Hence, zero tillage may be a viable option for different maize hybrids as it found higher growth parameters, yield attributes, yield as compared to raised bed.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Comparative study of various rice cultivars *vis-à-vis* non-monetary inputs under temperate conditions of Jammu and Kashmir

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A field experiment was conducted at Agronomy Farm of SKUAST-K, Shalimar during *kharif* 2010 and 2011 to find out the influence of age of seedling and time of harvesting on productivity of various rice cultivars, viz. Jhelum, SKUA-403 and SR-1. Only non-monetary inputs viz. age of seedling (20, 30, 40 days old) and harvesting schedules (35, 42 and 49 days after flowering) were altered. Results revealed that Jhelum recorded highest grain yield and harvest index as compared to other cultivars whereas straw yield was highest in SKUA-403. As far as the time taken to different phenological stages is concerned, Jhelum took lesser days to maturity as compared to other varieties. Except for plant height, leaf area index and 1000-grain weight, other growth and yield attributing characters were also significantly highest in Jhelum as compared to SKUA-403 and SR-1. As far as age of seedling was concerned, 40 days old seedlings performed better than 30 and 20 days old seedlings in all respects. The time taken by 40 days old seedlings to different phenological stages was also lesser than that of 30 and 20 day old seedlings. Performance in terms of grain, straw, biological yield and harvest index was significantly better than 30 and 20 day old seedlings. In so far as the harvesting schedule is concerned, it could not cause any significant variation with respect to growth and yield attributes. Highest grain yield was however, obtained from the crop harvested at 35 DAF while as highest straw yield and head recovery was obtained in the crop harvested at 49 DAF among all three cultivars.

Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Mechanical harvesting of pulses: Future perspectives

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Mechanization of pulses is vital for improving production efficiency, energy efficiency and reducing cost of production, eases in intercultural operations and in foliar application of nutrients and agro-chemicals. Moreover, manual harvesting is time consuming and expensive. Due to involvement of drudgery and scarce availability of labour, especially at the peak season of agricultural operations, mechanical harvesting of pulses especially chickpea and mungbean is being explored. In mungbean green foliage are the obstacle in mechanical harvesting, which could be overcome by using defoliant ethrel (AVRDC, 2002). Most of the varieties are having lower podding height from soil surface and closeness of the branches to the ground (spreading or semi-spreading growth habit). Hence, there is need to develop tall and non-spreading plant type varieties having podding height more than 20 cm, with suitable agro-techniques and machineries, which in turn will be amenable to mechanical harvesting at low cost. Therefore, the current investigation was undertaken to fulfill the twin objectives of (1) Developing chickpea cultivars suited to mechanical harvesting and (2) Evaluating suitable crop geometry for enhancing productivity and mechanical harvesting of chickpea.

METHODOLOGY

Experiments were conducted at ICAR-Indian Institute of Pulses Research, Kanpur during winter season of 2014–16. Through concerted breeding efforts ICAR-IIPR and International Crops Research Institute for the Semi Arid Tropics (ICRISAT), Patancheru (India) have developed several high yielding breeding lines having tall and erect growth habit. Accordingly, worth of promising elite breeding of desi and kabuli chickpea was assessed as 27 elite breeding lines of desi chickpea were evaluated under normal sown conditions along with two check varieties (DCP 92-3 and HC 5) for identification of suitable genotypes for mechanical harvesting and with better sunlight interception on crop canopy; (ii) 27 *kabuli* entries evaluated for mechanical harvesting Under agronomic experiments for determining suitable crop geometry for mechanical harvesting were conducted under randomized block design. The agronomic experiment consisted of eight treatment combinations comprising two chickpea cultivars GNG 1581 and HC 5 (during 2014–15) and JAKI 9218 and HC 5 (during 2015–16) and four plant densities 33 plants/m^2 (30×10 cm), 44 plants/m^2 (30 cm × 7.5 cm), 44 plants/m^2 (22.5 cm × 10 cm) and 59 plants/m^2 (22.5 cm × 7.5 cm) was laid out in randomized block design and replicated thrice. During 2015–16 a larger plot was demonstrated with combine harvesting of chickpea.

RESULTS

In a preliminary evaluation trial, tall and erect elite 15 breeding lines exhibited more plant height than check varieties (Shubhra and Pusa 1053) and these lines were in the range of >69 cm (IPCK 2014-57, IPCK 2014-161) to 85 cm. (IPCK 2014-139). Total 27 *kabuli* entries were evaluated, out of them three tall and erect genotypes viz. IPCK 2012-07 (2047 kg/ha), IPCK 2011-226 (1,820 kg/ha) and IPCK 2011-37 (1,520 kg/ha) performed well compared with rest of the entries. During 2014–15, 30 entries of desi chickpea (including 2 checks) were evaluated. Among them, 20 entries out yielded over tall and erect check variety HC 5. Whereas, four entries, viz. ICCV 08101, ICCV 13617, IPC 2012-253 and IPC 2012-164 out yielded the best check – a semi-spreading variety DCP 92-3. In another trial, 27 elite breeding

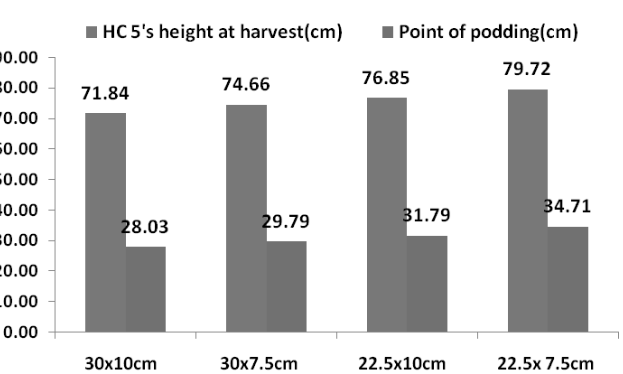

Fig. 1. Plant height and point of podding from surface of chicken HC5

lines of *desi* type were evaluated along with three checks (DCP 92-3, JG 16 and HC 5) under normal sown condition. Out of them genotypes viz. IPC 2011-28 (2060 kg/ha), IPC 2012-49 (2,083 kg/ha), IPC 2011-85 (2,163 kg/ha), IPC 2012-31 (2,167 kg/ha) and IPC 2010-142 (2,222 kg/ha) out yielded over best tall and erect check HC 5 (1,425 kg/ha). Further, elite breeding lines IPC 2012-49 and IPC 2011-85 performed well over two years indicating promising for mechanical harvesting. Findings reveal that taller plants were observed in HC 5 (79.72 cm) compared with GNG 1581. Moreover, highest point of podding from the surface soil was also observed in HC 5 when planted at 22.5 cm×7.5 cm (Fig. 1).

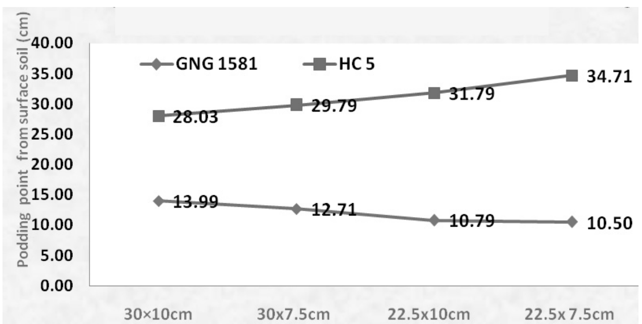

Fig. 2. Podding point from surface soil (cm) of chickpea genotypes showing the possibility of harvesting through combine harvester

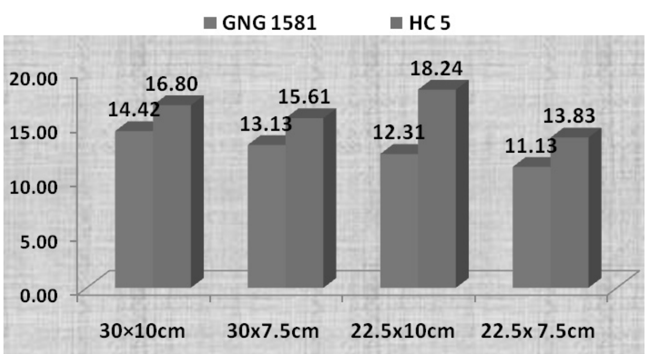

Fig. 3. Grain yield of chickpea under variable crop geometry

This could be attributed to intra as well as inter row competitions.

Further, the point of podding from soil surface was noticed at more elevated height (Fig. 2) in HC 5(34.71 cm) compared with GNG 1581 (13.99 cm). It clearly reflects that chickpea genotype HC 5 is suitable for mechanical harvesting. Since, the height of podding point is much lower in case of GNG 1,581 which could not be recommended suitable for mechanical harvesting. Similarly, during 2015–16 highest plant height at harvest was observed in HC 5 (77.29 cm) compared with JAKI 9218 (52.13 cm). Further, highest point of podding from soil surface was also observed in HC 5 (33.71 cm) compared with JAKI 9218 when sown at the spacing of 22.5×7.5 cm. Combine harvesting of chickpea HC 5 at the crop geometry of 22.5×7.5 cm was also demonstrated and confirmed the suitability of mechanical harvesting of chickpea. It was successfully demonstrated as the losses and breakages were under acceptable range. The chickpea genotype HC 5 out yielded compared with GNG 1581 at all the crop geometry (Fig. 3). Highest grain yield was recorded by chickpea genotype HC 5 at planting geometry of 22.5×10 cm (1,824 kg/ha) followed by 30 × 10 cm (1,680 kg/ha) and least under narrow planting geometry 22.5×7.5 cm (1,383 kg/ha). However, reverse trend was noticed in case of GNG 1581. Highest grain yield of GNG 1581 was recorded when planted at 30 × 10 cm (1,442 kg/ha).

CONCLUSION

The study concludes that chickpea HC 5 at the crop geometry of 22.5 × 10 cm is suitable for combine harvesting. Significantly higher productivity and energy efficiency were also realized under HC 5 at higher density (22.5 × 10 cm) over GNG 1581 and JAKI 9218. Kabuli genotypes, viz. IPCK 2012-07, IPCK 2011-226 and IPCK 2011-37 and *desi* genotypes, viz. IPC 2011-28, IPC 2012-49, IPC 2011-85, IPC 2012-31 and IPC 2010-142 are suitable for mechanical harvesting.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Is precision-conservation agriculture a way to achieve second green revolution in India?

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The present study was undertaken to understand farmers' perspectives of precision conservation Agriculture as a way of achieving second green revolution for sustainable food and livelihood in India.

METHODLOGY

A study was conducted during the year 2013–14 in three districts of North Eastern Karnataka. A random sampling technique was used to select 35 precision farming participant farmers and 35 non-participant farmers of the same selected crops making a total sample size of 70 respondents for the study. A developed perception scale was slightly modified and administered to the farmers to access their perception. The farmers' perceptions was analyzed with descriptive statistics categorizing the perception scores into low, medium and high favourable perception based on the mean and standard deviation as a medium of check.

RESULTS

The results revealed that 40% of the respondents had high favourable perception about precision farming technology followed by 31.43% with medium perception, while 28.57% had low perception. Also, the results of yield performance evaluation of precision conservation agricultural practices shows that participant famers recorded an increase in yield compared to the yield achieved at the farmers' conventional practice especially in pigeon pea and paddy as the yield was statistically significant at 1% level of significance while yield achieved in cotton was not significant.

CONLCUSION

The moderate perception of farmers about precision farming calls for more responsibilities on the side of the stakeholders to promote the technologies at the field level towards sustainable farming practices.

Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Crop diversification options to enhance farm productivity and rural livelihoods in north–western Himalayas

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INTRODUCTION

Agriculture is the mainstay of rural livelihoods in the North-Western Himalayas (NWH), however, more than 80% of the farmers in the hill and mountain region of NWH are marginal or small land-holders (Choudhary *et al*., 2012). Three hill states of India, viz. Himachal Pradesh, Uttarakhand and Jammu and Kashmir fall under NWH region where majority of marginal and small farmers practice traditional farming which is not so remunerative as the crop management and land use is quite poor to harness the potential of crops and farm enterprises resulting in low crop productivity and profitability (Paul *et al*., 2016). In general, there is a large scope for crop diversification through fruits, vegetables and other farm enterprises in the region due to wide variety of agro-climatic conditions and soil types that enable the cultivation of various field crops, vegetables and fruits crops (Choudhary *et al.,* 2013). No doubt, the technical and financial support of the state governments as well as Government of India has played a very crucial role in promoting the crop diversification in NWH states like Himachal Pradesh through programmes like Horticultural Technology Mission (HTM), PDD Kisan Bagwan Samridhi Yojna (PDDKBSY), KVK–ATMA (Agricultural Technology Management Agency) convergence, JICA and Rashtriya Krishi Vikas Yojna (RKVY) and National Food Security Mission (NFSM) in the region (Choudhary, 2016). Still, it calls for a more intensive focus on the crop diversification options from the perspective of policy, research, development and extension. At the same time, the policy reorientation, improving the institutional capabilities and human resources development are the key areas which need dire attention to achieve above goals.

WINDS OF CHANGE IN TRADITIONAL FARMING IN NW HIMALAYAS

The farmers of NWH region are resource-poor with meager land holdings in geographically land locked hilly terrains coupled with poor road and information connectivity. Despite of that, the focus of agriculture in the Himalayan region is slowly shifting from traditional cereal crops to high-value cash crops, vegetables and horticultural crops through technological interventions and technical back-up supported by Govt. This transformation from subsistence farming to commercial farming poses new opportunities and challenges for improving and maintaining the productivity, quality and rural livelihoods. Most agricultural land in the mountain areas is not only marginal in terms of potential productivity, but its quality also appears to be deteriorating as indicated by declining soil fertility and crop productivity. Therefore, it is necessary to explore all possible means of enhancing productivity and carrying capacity of the hill production systems through diversification options in order to improve the livelihoods of small and marginal mountain households. In order to enhance the competitive capabilities of resource-poor hill farmers with the mainstream, they need to be given diversification options and alternatives that are not already captured by the competition. In highlands of the Himalayan region, off-season vegetables and fruits provide the comparative advantage to the farmers. The high value cash crops, off-season vegetables, and fruit crops suitable to specific agro-climatic conditions; are the best options to earn better livelihoods to hill farmers. In this direction CSK Himachal Pradesh Agricultural University, Palampur and its KVKs' alongwith rural development departments of the state like agriculture and horticulture have executed many agrarian projects in Himachal Pradesh. As a result, the mountain agriculture is shifting from traditional cereals' farming to high value cash crops and off-season vegetables both for local and regional markets; and certainly increasing too. This paper specifically highlights the sincere efforts of CSKHPKV, KVK, Sundernagar (HP) on crop diversification interventions in Mandi district of Himachal Pradesh for last one decade which brought winds of change in farm productivity and profitability in hill farmers.

CROP DIVERSIFICATION OPTIONS IN NW HIMALAYAS

Protected Cultivation in Himachal Pradesh

Himachal Pradesh is a hill state where majority of farmers are marginal and small practicing traditional farming which is not so remunerative. A manifold increase in the resource-use efficiency in crop production can be obtained through protected cultivation when compared to open field conditions. In protected cultivation, high value cash crops, vegetables and flowers are grown and managed under controlled conditions with higher per unit productivity and profitability than open conditions. Overall, with financial support under HTM and PDDKBSY over 8000 polyhouses has been constructed so far out of which about 4352 are medium (≥250 m^2) to large-sized (≥500 m^2). At present, about 223.2 ha area is covered under protected cultivation in Himachal Pradesh through government support, NGOs as well as through farmers' personal efforts (Fig. 1) (Choudhary, 2016). The technological interventions of 2 SAUs (CSK HPKV, Palampur and UHF, Solan) and their 12 KVKs in collaboration with line departments has played a pivotal role in horizontal spread of protected cultivation technology in the state.

An extensive field experimentation done by KVK, Sundernagar (HP) on productivity and economic analysis of protected cultivation revealed that average annual income from cut-flowers and vegetables under protected conditions in the state is around ₹ 164,040 and ₹ 117,763 per 500 m^2 polyhouse unit (n=56), respectively (Table 1). Besides this, protected cultivation has also generated employment to rural masses in terms of polyhouse construction, vegetable transport and marketing. From this field study, it was realized

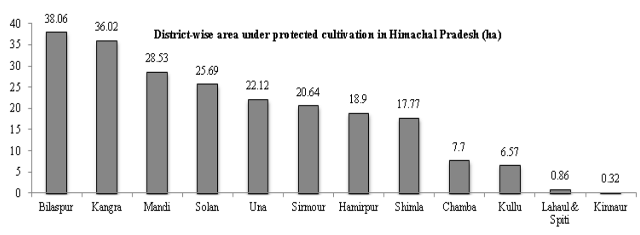

Fig. 1. District-wise area (ha) under protected cultivation in Himachal Pradesh (2013–14).

Table 1. Income earned by the farmers from different enterprises under protected conditions (n=56)

Particular	Unit size	Net income (₹/annum)	
		Range	Average
Flower cultivation (Carnation & roses)	500 m^2	40,000–303,030	164,040
Vegetable cultivation (Coloured capsicum, tomato, cucumber)	500 m^2	50,000–350,000	117,763

(*Source:* Choudhary, 2016)

that coloured capsicum, cucumber and tomato are the favorite choice of polyhouse farmers having polyhouse size of 250–500 m^2 area in Himachal Pradesh (Choudhary, 2016). Protected cultivation helped in increasing the income generation of farmers by producing higher yields with 2–3 crops grown in a year. Hence, protected cultivation technology has great potential in bringing socio-economic transformations in livelihoods of hill farmers in NW Himalayas.

Introduction of high value cash crops and off-season vegetables coupled with INM technology

Introduction of high value cash crops and vegetables can be more remunerative in existing cropping systems in Himachal Pradesh. But the crops are still grown under nutrient starved conditions, rendering in low productivity compared to national averages. The integrated nutrient management (INM) technology coupled with high value cash crops and vegetables in irrigated eco-systems of NWH can prove as boon. In a study by KVK, Sundernagar, the potato–*Kharif* onion cropping system using INM technology resulted in higher system productivity in terms of blackgram equivalent yield (7.67 t/ha) as well as gross (₹ 306,920/ha) and net returns (₹ 2,22,295/ha) followed by tomato–blackgram and greenpea–okra production systems, respectively (Table 2) (Choudhary *et al*., 2013). The study also revealed improvement in available NPK and soil organic carbon pool besides enhanced crop productivity and profitability in field trials under INM practices over farmers' practiced plots.

Off-season cabbage based cropping systems in high hill wet-temperate region of Himachal Pradesh

Off-season cabbage production has become a boon to hill farmers in Himachal Pradesh in general and high hill wet temperate region in particular. After introduction of *off-season* cabbage (April–June) in high hill wet temperate region of Mandi district, farmers were generally growing only one cash crop in their existing cropping systems either off-season cabbage or off-season pea. In order to develop profitable cropping sequences, KVK, Mandi developed and standardized new cropping systems by introducing off-season pea (July–Nov.) in existing *off-season* cabbage cultivation

Table 2. System productivity and profitability under high value production systems and their impact analysis in selected villages

S. No.	Name of village	Crop sequence	System productivity (q ha^{-1}): Crop-wise productivity in terms of blackgram equivalent yield (BEY) (q ha^{-1})				System productivity in terms of (BEY) (q ha^{-1})		Gap analysis of cropping systems: % increase in system productivity over FP	Extension gap (q ha^{-1})	System profitability: Cost of cultivation (₹ ha^{-1})		Gross returns (₹ ha^{-1})		Net returns (₹ ha^{-1})		B:C ratio	
			RP		FP		RP	FP			RP	FP	RP	FP	RP	FP	RP	FP
			Crop I	Crop II	Crop I	Crop II												
Crop sequence for the First Year																		
1	Sakroha	Green pea–okra	31.8	26.79	18.75	14.13	58.59	32.88	78.2	25.71	38600	28130	234360	131520	195760	103390	5.07	3.68
2	Badyal	Tomato–blackgram	58.8	28.7	25	4.5	67.5	29.5	128.8	38	65420	40695	270000	118000	204580	77305	3.13	1.9
3	Tarot	Frenchbean–blackgram	24.38	8.9	10.31	4.7	33.28	15.01	121.7	18.27	32670	23945	133100	60050	100430	36105	3.07	1.51
4	Chhatter	Potato–okra	25.31	21.42	16.88	14.79	46.73	31.67	47.6	15.06	64050	45880	186930	126660	122880	80780	1.92	1.76
Crop sequence for the Second Year																		
1	Sakroha	Green pea–okra	35.4	26.25	19.5	13.74	61.65	33.24	85.5	28.41	42750	31000	246600	132960	203850	101960	4.77	3.29
2	Badyal	Cauliflower–blackgram	31.85	9.8	18.55	5.3	41.65	23.85	74.6	17.8	39450	29150	166600	95400	127150	66250	3.22	2.27
3	Tarot	Cauliflower–blackgram	30.63	10.1	17.85	5.5	40.73	23.35	74.4	17.38	39450	29150	162900	93400	123450	64250	3.13	2.2
4	Chhatter	Potato–*Kharif* onion	36.63	40.1	17.66	22.54	76.73	40.2	90.9	36.53	84625	60790	306920	160810	222295	100020	2.63	1.65

Table 3. Economics of off-season cabbage based new cropping sequences in high hill wet temperate region of Mandi district in Himachal Pradesh

Cropping sequences*	Crops & their duration	Average yield (q/ha)	Cost of cultivation (Rs/ha)	Gross returns (Rs/ha)	Net returns (Rs/ha)	B:C ratio
I	• Cabbage (April–June)	128.27	38043	64135	26092	1.68
	• Peas (July–Nov.)	44.83	24137	67245	43108	2.78
II	•Cabbage (June–Nov.)	226.46	38043	113230	75187	2.97
	• Peas (Dec.–April/May)	92.59	24137	90590	68453	3.83
III	• Cabbage (June–Nov.)	226.46	38043	113230	75187	2.97
	• Potato (March–June)	112.62	43987	90096	46109	2.04

*(n=20 each) (*Source:* Rahi and Choudhary, 2015)

Table 4. Profitable cropping sequences in high hill wet temperate region of Mandi district in Himachal Pradesh

	Cropping sequences*	Gross returns (Rs/ha)	Net returns (Rs/ha)	Rank
1.	Cabbage (June–Nov.) – Peas (Dec.–April/May)	203820	143640	I
2.	Cabbage (June–Nov.) – Potato (March–June)	203326	121296	II
3.	Cabbage (April–June) – Peas (July–Nov.)	131380	69200	III

*(n=20 each)

Table 5. Effect of varying FYM doses on crop and rainwater productivity and profitability of turmeric cultivars

Treatments		Rhizome yield (q ha^{-1})	Rainwater use efficiency (kg ha^{-1} mm^{-1})	Net returns (₹ ha^{-1})	B:C ratio
Crop season 2010–2011					
T_1	*Palam Pitamber* + FYM @ 20 t ha^{-1}	328.45	15.41	427675	6.58
T_2	*Palam Lalima* + FYM @ 20 t ha^{-1}	322.32	15.12	418480	6.44
T_3	*Suketi Haldi* (Local strain) + FYM @ 5 t ha^{-1} (FP*)	124.02	5.82	113730	1.57
Crop season 2011–2012					
T_1	*Palam Pitamber* + FYM @ 20 t ha^{-1}	330.25	13.94	430375	6.62
T_2	*Palam Lalima* + FYM @ 20 t ha^{-1}	324.69	13.71	422035	6.49
T_3	*Suketi Haldi* (Local strain) + FYM @ 5 t ha^{-1} (FP*)	125	5.28	115200	1.59

**FP: farmers' practice* *(Source: Rahi et al., 2014)*

(April-June) while shifting their cabbage cultivation from April–June (general planting time) to June–November (Table 3). This slight adjustment in cropping time has opened a choice of new cropping systems *viz.* cabbage (April–June) – peas (July–Nov.), cabbage (June–Nov.) – peas (Dec.–April/ May), cabbage (June–Nov.) – potato (March–June) to hill farmers. The farmers were also mobilized in intensive manner during 2006–12 to adopt these new cropping sequences through appropriate technology transfer tools. Before KVK interventions, the farmers were growing off-season cabbage during April–June and peas during July–November with gross earnings of hardly ₹ 131,380/ha with net returns of ₹ 69,200/ha (Tables 3 & 4). But after slight modification in planting time of cabbage (KVK intervention), the new sequences resulted in net returns to the tune of ₹ 1,43,640/ha from cabbage-peas and ₹ 1,21,296/ha from cabbage–potato cropping sequences (Rahi and Choudhary, 2015). Today, farmers of wet temperate high hill region of Seraj, Gohar and Karsog blocks of Mandi district are now practicing these remunerative cropping sequences in about 375 ha area in the district. With sound technical backup of KVK-Mandi and line departments of agriculture and horticulture and farmer-led extension approach, these cropping systems have become most remunerative and sustainable in the region. This is a great success story which has brought winds of change in farming and rural livelihood in this remote region of the district. Better quality produce further lead to easy and quick marketing from these production systems in the region.

Cultivation of high yielding turmeric (*Curcuma longa* L.) cultivars in Monkey menace areas of NW Himalayas

Turmeric (*Curcuma longa* L.) is an important spice crop in Himachal Pradesh grown mostly organic by default using local strains. The rhizome yield of this local cultivars is quite low, but this crop is an alternate crop in monkey–menace areas in NW Himalayas. Field experimentation by KVK Mandi during 2010–12 in 6 monkey–menace affected blocks

Table 6. Productivity and profitability of garlic as influenced by integrated nutrient management

Treatments		Clove yield (q ha^{-1})	Net returns (Rs. ha^{-1})	B:C Ratio
Rabi 2012–2013				
T_1	Vermicompost @ 12.5 t ha^{-1} + NPK @ 125:75:60 kg ha^{-1}	223.32	258580	4.38
T_2	FYM @ 25 t ha^{-1} + NPK @ 125:75:60 kg ha^{-1}	214.54	245410	4.21
T_3	FYM @ 15 t ha^{-1} + NPK @ 60:40:20 kg ha^{-1} (FP)	95.45	84705	2.44
Rabi 2013–2014				
T_1	Vermicompost @ 12.5 t ha^{-1} + NPK @ 125:75:60 kg ha^{-1}	183.69	463056	6.63
T_2	FYM @ 25 t ha^{-1}+ NPK @ 125:75:60 kg ha^{-1}	155.85	392030	6.19
T_3	FYM @ 15 t ha^{-1} +NPK @ 60:40:20 kg ha^{-1} (FP)	90.32	209045	4.37

(Source: Rahi and Choudhary, 2016)

Table 7. Green fodder and grain yield as well as profitability of dual-purpose wheat cultivar VL-829 in wet temperate NW Himalayas.

Treatment No.	Treatment details	Green fodder yield (q ha^{-1})	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	Harvest index (%)	Net returns (₹ ha^{-1})	B:C ratio*
OFT–I: Under rainfed conditions							
T_1	No fodder cut + NPK @ 80:40:40 kg ha^{-1} + seed rate @ 100 kg ha^{-1} (Check)	-	21	30.45	40.82	13740	1.35
T_2	Fodder cut at 85 DAS + NPK @ 80:40:40 kg ha^{-1} + 20 kg N ha^{-1} at fodder cut at 85 DAS + seed rate @100 kg ha^{-1}	44	15	21.39	41.22	10858	0.93
T_3	Fodder cut at 85 DAS + NPK @ 80:40:40 kg ha^{-1} + 20 kg N ha^{-1} at fodder cut at 85 DAS + seed rate @ 125 kg ha^{-1}	58.75	20	28.59	41.16	18019	1.5
OFT–II: Under Irrigated conditions							
T_1	No fodder cut + NPK @ 80:40:40 kg ha^{-1} + seed rate @ 100 kg ha^{-1} (Check)	–	45	66.15	40.49	49345	4.49
T_2	Fodder cut at 85 DAS + NPK @ 80:40:40 kg ha^{-1} + 20 kg N ha^{-1} at fodder cut at 85 DAS + seed rate @100 kg ha^{-1}	80	39	57.14	40.57	49772	3.99
T_3	Fodder cut at 85 DAS + NPK @ 80:40:40 kg ha^{-1} + 20 kg N ha^{-1} at fodder cut at 85 DAS + seed rate @ 125 kg ha^{-1}	92	41	60.19	40.52	53612	4.17

*OFT- *On Farm Trial* (*Source:* Choudhary and Suri, 2014a)

Table 8. Effect of different sources of plant nutrients on yield attributes, yield and profitability of potato (Av. value of 5 years)

Treatments	Grade–wise tuber yield (%)			Total tuber yield (t ha^{-1})	Marketable tuber yield (t ha^{-1})	Profitability		
	Large (>75 g)	Medium (25–75 g)	Small (<25 g)			Gross returns (INR ha^{-1})	Net returns (INR ha^{-1})	B:C ratio
T_1	22.4^{f}	64.2^{a}	13.4^{a}	9.26^{f}	8.01^{f}	87,082^{f}	34,392^{f}	1.64^{f}
T_2	27.6^{e}	61.6^{b}	10.8^{b}	12.67^{e}	11.30^{e}	1,19,312^{e}	58,082^{de}	1.93^{d}
T_3	40.8^{b}	53.4^{e}	5.8^{d}	22.60^{b}	21.28^{b}	2,12,622^{ab}	1,33,017^{b}	2.66^{b}
T_4	32.8^{d}	58.4^{c}	8.8^{c}	15.49^{d}	14.13^{d}	1,45,838^{d}	62,408^{d}	1.74^{e}
T_5	36.6^{c}	55.6^{d}	7.8^{c}	18.61^{c}	17.15^{c}	1,75,165^{c}	1,02,585^{c}	2.40^{c}
T_6	44.2^{a}	50.6^{f}	5.2^{d}	23.43^{a}	22.22^{a}	2,20,612^{a}	1,61,599^{a}	3.72^{a}
HSD (± = 0.05)	1.83	1.04	1.78	0.14	0.74	12,224	11,857	0.09

(*Source:* Paul et al., 2016)

Note: T_1 = Control; T_2 = Farm yard manure (FYM) @ 25 t ha^{-1} + Microbial consortia* (MC); T_3 = Chicken manure (CM) @ 7.5 t ha^{-1} + Microbial consortia; T_4 = Vermi–compost (VC) @ 10 t ha^{-1} + Microbial consortia; T_5 = FYM @ 10 t ha^{-1} + CM @ 2.5 t ha^{-1} + VC @ 2.5 t ha^{-1} + Microbial consortia; and T_6 = FYM @ 10 t ha^{-1} + Chemical fertilizers to meet remaining RDF** (CF_{RDF})+ MC.

Table 9. Integrated farming system model for wet temperate NW Himalayas

S. No.	Component	Net area (m^2)	Remarks
1	Crop production	2300	On cropping system basis under rainfed conditions
2	Vegetable production	700	On cropping system basis with transmittent irrigation supply from rain water harvesting unit
3	Nursery raising	20	Based on demand
4	Rain water harvesting unit	100	Established in 100 m^2 area with 1 lakh litre water capacity
5	Fodder production	500	Established as an agri-horti-pastoral agro-forestry system model as farm entrepreneurship*
6	Fruit production		
7	Vermi-composting unit-cum-vermiculture hatchery	150	• Vermi-compost utilised in vegetables and other IFS crops. • Vermiculture for sale as farm entrepreneurship*
8	Mushroom production	40	As farm entrepreneurship*
9	Polyhouse cultivation	100	As farm entrepreneurship*
10	Dairy farming	2 Milch cow	As farm entrepreneurship*

(Source: Choudhary *et al*., 2012)

Table 10. Performance of established units of integrated farming system model in wet temperate NW Himalayas

Components	Net area (m^2)	Gross area (m^2)	Net returns (Rs./unit)	B:C ratio
Crop production unit	2300	4600	19681	3.15
Vegetable production unit	700	1250	10730	3.81
Vegetable nursery unit	20	35	37072	4.16
Economics of crop units (A)	3020	5885	67483	3.73
Economics of entrepreneurship units* (B)	980	123920	102430	4.77
Overall economics (A+B)	4000	129805	169913	4.24

**Average of 02 productive years*.
(*Source:* Choudhary *et al*., 2012; Choudhary, 2015)

Table 11. Performance of IFS model developed in participatory mode on farmers fields in Mandi district of Himachal Pradesh

Components units (Rs./unit)	Net area/	*Cost of cultivation (Rs./unit)	Net returns
Crop/vegetable production unit	1.0 ha	30042	79816
Dairy unit	5 buffalo	118260	76850
Sericulture unit	1 unit	1300	11478
Mushroom production unit	300 bags	25680	41448
Vermi-composting unit	1 small unit	500	4500
Mini-floor mill	1 unit	51600	31920
Total	1.0 ha	227382	246012

**Operational costs* (*Source: Choudhary, 2015*)

of Mandi district (Dharampur, Sundernagar, Gohar, Seraj, Sadar & Gopalpur Block) at 10 locations using two newly released annually harvested high yielding cultivars (*Palam Pitamber* and *Palam Lalima*) alongwith organics i.e. FYM @ 20 t ha^{-1} as well as farmers' practice ('*Suketi Haldi*' supplied with FYM @ 5 t ha^{-1}); revealed that *Palam Pitamber* resulted in highest rhizome yield (329.4 q ha^{-1}) and rainwater use efficiency (RWUE) (14.68 kg ha^{-1} mm^{-1}) followed by *Palam Lalima* compared to '*Suketi Haldi*' under farmers' practice. Likewise, *Palam Pitamber* supplied with FYM @ 20 t ha^{-1} resulted in highest net returns and B:C ratio to the tune of ₹ 429025 ha^{-1} and 6.6, respectively; followed by *Palam Lalima* fetching net returns to the tune of 420257 ha^{-1} with B:C ratio of 6.46 (Table 5). Local cultivar '*Suketi Haldi'* registered lowest net returns and B: C ratio to the tune of 114465 ha^{-1} and 1.58, respectively (Rahi *et al*., 2014). Overall, it is inferred that turmeric rhizome yield can be enhanced by almost two–folds, RWUE by 2–3 folds and profitability by 3–4 folds by introduction of high yielding cultivars (*Palam Pitamber* and *Palam Lalima*) coupled with organic nutritional management utilizing locally available FYM @ 20 t ha^{-1}. This technology has great potential in boosting the turmeric acreage and productivity in monkey–menace areas to enhance rural livelihoods and make organic turmeric

CONCLUSIONS

With technological and infrastructural development, numerous new hill and mountain production systems and integrated farming systems have emerged in NW Himalayas in general and Himachal Pradesh in particular. The resultant higher productivity and profitability through various high value crops and vegetables as well as farm enterprises have shown great potential to fetch better livelihoods which strongly advocate that by adhering to crop diversification option vis-à-vis integrated farming systems under hill production systems we can transform these less remunerative hill production systems into highly remunerative systems using available farm resources following appropriate farm technologies to generate better farm gains, climate resilience, livelihoods and employment on sustainable basis.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

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 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 SSG×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 4 m 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

Table 1. The winning genotypes identified through AMMI analysis suitable for both environment and only drought stress conditions in late to medium maturity group

Both conditions (Medium and late maturity)			Drought stress only (late maturity)	
Genotype	Yield (kg/ha)-Drought stress	Yield (kg/ha)-Optimal environment	Genotype	Yield (kg/ha)-
C0H (M)11	5,785	6,680	PMH 3	5,044
PMH 4	5851	6,242	DHM 111	5,259
DMRH 1306	5,014	6,347	C0H (M)10	4,958

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	4,167	DMRH 1305	5,202
FH 3664	4530	VIVEK QPM 9	5460
JH 31613	4,365	Vivek hyb 39	4,799
PRAKASH	4,362	–	–

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

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Integrated nutrient management on growth and yield of sugarcane

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EXTENDED SUMMARY

The use of inorganic fertilizers does not necessarily lead to better farming than the use of natural and organic methods in agriculture. Due to continuous application of only inorganic fertilizers and plant protection chemicals in agriculture, the soils have been badly degraded. It has destroyed stable traditional ecosystem of the soil and this high analysis N-fertilizers has resulted in imbalance of nutrients in soil, poor growth and decline in sugarcane productivity. In view of the increasing cost of fertilizers and the need to improve and sustain soil health, integrated nutrient management (INM) involving a judicious combination of organic, inorganic and biofertilizers is essential for sustainable sugarcane production. The integrated nutrient supply has proved superior to the use of its components separately. The efficiency of nutrient use may be raised by the conjunction use of biofertilizers and inorganic fertilizers. Hence, the present investigation was carried out to determine the effect of integrated nutrient management (INM) on growth, cane and sugar yield of sugarcane.

METHODOLOGY

The Field experiments were conducted at Sugarcane Breeding Institute, Coimbatore (11°N latitude and 77°E longitude at an altitude of 427m MSL) during the year 2007–10 crop seasons. The experiment was laid out in Factorial RBD with 18 treatment combinations involving 3 levels of Nitrogen (140, 210 and 280 kg/ha), 3 levels of Farmyard manure (no FYM, 6.25 t/ha and 12.5 t/ha) and 2 levels of liquid biofertilizer mixture (no biofertilizer, biofertilizer @ 6 litre/ha) with three replications. The sugarcane variety was Co 86032. Fertilizers were applied according to the experimental treatments. Nitrogen, phosphorous and potassium were applied in the form of urea, single super phosphate and muriate of potash, respectively. Recommended dose of nitrogen fertilizers were applied at 45 and 90 days after planting (DAP) and full dose of phosphorus and potash fertilizers were applied as basal to both plant and ratoon crops. Two earthings were done both in plant as well as in ratoon crops. The 4R nutrient emphases on sustainability were advocated in this experiment. The observations on number of millable canes (NMC), cane and sugar yield and juice quality parameters were recorded adopting standard procedure at the harvest.

Key words: Integrated nutrient management, sugarcane, organics, inorganic and biofertilizer

RESULTS & DISCUSSION

The results revealed that integrated use of organic and inorganic N-fertilizers produced higher number of millable

Table 1. Effect of INM on growth - NMC of sugarcane plant – ratoon

Treatment	Number of millable cane (NMC × 10^3/ha)			
N Levels (kg/ha)	Plant crop		Ratoon crop	
	2007–08	2008–09	2008–09	2009–10
N 140	121.3	106.3	119.2	121.2
N 210	121.8	107.7	114.3	121.8
N 280	**124.3**	107.8	116.7	122.1
CD	NS	NS	NS	NS
FYM Levels (t/ha)				
FYM 0	120.2	103.3	118.2	118.1
FYM 6.25	**124.8**	104.3	115.6	119.1
FYM 12.5	122.4	**111.3**	116.4	127.8
CD	NS	**5.7**	NS	NS
Bio fertilizer (l/ha)				
B 0	123.7	106.6	116.3	121.6
B 6	121.3	108.0	117.1	121.7
CD	NS	NS	NS	NS

It was observed the addition of organics and biofertilizer has a tendency to increase cane yields in plant as well as ratoon crops, even though the effects were non-significant (except N-levels in ratoon crop) and was almost identical. In first plant crop, N level (280 kg/ha) has responded to cane yield (200.6 t/ha). At lower levels of N (140 and 210 kg N/ha), there was increase in trend of cane yield (191.3 t/ha at 140 kg N/ha and 199.3 t/ha at 210 kg N/ha). While in second plant crop, higher cane yield of 138.9 t/ha with 12.5 t/ha FYM and 137.6 t/ha at 280 kg N/ha were recorded, however non-significant. Similarly, both the years of ratoon crop, N levels (280 kg/ha), there was significant response to cane yield (170.3 t/ha in 2008–09 and 135.4 t/ha in 2009–10). Similar increase in trend of cane yield was recorded with application of FYM levels (Table 2).

The mean cane and sugar yields of plant and ratoon crops of two crop cycles obtained from the integrated application, showed that application of 140 kg N along with 12.5 t of FYM and 6.0 litre/ha biofertilizer produced the highest cane cane (Table 1), cane yield and commercial cane sugar (CCS) yield (Table 2).

Table 2. Effect of INM on cane and commercial cane sugar (CCS) yield of sugarcane

Treatment	Cane yield (t/ha)				CCS yield (t/ha)			
	Plant crop		Ratoon crop		Plant crop		Ratoon crop	
	2007–08	2008–09	2008–09	2009–10	2007–08	2008–09	2008–09	2009–10
N Levels (kg/ha)								
N 140	191.3	130.2	155.8	125.7	23.4	17.6	19.1	17.1
N 210	199.3	134.0	151.4	125.4	24.0	17.9	19.1	16.7
N 280	**200.6**	137.6	**170.3**	135.4	24.1	18.5	21.8	18.6
CD	NS	NS	**14.9**	**4.1**	NS	NS	NS	NS
FYM Levels (t/ha)								
FYM 0	193.1	129.3	157.8	126.8	24.1	17.5	19.9	17.1
FYM 6.25	197.1	133.6	155.2	128.6	24.2	17.9	19.6	17.3
FYM 12.5	**201.1**	138.9	**164.3**	131.1	23.2	18.5	20.4	17.9
CD	NS	NS	NS	**4.1**	NS	NS	NS	NS
Biofertilizer (l/ha)								
B0	199.4	134.2	155.5	123.9	24.1	17.8	19.7	16.7
B6	194.7	133.6	162.7	127.5	23.5	18.2	20.3	17.3
CD	NS	NS	NS	NS	NS	NS	NS	NS

In first plant crop, higher NMC of 124.8 thousands/ha was produced with 6.25 t/ha FYM closely followed by 124.3 thousands/ha at 280 kg N/ha. Similarly, in second plant crop significantly higher NMC of 111.3 thousands/ha was produced with 12.5 t/ha FYM. There were no significant differences in number of millable cane (NMC) due to N levels in the plant and ratoon crops of both the crop cycles. Application of FYM also did not significantly improve the NMC except in the second plant crop in which application of FYM 12.5 t/ha produced higher NMC (111.3 thousand/ha) than FYM 6.25 t/ha (104.3 thousand/ha) and no FYM application (103.3 thousand/ha). Further, application of biofertilizer did not influence the NMC.

(154.74 t/ha) and sugar yields (19.71 t/ha) as compared to their individual application. This was due to integrated use of inorganics and organics which gave markedly higher productivity, besides bringing out a general improvement in soil fertility status than that of chemical fertilizers alone. It also created favourable physical and biological environment which leads better uptake of nutrients than other sources. This study is fully supported by Virdia and Patel (2010) and also Rakkiyappan *et al*. (2001) reported that highest cane and sugar yields could be achieved with the application of 75% NPK + press mud, whereas, combined application of organic and chemical fertilizers significantly enhanced the yield over chemical fertilizers alone. From the results of two plant and two ratoon crops, it showed that integrated nutrient management saved 50% N fertilizers due to application of

FYM (12.5 t/ha) along with liquid bio-fertilizers (6 litre/ha). Use of FYM in association with

N- fertilizers has proved superior to its individual components. The 4 R nutrients emphasize (application of right source at the right rate, at the right time and in the right place of fertilizer nutrients and cultural operations) in sustainability. Moreover, organics increase the nutrient use efficiency and help in correcting the emerging deficiencies of nutrients N, P and K.

CONCLUSION

It is concluded that integrated nutrient management recorded saving 50% N fertilizers due to application of FYM (12.5 t/ha) along with liquid bio-fertilizers (6 litre/ha). Integration of organic and inorganic nutrients, application of farm yard manure and bio-fertilizers should be practiced. This will not only enhance growth, yield and quality of sugarcane but also conserve agro-ecosystem for higher sugarcane productivity, sustaining soil health and food security.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Zero tillage reduces soil and nutrient losses and improves soil quality compared to conventional tillage

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Most of the population (82%) in Himalayan region lives in rural areas. The rural population chiefly depends upon agriculture. The land holding is very small and fragmented and the slope is very high (Tuti *et al*., 2013). Tillage on sloping lands results in severe soil erosion and reduces soil organic C (SOC) content. In contrast to conventional tillage (CT), zero tillage (ZT) encourages soil stabilization and water conservation and the increase of soil organic matter in top soils (Beniston *et al*., 2015). Surface residues maintained under ZT systems moderate moisture fluctuations and thus reduce runoff. Many studies report increased macronutrient export with increasing rainfall intensity, with the amplitude of the response affected by tillage management (Beniston *et al*., 2015). Hence, adoption of ZT under rice-wheat systems may be a viable alternative for better soil and resource conservation (Bhattacharyya *et al*., 2008). Tillage systems also affect soil quality differently, because of their varied tillage intensities. Conversion from conventional tillage (CT) to ZT usually increases water holding capacity and decreases runoff (Bhattacharyya *et al*., 2008). Low yield in this region is mainly attributed to soil moisture deficits in the critical crop growth stages, as the region is mostly rainfed system. The importance of irrigation is clear, as both rice and wheat crops require water in drier periods (Singh *et al*., 2006). Aboveground and underground biomass crop yields vary with different irrigation levels, resulting in variations in crop residue on the soil surface. However, the specific effects of tillage and irrigation on soil and nutrient losses and soil quality are rarely investigated in the Himalayan region. Hence, we chose to estimate the impacts tillage and irrigation on soil and nutrient losses along with soil quality under rice-wheat system in the north-western Himalayas after twelve years of cropping. The objectives of the study were (*i*) to estimate soil and nutrient losses and (*ii*) to evaluate different soil quality parameters under different tillage system and irrigation levels under rice–wheat system.

METHODOLOGY

The field experiment was conducted during 2001 to 2013 at the experimental farm of ICAR-Vivekananda Parvatiya Krishi Anusandhan Sansthan, Almora in the state of Uttarakhand, India. The experiment was laid out in a split-plot design with tillage operation (ZT in the form of no disturbance of the soil and CT in the form of two diggings

Table 1. Effects of tillage and irrigation on soil quality parameters under rice–wheat system

Treatment	SOC content (g/kg)	Available nutrient (mg/kg)			DTPA extractable micro-nutrient (mg/kg)				Bulk density (Mg/m^3)	Dehydrogenase activity (µg TPF produced g/24 h)
		N	P	K	Fe	Mn	Zn	Cu		
Tillage										
ZT	8.37	186	8.21	73.3	42.1	38.6	0.971	1.25	1.34	66.8
CT	7.33	172	7.44	67.8	40.6	36.6	0.894	1.17	1.39	61.4
CD (P= 0.05)	0.85	13	0.75	5.2	1.3	1.7	0.071	0.08	0.02	3.3
Irrigation										
I_1	6.84	168	7.15	66.0	39.7	35.9	0.883	1.15	1.40	56.9
I_2	7.36	173	7.69	69.1	41.1	36.9	0.903	1.18	1.38	61.3
I_3	8.33	182	8.08	72.1	42.0	38.3	0.964	1.24	1.35	66.7
I_4	8.86	193	8.39	74.9	42.7	39.2	0.980	1.26	1.33	71.5
CD (P= 0.05)	0.58	8	0.40	1.6	2.1	1.9	0.047	0.04	0.02	6.1

with a spade to the 15-cm depth to prepare a seedbed for both rice and wheat) as main plots and application of four irrigation levels as subplots. Irrigations were applied at pre-sowing and critical growth stages of both crops.(Treatment I_1: pre-sowing; I_2: pre-sowing + active tillering or crown root initiation; I_3: pre-sowing + active tillering or crown root initiation + panicle initiation or flowering; and I_4: pre-sowing + active tillering or crown root initiation + panicle initiation or flowering + grain filling). These treatments were repeated in the same plots each year. Each treatment was replicated four times. Soil loss was estimated through height differences of experimental plot from reference point with help of dumpy level and bulk density after completing twelve years experiment. Nutrient losses are estimated by multiplying the nutrient concentration with amount of soil loss. Hydraulic conductivity was estimated following the standard method. Soil samples were collected from 0-15 cm depth at the end of the 12th cropping cycle and analyzed for soil organic C, available N, P and K, DTPA extractable Fe, Mn, Zn and Cu, dehydrogenase activity and water holding capacity using standard analytical methods. Bulk density was determined as the oven-dried core mass divided by the core volume using one sample set (three cores).

RESULTS

Pooled analysis of last three years experiment showed that rice and wheat yield under ZT plots (2.42 and 4.31 t/ha for rice and wheat, respectively) was higher than CT plots (2.40 and 4.31 t/ha for rice and wheat, respectively), but both are significantly at par with each other. The gain in yield under ZT might be due to lower soil and nutrient losses and higher soil quality parameters (Table 1). The better soil quality parameters under ZT than CT was not proportionately reflected due to very high density of weed (data is not presented). The soil and nutrient losses under ZT and CT applied with different number of irrigations were studied after 12 cycles of rice-wheat system. The estimation informed that the loss of soil under conventional tillage (167 t/ha/year) was 157 t/ha/year higher than zero tillage. The soil erosion might have been reduced due to residue retention, higher soil organic carbon and hydraulic conductivity under ZT plots. The soil loss was reduced as the irrigation number increased. Application of four irrigations at CRI, tillering, flowering and grain filling reduced 40 t soil/ha/year soil erosion than under one pre-sowing irrigation. The increase in irrigation provided higher residue retention and reduced erosion. The total reduction of erosion of available N, P and K under zero tillage were 26.9, 1.2 and 10.6 kg/ha/yr than conventional tillage, respectively. The soil organic carbon concentration under ZT was 14% higher than CT (7.33 g/kg) (Table 1). The higher SOC under ZT might have been due to the reduction of soil erosion and addition of more root biomass and stubble. Similarly available N, P and K, DTPA extractable Fe, Mn, Zn, Cu, water holding capacity, hydraulic conductivity and dehydrogenase activity were higher in ZT than CT. The bulk density under ZT plot was 3.7% lower than the CT (1.39 Mg/m^3). All of the soil quality parameters improved under ZT might have been due to the higher SOC under it (Table 1).

CONCLUSION

The grain yield and soil quality parameters improved under ZT than CT. Hence, zero tillage could be recommended under rice-wheat system in the north-western Himalayas to reduce soil and nutrient erosions and for higher soil quality and yield.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Design, development and evaluation of new innovation – Lucky Seed Drill for simultaneous seeding and spraying of pre-emergence herbicides in various crops

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Owing to the climatic diversity almost all types of crops are grown in India and in all regions cultivated crops are vulnerable to abiotic and biotic stresses. Amongst biotic stresses, apart from insect, diseases and rodents, weeds are very crucial yield reducers as these unwanted & uneconomical plants are hardy in nature compete for nutrients, moisture, light, space etc., and reduce quality and yield of crops which ultimately lower the income of the farmers. The recommendations of national agricultural research institutions and SAUs regarding the weed management in pulses, fodders, oilseeds, vegetable crops are negligible for post emergence weed control in these crops. That's why an option of manual weeding (that is costly and full of drudgery) only remains with us to keep our crops weeds free for attaining better yields. But at the same time in cereal-cereal cropping system several group of post emergence herbicides are available, but these are costly, more hazardous and less effective in controlling diverse type of weed flora due to their specificity. Moreover there are several anxiety causing reports of the development of cross-resistance in weeds against some groups of herbicides especially in wheat for example *Phalaris minor* has developed resistance against Isoproturon in nineties and also developing resistance against Clodinofop group of herbicides. To control hardy and/or diverse weed flora farmers have to go for two to three sprays of herbicides and/or herbicide mixtures which consequently increases spraying and chemical cost that ultimately reduces the net returns of the farmers and increases pesticide load in nature. Alternate to douse these problems another class of agro-chemicals known as pre-emergence herbicides (like pendimethalin, atrazine, fluchloralin, metribuzin, etc.) are recommended for spray within one or two days of sowing using spray solution up to 500 liters per ha as preventive weed control measure in different crops according to their selectivity.

The application of pre-emergence herbicides reduces the drudgery/cost of one or two hand weedings in various crops. But at the same time, there are certain bottlenecks also in the applications of pre-emergence herbicide.

One or two hand weeding can be omitted with the timely application of pre-emergence herbicides. In some crops where smothering effect is higher due to rapid initial growth rate there is complete exclusion of hand weeding (Hand weeding is costly and full of drudgery) and/or the application of costly post emergence herbicides. Although recommendation regarding the application of pre-emergence herbicides is that, these chemicals should be applied within a day after sowing. But results are more promising when these herbicides were applied just after sowing. This is due to the fact that pre-emergence herbicides require desirable moisture in uppermost layer of soil for their better efficacy but soil moisture drastically reduces after seeding due to evaporation losses. This moisture loss is very fast in hot summers when *kharif* crops like direct seeded rice, maize, soybean, moong, mash etc are planted. This is specifically due to the higher evaporative demand of atmosphere in months of May-June. Similarly, during peak sowing season, labour availability drastically reduces and wage rates becomes sky rocketing. Moreover, manual spraying (using knapsack type sprayer) after sowing not only costs very high up to ₹ 500/ha but also results in poor efficacy of applied herbicides due to variable pressure, non uniform overlapping of swath, using less than recommended quantity of water for making spray solution, delay in spray of pre-emergence herbicides after sowing up to 3-4 days etc. Similarly, mechanical weed control measures are also not very efficient as these measures are feeble to remove intra-row weeds, to uproot underground weed plant propagules (i.e. *Cyprus rotundus*) that regenerates within few hours after weeding etc.

Due to these bottlenecks, farmers remain only with the option of hand weeding in crops, where there is no any

Table 2. Grain yield of trial of wheat crop seeded with Lucky Seed Drill at Kapurthala during *Rabi* 2013–14

Treatments		Grain yield (t/ha)	No of weeds/m^2 at harvest
Lucky drill with simultaneous spray	Pendimethalin @ 750g (ai)/ha	5.63	0.4
Conventional Seed Drill *fb* manual spray within one day after sowing	Pendimethalin @ 750g (ai)/ha	5.44	1.9
Conventional Seed Drill *fb* manual spray within two day after sowing	Pendimethalin @ 750g (ai)/ha	4.82	3.9
Conventional Seed Drill	Untreated Control	4.17	9.3
CD (P=0.05)		0.38	

alternative post emergence herbicide and application of post emergence herbicides in crops in which they are present. To overcome these bottlenecks a novel machine named Lucky Seed Drill fitted with Automatic Spraying Attachment was developed specially meant for the application of pre-emergence and pre-plant incorporation herbicides in different crops. In addition, this machine can be used to apply any type of agro-chemicals in field crops, vegetables crops etc. This system has an automatic function, as it applies pre-emergence herbicidal spray just after sowing (with 0.4 seconds). Spray application starts automatically as seeding begins and stops when seeding stops. This machine was developed due to dire need based as hand weeding is tedious job and labour is very costly and also not available at the peak periods. Sometimes it so happen that the hoeing operations and spray of post emergence herbicides cannot be completed due to weather vagaries. So the development of this machine will help in dousing all these problems. With the use of this machine we can save millions of rupees (Table 1) at national and state level that are spent as spraying charges.

SPECIAL REFERENCE TO RAINFED AGRICULTURE

In our nation 2/3 coarse grains including pulses and oilseeds even cotton comes from rainfed areas. Success of crops in these areas largely dependent on rainfall and sowing is only possible when there is enough conserved soil moisture by virtue of precipitation, in such areas sufficient soil moisture is only ensured during sowing time thereafter crop success is dependent on post sowing rainfalls. Controlling weeds in such type of farming is very crucial because, weeds exhaust substantial amount of soil moisture and making crops deprive of it that may result in crop failure. in such situation simultaneous application of pre-emergence herbicides is most suitable avenue for saving crops. (In general every type of herbicides requires sufficient soil moisture for its better efficacy.)

RESULTS

Machine is being evaluated almost in all crops where there is an option of managing weeds through application of pre-emergence herbicides. But in this paper evaluation of machine for wheat sowing has been discussed. It was observed that there is 30 per cent (₹ 300/ha) cost saving with use of Lucky Seed Drill than conventional practice, i.e. seeding with conventional seed drill followed by manual spray application of pre-emergence herbicide (Pendimethalin) using Knap-sack sprayer. Furthermore there is also saving in time up to 7.5 h/ha that usually accrues on manual application of pre-emergence herbicides. Better weed control was observed in treatments where pre-emergence herbicide (Pendimethalin @ 750 g (a.i.)/ha) was applied immediately (within 0.5 sec) after sowing that is only practically possible with the use of Lucky Seed Drill, as compared to treatments where herbicide was applied within one and two days after sowing with conventional seed drill. Similarly 3.2, 16 and 35 per cent more yield was obtained where herbicide was applied simultaneous along with sowing over the treatments where herbicide was applied within one and two days after sowing and untreated check conditions, respectively (Table 2). As far as weed density is concerned only 0.4 weeds/m^2 was reported in treatments were Pendimethalin was applied simultaneously along with sowing with use of Lucky Seed Drill as compared to 1.9, 3.9 and 9.3 weeds/m^2 (Table 2) where Pendimethalin was applied within one, two days after sowing and under check treatments, respectively at Kapurthala.

Table 1. Estimation of extent of saving (Million Rupees) by Lucky Seed Drill over conventional sowing and manual spraying using knapsack sprayer in wheat in Punjab state

Area sown under wheat (m ha)	Wage rate (₹/day)			
	250	300	350	400
	₹ (Million)			
3.5	2,500	3,000.0	3,500.0	4,000.0
2.5	875.0	1050.0	1,225.0	1,400.0
1.5	623.0	750.0	875.0	1,000.0
0.5	375.0	450.0	525.0	600.0
0.1	125.0	150.0	175.0	200.0

CONCLUSION

Lucky Seed Drill (modified seed drill fitted with automatic spraying attachment) is better preposition for curtailing drudgery and the cost (upto ₹ 500/ha) of manual spraying totally vis-à-vis for attaining the maximum efficacy of applied pre-emergence for better weed control efficacy with yield improvement.

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Nitrogen and weed management in conservation agriculture based maize–wheat cropping system

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Weed management is the greatest challenge in the wide spread adoption of conservation agriculture. Conservation agriculture improves soil fertility, crop productivity and sustainability in long run, but changing weed dynamics require suitable modification in weed control measures is required. Continuous zero tillage, residue mulching, brown manure, real time nutrient application and use of low dose broad-spectrum herbicides are important for improving weed control efficiency. Maize–wheat cropping system is one of the most potential systems which can replace the predominant rice–wheat cropping system to address the third principle of conservation agriculture which emphasizes crop diversification. Thus, the weed management under maize–wheat cropping system was evaluated under variable nitrogen management options, including the green seeker guided nitrogen application.

METHODOLOGY

A field experiment was carried out during the *kharif* and *rabi* seasons of 2015–16 at the ICAR-Indian Agricultural Research Institute, New Delhi, in a splitplot design, comprising of 3 weed management treatments in main plot and 4 N management treatments in subplot. For maize, the main treatments were weedy check, chemical weed management atrazine (0.75 kg/ha) + pendimethalin (0.75 kg/ha) as PRE tank mix) and Sesbania brown manure in main plot and 100% N as basal, 50% basal and rest as top dressing, 75% basal + rest through green seeker and 50% N as basal + rest through green seeker. For wheat, the main plot treatments were weedy check, pendimethalin (1 kg/ha) + carfentazone (20 g/ha) as PRE tank mix and clodinafop-propargyl (60 g/ha) + carfentazone (20 g/ha) as POST tank mix 25–30 DAS, while sub-plot treatments were same. The maize and wheat cultivars were HQPM-5 and HD 2967, respectively. The data were analysed using analysis of variance (ANOVA) and the differences were considered significant at 5% level of probability.

RESULTS

Dominant weed flora in maize comprised *Digera arvensis*, *Commelina benghalensis*, *Trianthema monogyna* and among the narrow leaf weeds, the predominant species were *Cyperus rotundus, Cynodon dactylon* and *Dactyloctenium aegyptium* at 30 and 45 days after sowing, highest weed dry weight was recorded in weedy check (Table 1). The weed dry weight at 30 DAS was statistically at par for both broad and narrow leaf weeds with PRE and POST applications. However, at 45 DAS, the dry weight at 45 DAS was higher with PRE application over brown manure. Among the N application, maximum weed dry weight was observed where 100% N was applied as basal and minimum was obtained where 50% N was applied as basal and rest through green seeker at both 30 and 465 DAS in maize. The highest yield of maize (5.12 t/ha) was obtained where 2.4-D was applied through brown

Table 1. Weed dry weight in maize as influenced by weed and nitrogen management

Treatment	Weed dry weight (g)			
	30 DAS		45 DAS	
	BLW	NLW	BLW	NLW
Weed management				
WC	23.9^{b}	16.8^{b}	50.4^{c}	50.8^{b}
PRE	8.2^{a}	11.3^{a}	33.8^{b}	30.7^{a}
POST	8.1^{a}	9.5^{a}	24.5^{a}	32.8^{a}
N management				
N_1	18.6^{a}	14.5^{a}	52.1^{c}	42.5^{b}
N_2	14.4^{b}	12.8^{b}	41.3^{b}	33.4^{a}
N_3	10.3^{b}	12.2^{b}	37.8^{b}	30.7^{a}
N_4	9.4^{c}	10.6^{c}	22.8^{a}	27.4^{a}

BLW: broad leaf weeds; NLW: narrow leaf weeds

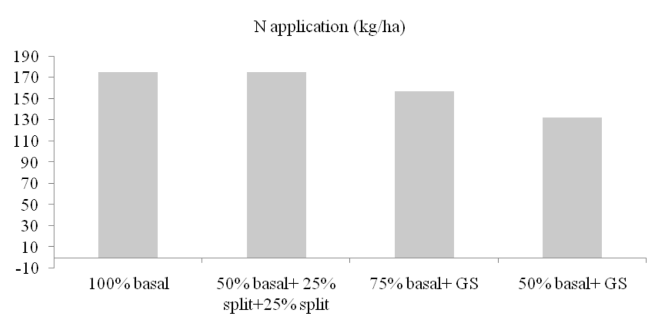

Fig. 1. Nitrogen saving in maize through green seeker based application

manure crop. It was found statistically at par with PRE application (4.99 t/ha). The N application through Green seeker saved 18 and 43 kg N in maize where 75% N was applied as basal + rest through green seeker and 50% N basal+ rest through green seeker as compared to 100% basal application (Fig. 1).

CONCLUSION

Brown manure in maize can substantially improve grain yield both due to smothering effect on weeds and nitrogen availability for the crop. Real time green seeker based N application in maize is useful in capturing initial advantage in terms of growth, yield and weed control.

Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

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.

MATERIALS AND METHODS

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

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

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 × 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 AND DISCUSSION

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. 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).

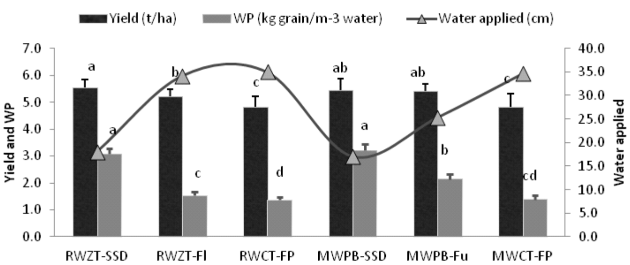

Fig. 1. Grain yield, irrigation water use and water productivity of wheat under different scenarios of conservation agriculture based cropping systems with precision water management

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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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Grain yield response of rice-wheat system under conservation and conventional agriculture in Inner Terai of Nepal

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The rice-wheat cropping system is very intensive and more exhaustive system in inner Terai region of the Nepal. Production and productivity of the system is very low. Declining or stagnant yield and impact on environment are major well known problems of cropping system. In current scenario, intensive farming practice, fertilizer, water and fuel are major inputs. Use of these inputs haphazardly increase yield for very short period but increase cost of production, threatened the sustainability of the cropping system as well as for environment hazards. The possible causes of yield stagnation or decline in this system is due to reduction of soil carbon content, nutrients imbalances and reduction in overall soil quality. Singh and Kaur (2012) and Mandel *et al.* (2005) support that rice–wheat cropping system sustainability and productivity associated with residue retention and zero tilled practice. Hence, this experiment was conducted in four seasons for the evaluation of different planting methods and practices of conservation agriculture and conventional agriculture for yield of this system.

METHODOLOGY

Rice and wheat were continuously cropped before this treatment setup since many years in this experimental field. The trial was initiated during 2011 and treatments setup was started since May, 2011. The fallow period between wheat and rice was utilized by growing mungbean other than conventional plots and 30% residue of rice and wheat and 75% of mungbean residue on rice was retained on residue retained treatments. Treatments were conventional tilled dry direct seeded rice followed by zero tilled wheat (CTDSR + ZTW), transplanted rice followed by conventional tilled wheat (TPR + CTW), zero tilled rice followed by wheat without residue retention (ZTR-ZTW + RH), zero tilled rice followed by wheat with residue retention (ZTR-ZTW + RR), permanent raised bed rice followed by wheat without residue retention (BPR-BPW + RH) and permanent raised bed rice followed by wheat without residue retention with residue retention (BPR-BPW + RR).

Table 1. Rice–wheat system yield as influenced by CA practices of Chitwan, Nepal, in 2012/13

Treatment	System yield t/ha
CTDSR-ZTW	6.86[a]
TPR-CTW	7.70[a]
ZTR-ZTW + RR	7.21[a]
ZTR-ZTW + RH	5.35[b]
BPR-BPW + RH	4.49[b]
BPR-BPW + RR	6.70[a]
SEm (±)	0.326
LSD (P=0.05)	1.028

RESULTS

The higher system yield was obtained in TPR-CTW, statistically at par with ZTR-ZTW + RR, CTDSR-ZTW and BPR-BPW + RR and significantly higher from BPR-BPW + RH and ZTR-ZTW + RH treatments. Statistically, performance of zero tillage and bed planting with residue retention in the system were similar with conventional methods of planting. Significant difference in between residue retained treatment and harvested treatment might be due to nutrients deficiency and moisture stress in residue harvested treatments. The significant contrast was observed in between residue retention versus harvested rice-wheat system but not significantly different on flat versus beds and conservation versus conventional system even in higher performance by flat and tilled treatments of the system. Residue retention continuously from previous cropping system might be gradually enhanced soil health and soil more fertile than residue harvested plots.

CONCLUSION

The CA based rice–wheat system led to almost similar yield to conventional practice with reduced cost of cultivation. However, incomplete CA practice has not benefited to farmers in terms of yield. Residue retention in zero tillage either in flat system or in bed system appears more sustainable for productivity and cost reduction. Further long term research result can only be realized for the better adoption in farmer's level under wide range of environmental conditions.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Improving nutrient-use efficiency in a changing climate

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Food crops grown using organic inputs having less or no chemicals are being preferred over conventionally produced food by the end users. Food material produced organically has got it place in food market in developed and developing countries. Application of organic manures not only improves the soil organic carbon for sustaining the soil physical quality but also increases the soil N.About 18 lakhs hectare area in north-east India can be classified as 'Organic by Default'. The use of agrochemicals like fertilizers (12 kg/ha) and pesticides is negligible.The region is therefore identified as one of the potential zone for organic food production in India (Bujarbaruah, 2004). Keeping this in view field experiment was conducted during 2006-07 to 2008-09 at research farm of ICAR Research Complex for NEH region, Umiam (950 m MSL),Meghalaya to evaluate different organic inputs on rice and maize based cropping systems.

METHODOLOGY

Field experiment was conducted at well drained land, in Research farm of ICAR Research Complex for NEH Region, Umiam Meghalaya, India. The soil of the experimental field was high in soil organic carbon, low in pH, available N, P and high K.The experiment was laid out in a split plot design with treatment combinations of four cropping sequences in main plot, viz., Rice + soybean (4 : 2 row ratio) – toria (CS1), Rice + soybean (4 : 2) - tomato (CS2), Maize + soybean (2 : 2) – groundnut (CS3) and Maize + soybean (2 : 2) – frenchbean (CS4) along with five organic amendments such as farmyard manure (FYM), vermicompost (VC), local compost (LC), integrated sources (1/3 FYM +1/3 VC + 1/3 LC) and compared with control (no manure) in sub-plots. Organic manures were applied on the basis of N-equivalent and phosphorus requirement was compensated through rock phosphate.Varieties used were rice (Bhalum-1), maize (DA 61-A), frenchbean (Naga local), tomato (Avinash-2), potato (Kufri Jyoti) and toria (M-27). Yield of different crops were converted to Maize Equivalent Yield (MEY) for comparison. The MEY of different crops under various nutrient management practices were calculated on the basis of prevailing market prices. The post harvest soil samples were collected from 0 to 15 cm horizon for analyzing the available nutrient status after every year. Insect pest and diseases were controlled through organic means.Organic blockwas protected from all possible contaminations by giving proper drainage, buffer zone, bunds etc.

RESULTS

Rice grain yield was recorded maximum in FYM treatment followed by integrated in the year 2006–07. However, from second year (2007–08) onwards, maximum grain yield was recorded in integrated (1/3 FYM+ 1/3 VC+ 1/3 LC) nutrient management. The average (3 years) rice yield data indicated that integrated nutrient management recorded highest productivity of 2.41 and 2.13t/ha in CS1 and CS2 respectively. Integrated source of nutrient supply produced highest average yield of maize in both the cropping system. Soybean yield was also maximum in integrated nutrient supply under cropping system CS1, CS2 whereas, FYM treatment produced highest seed yield in the cropping system CS3 and CS4. Yield of soybean was 1.32, 1.41,1.25 and 1.19t/ha inCS1, CS2, CS3 and CS4, respectively. The fruit yield of tomato and green pod yield of frenchbean was found maximum in FYM treatment followed by integrated source of nutrient supply (1/3 of FYM, VC and LC) in all the year. Maximum average yield of 16.29 t/ha and 7.47 t/ha of tomato and frenchbean, respectively,were recorded in FYM treatment. The average yield of groundnut was also recorded maximum in FYM treatment whereas, average yield of mustard was highest under integrated treatment.The groundnut pod yield was recorded 3.18 t/ha in FYM treatment followed by integrated and vermicompost as source of nutrient supply.Among the cropping system, rice + soybean (4 : 2) - tomato (CS2) produced maximum MEY followed by maize + soybean (2 : 2) – frenchbean (CS4) cropping system.FYM (17.25 t/ha) treatment produced maximum system productivity followed by integrated (16.65 t/ha). After 3 cropping sequences maximum soil organic carbon,available N, P and K was recorded under integrated nutrient management supply which were 47.2, 24.91, 54.36 and 33.32% respectively higher compared to control. Among the cropping systems, maize based systems were found to give more income compared to rice based and FYM as sources of nutrient supply gave highest benefit : cost ratio (2.37) in maize + soybean (2 : 2) – frenchbean (CS4)

Table 1. System productivity and soil parameters as influenced by cropping system and nutrient management sources (After 3 cropping cycles)

	Maize equivalent yield (t/ha)				O.C.(%)	Avail.N (kg/ha)	Avail.P (Kg/ha)	Avail.K
	2006–07	2007–08	2008–09	Average				
A. Cropping Systems								
Rice + Soybean–Mustard	7.87	9.09	4.81	**7.26**	1.9	220.5	15.5	229.6
Rice + Soybean–Tomato	12.90	13.57	31.06	**19.18**	2.1	225.8	16.9	232.5
Maize + Soybean–Groundnut	13.13	15.17	9.98	**12.76**	2.2	237.6	16.9	235.3
Maize + Soybean–Frenchbean	14.18	15.79	13.33	**14.43**	2.2	232.3	19.2	233.6
CD(*P=0.05*)	1.25	1.12	0.47	–	0.08	4.3	0.82	4.4
B. Nutrient sources								
FYM	16.79	17.24	17.73	**17.25**	2.3	239.6	20.5	242.3
Vermicompost	13.96	15.04	16.46	**15.15**	2.0	226.8	16.4	230.4
Local compost	9.61	11.89	13.35	**11.62**	1.9	216.6	15.7	219.9
Integrated	15.03	16.81	18.11	**16.65**	2.5	247.2	22.7	247.6
Control	4.71	6.06	8.32	**6.36**	1.7	202.4	10.4	217.1
Initial value	–	–	–	–	**1.32**	**185.61**	**10.36**	**165.10**
CD *(P=0.05)*	**1.34**	**1.30**	**0.64**	–	**0.09**	**3.8**	**1.3**	**3.4**

cropping system.

CONCLUSION

Inclusion of vegetables resulted higher equivalent yield and income of rice/maize based system.Application of organic manureirrespective of sources enhanced soil organic carbon, available N, P and K in soil, integrated source of nutrient supply being the best.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Effect of different tillage methods and crop residues on yield and yield components of cotton-wheat crop rotation

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Where traditional tillage and residue removal practices have been used over of the world and also in Iran, soil has been lost through erosion while the soil resource has been degraded physically, chemically and biologically (Verhulst *et al*., 2010). As a result, improved or new varieties of crops (such as wheat) as well as use of other inputs are not able to deliver their potential contribution (Dee-Vita *et al*., 2007). The term conservation agriculture removes the emphasis from the tillage component and addresses an enhanced concept of the complete agricultural system; it involves major changes in many aspects of the farm cropping operation. Normally starting of conservation agriculture with reduced or zero tillage, it progresses to the retention of adequate levels of crop residue on the soil surface, then to appropriate crop/cultivar selection and rotations (Sayre *et al*., 2001). The purpose of this experiment to investigate the effect of different tillage methods and rate of crop residue on yield and yield components of cotton and wheat in temperate region of Iran.

METHODOLOGY

This experiment was conducted in Agricultural Research Station of Gonabad, Khorasan-e Rzavi province with 34° and 22′ Longitude, 58° and 45′ latitude, 1,060 m above the sea level and long term annual mean precipitation 160 mm during 2013–14 growing seasons. Experiment was conducted using a split-plot design with three replication of three levels of tillage method (Conventional tillage (mold board plow, disking, leveling and seeding); reduced tillage (disking, leveling and seeding) and zero tillage (Direct seeding with direct planter) in main plots and three levels of residue management, i.e. without residue, retention of 30% residue and retention of 60% residue were allocated in sub plots under cotton–wheat rotation. Wheat residue (previous crop) was retained on the soil surface based on residue treatments.

RESULTS

Results showed that, only the effect of tillage treatments were significant on boll weight (Table 1). Results of mean comparison showed that the highest and lowest level of cotton boll weight was related to interaction effect of NTR_2 and RTR_0 treatments, respectively. The highest and the lowest cotton yield was obtained in RTR_2, and NTR_1 treatment, respectively and maximum open boll was in NTR_0 treatment. For wheat, results showed that different tillage methods and residue management had no significant effects on grain yield, biological yield and harvest index (Table 2). The highest and the lowest level of biological yield were obtained from RT and NT treatments, respectively. With increasing of residue from zero to 60%, biological and grain yield were increased. The highest and the lowest level of grain yield were related to interaction effect of CTR_2 and NTR_0 treatments, respectively. In addition, the highest amount of harvest index was to RTR_0 treatment.

CONCLUSION

Reduction or deletion of tillage practices in addition to retention of crop residue will be more profitable in cotton-wheat system because of reduction of input costs and protection of environment as well as increasing of crop yield and yield sustainability in medium and long-term in this region.

Table 1. Interaction effects of different tillage methods and residue retention on yield of cotton

Interaction effects between tillage and residue retention	Yield (kg/ha)	Plant height (cm)	Boll weight (kg/plant)	Open boll
Conventional Tillage + Residue 0% (CTR_0)	$1,530^{a}$	64.7^{abc}	4.5^{a}	15.1^{abc}
Conventional Tillage + Residue 30% (CTR_1)	$1,560^{a}$	56.7^{c}	4.2^{b}	13.0^{c}
Conventional Tillage + Residue 60% (CTR_2)	$1,514^{a}$	63.3^{abc}	4.5^{ab}	14.8^{abc}
Reduced Tillage + Residue 0% (RTR_0)	$1,571^{a}$	59.7^{bc}	4.2^{b}	12.5^{c}
Reduced Tillage + Residue 30% (RTR_1)	$1,569^{a}$	63.3^{abc}	4.4^{ab}	14.7^{abc}
Reduced Tillage + Residue 60% (RTR_2)	$1,681^{a}$	60.3^{bc}	4.6^{ab}	12.6^{c}
Zero Tillage + Residue 0% (NTR_0)	1591^{a}	72.0^{a}	4.5^{ab}	21.1^{a}
Zero Tillage + Residue 30% (NTR_1)	$1,442^{a}$	69.0^{ab}	5.1^{a}	16.0^{abc}
Zero Tillage + Residue 60% (NTR_2)	$1,656^{a}$	73.3^{a}	4.9^{ab}	20.0^{ab}

Means, in each column, followed by at least one letter in common are not significantly different at the 5% probability level.

Table 2. Interaction effects of different tillage methods and residue retention on yield of wheat

Interaction effects between tillage and residue retention	Biological yield (kg/ha)	Grain yield (kg/ha)	Harvest index HI (%)
Conventional Tillage + Residue 0%	9.494^{a}	$4,429^{a}$	46.7^{ab}
Conventional Tillage + Residue 30%	9.828^{a}	$4,382^{a}$	44.6^{ab}
Conventional Tillage + Residue 60%	9.917^{a}	$4,466^{a}$	44.6^{ab}
Reduced Tillage + Residue 0%	9.783^{a}	$4,400^{a}$	45.1^{ab}
Reduced Tillage + Residue 30%	9.050^{a}	$4,134^{a}$	45.6^{ab}
Reduced Tillage + Residue 60%	9.894^{a}	$4,291^{a}$	43.3^{b}
Zero Tillage + Residue 0%	9.494^{a}	$4,633^{a}$	48.7^{a}
Zero Tillage + Residue 30%	10.180^{a}	$4,773^{a}$	47.0^{ab}
Zero Tillage + Residue 60%	10.510^{a}	$4,896^{a}$	46.6^{ab}

Means, in each column, followed by at least one letter in common are not significantly different at the 5% probability level.

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Wheat shoot bending characteristics: A technology to determine the lodging tendency

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Among cereal available all over the world, wheat is the wholesome and most common one. It is the most sustainable cereals crops. Lodging in wheat is an important factor behind large reductions in grain yield and quality. A study to analyze the bending characteristics of wheat shoots was performed on ten wheat cultivars grown under controlled and moisture stress conditions. Three replicas of each wheat cultivar in two different conditions were used as dataset responsive to different bending force applied. Various parameters like wall thickness, moment of inertia and bending stress were studied at three different nodes from lower to upper region on shoot. The study was conducted to evaluate the effects of moisture stress, node position and response of various wheat cultivars to bending stress in relation to lodging. Results showed that the observed estimates of lodging in different cultivars were significantly correlated with the measured bending stress values. Thus bending stress can be a reliable parameter to screen wheat crop cultivars for lodging resistance to ultimately reduce the yield losses.

METHODOLOGY

Plant samples were collected in late March (mature stage) from field of wheat cultivars (HD-2987, HDR-77, PBW-343, PBW-175, HD-2967, HD-2781, HD-2985, HD-3043, C-306, PBW-343) grown under two different conditions-irrigated and moisture stress. To evaluate shoot bending stress, three shoots samples from each of the 10 wheat cultivars were randomly selected and cross-sectionally cut at three nodes N_1, N_2 and, N_3 from bottom of the plant towards top. All samples were collected from main tillers. The roots and leaves were removed before testing the physical parameters, major cross sectional diameter (a), minor cross sectional diameter (b) of shoot, and thickness of cross-sectional area (t). Diameter and thickness of each sample node was measured using screw gauge having a resolution of 0.01 mm before starting the tests. The wheat shoots samples removed from the field were carefully cleaned to remove the soil and then prepare for mechanical testing. The roots and leaf sheaths were removed from the plant and the lowermost three nodes were marked. Three nodes from the bottom of the shoot were then subjected to three-point bending tests to determine their bending stress. The samples were cautiously cut at the node and the wall thickness at the area of cross section was measured in replica. Forces versus displacement curves were obtained and data was exported using exponent software with the system. The system provides option of variable loading speed, but it was kept constant throughout the experiment. Each wheat sample was subjected to bending test using three point bending probe. The bending force versus displacement data were recorded directly by testing system. The semi-major and semi-minor axis diameters and wall thickness were measured at the instant of test with the help of a micrometer. The nodes were assumed to be of slightly elliptical shape and hence the second moment of inertia was calculated based on measurements of physical parameters.

RESULTS

In irrigated conditions, at node 1, wall thickness varies in range 0.56–0.86 mm and in moisture stress it varies in the range 0.26–0.53 mm. While at node 2, the variation in irrigated conditions were 0.47–0.87 mm and in moisture stress conditions it varied in range 0.26–0.52 mm. At node 3 values vary in range 0.42–0.69 mm for irrigated and in range 0.24–0.49 mm in moisture stress. The wall thickness is found to be decreasing from lower nodes to upper nodes. On the basis of wall thickness and second area of moment bending force was calculated at all the three nodes on the shoots. The graphs were obtained between the bending force and distance moved by the three point bending probe till the maximum bending. The maximum bending force in each of the cultivars is found to be decreasing from N_1 to N_3. Thus, the larger stem diameter, the higher cutting forces. Force varies from 5.5 N to 9.6 N at node 1 in controlled condition and 2.7 N – 4.7 N from under moisture stress. At node 2 the bending force varies from 5.1N to 9.6 N and 2.4 N to 4.6 N under controlled and moisture stress conditions respectively. At node 3 the value of bending force varies from 4 N to 9.2 N and 2.2 N to 4.2 N under controlled and moisture stress conditions. At node N_1, The lowest value of bending stress is 1.02 MPa and highest value is 1.4 MPa under controlled condition, and in stressed conditions the values are 1.07 MPa and 2.3 MPa for varieties 1 and 9 respectively, in controlled conditions. The values of bending stress at lower nodes is low than higher nodes for all cultivars. The bending stress increases from

Table 1. Variation of correlation coefficient in controlled and stressed condition in wheat cultivars in relation to lodging

Parameter	Node 1		Node 2		Node 3	
	CT	ST	CT	ST	CT	ST
Wall thickness	0.338^{ns}	0.391*	0.619***	0.606***	0.507**	0.595**
Second moment of area	-0.095^{ns}	0.874***	-0.187^{ns}	0.669***	–0.424*	0.649***
Bending force	–0.777***	-0.305^{ns}	–0.774***	–0.432*	–0.806***	–0.305*
Bending stress	–0.992***	–0.976***	–0.924***	–0.958***	–0.937***	–0.936***

*significant at p>0.05;**significant at p>0.01;***significant at p>0.001

node 1 to 3 for all varieties. The maximum bending stress increases upwards from N_1 to N_3. Since the bending stress is directly proportional to bending force and inversely proportional to second moment of area, the bending stress is found to be low at lower nodes than upper node. N_1 node has lowest bending stress as compared with N_2 and N_3.

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Improving the quality of farmers saved seed through seed village programme

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The Seed replacement rate in the agriculturally developed states like Punjab, Haryana, Western UP and Uttaranchal is 30–40% which indicates that 60–70% of the farmers sow their own saved seed. Unavailability and short supply of quality seed is a constraint in higher production of food grains. To cover large area in the country like India farmer's participation in seed production is much needed to ensure supply of quality seed to each and every farmer and to enhance seed replacement rate. To upgrade the quality of farmer-saved seed, Seed Village Programme sponsored by DAC, Ministry of Agriculture, GOI was started under the supervision of scientists at ICAR-IARI, Regional Station, Karnal since *kharif* 2009 and continue till date for farmer-to-farmer horizontal spread of seeds of latest popular varieties of rice, wheat and berseem. The objective was to increase availability and horizontal spread of quality seed of improved varieties with the participation of resource poor farmers by Capacity building through Seed Village Programme.

METHODOLOGY

In the Seed Village Programme the target group is resource poor farmers including women farmers were selected in cluster from different villages around Karnal in the year 2009 to 2014–15. Under the Programme quality seed of latest variety of Wheat, Paddy and Berseem crop for one acre was supplied at 50% subsidy to each farmer. Three trainings on different aspects of quality seed production were provided to farmers under seed village programme at different crop stages of each crop season.In the first training information on importance of quality seed, seed treatment, agronomic management including nursery management, seed rate, time and method of sowing, spacing, fertilizer, weed and irrigation management was given. Second training was given at farmer's field by the group of scientists on fertility problems, plant protection measures and rouging to improve the quality of seed. Third training wasgiven to share the knowledge on harvesting, cleaning, drying, post-harvest precautions including protection from insects during seed storage.Farmer was free to sell the surplus seed to neighboring farmers in the village for the horizontal spread of quality seed. Seed village programme was taken for two years in each village.

RESULTS

After two years association with ICAR-IARI, Regional

Table 1. Seed Production by farmers under Seed Village Programme

Season	Village	No. of Farmers	Crop	No. of trainings	Seed production (area/ha)	Seed production(t)
Kharif 2009	1	32	Paddy*	6	6.4	27.2
Rabi 2009–10	6	224	Wheat**	13	44.8	224.0
Kharif 2010	4	76	Paddy	7	15.2	57.8
Rabi 2010–11	5	76	Wheat	6	15.2	76.0
Kharif 2011	3	80	Paddy	5	16.0	72.0
Rabi 2011–12	3	80	Wheat	4	16.0	96.0
*Kharif*2012	3	80	Paddy	5	16.0	75.2
Rabi 2012–13	2	80	Wheat	4	16.0	88.0
Rabi 2012–13	2	10	Berseem***	4	2.0	88.0
Kharif 2013	2	80	Paddy	4	16.0	0.5
Rabi 2013–14	4	136	Wheat	7	27.2	69.6
Rabi 2013–14	4	28	Berseem	7	13.6	144.2
Kharif 2014	6	96	Paddy	6	38.4	1.7
Rabi 2014–15	6	96	Wheat	7	38.4	211.2
Rabi 2014–15	5	16	Berseem	7	1.28	188.2
Total	–	1190	–	74	279.6	2.6

*Paddy–Cv PB1121, PB 1509; **Wheat – Cv HD 2894, HD 2967, HD 3086: *** Berseem Cv– BL 42

Station, Karnal, and through active participation in the trainings following production technologies were adopted by farmers &their level of knowledge for production of quality seed by scientific interventions has increased. Raising of green manure crop and mixing in soil improves physical condition of soil, promote root growth and increase soil fertility there by reducing doses of nitrogen fertilizer particularly in basmati rice.Seed treatment before sowing protects the crop from diseases pests.Sowing of seed crops in rows helps in fertilizer application, plant protection measures to be taken, removal of volunteer plants and rouging of 'off type' plants to maintain genetic purity of the crop.Balanced use of nitrogen fertilizer not only saved the fertilizer but also check the increased vegetative growth of the crop which helped to protect the crop from lodging and reduction in seed yield and quality.Use of herbicides at proper time and in proper dose controlled the objectionable weeds and improved the physical purity of crop and put fewer burdens on processing.To protect the crop from diseases and insect pest, pesticides were applied at proper time to avoid crop loss. Safe storage of seed at proper moisture for next cropping season.

CONCLUSION

Farmers are becoming aware about the importance and use of quality seed as local varieties are being replaced with high yielding new varieties.Seed production in group helps in the monitoring of seed crops. Risk of mixture in seed is reduced due to single variety coverage on a particular area. Farmers of neighboring villages showed interest to learn seed production technology due to seed production technology demonstration at farmers' field.

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Can Africa achieve food sufficiency? Taking lessons from Indian agriculture in the face of 21st century agricultural challenges

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There is no gainsaying the fact that Agriculture remains the backbone of developing nation's economy considering its importance for food security as well as major source of employment and rural livelihood. This is true in Africa as Agriculture remains the major source of income though this varies widely across countries. However, percentage share of agriculture in national GDP of many African countries in the recent time is declining. This coupled with increase in demand for food, population growth as well as changing in consumers' food patterns have led to increment in food importation bills of many African countries in other to meet their domestic food demand. This paper therefore reviewed the possibilities of African agriculture achieving food sufficiency in the face of 21st century agricultural challenges and opportunities. Effort was made to understudy the pathway to India Agriculture attaining food sufficiency keeping in mind the similarity of India Agriculture to African agricultural scenario with nearly same opportunities and challenges. We therefore conclude that a proactive and innovative pathway should be created in Africa using policy tools, adoption of proven adaptable agricultural technologies as well as promotion of climate smart agricultural technologies for transformation of Africa Agriculture from net importer of food to food sufficiency as well as becoming net exporter of food.

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Seed bed preparation and weed management practices on weed control efficiency and productivity of dry direct seeded rice

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Direct seeding of rice (DSR) has evolved as a promising technology to minimize cost of production by drastically reducing labor and water requirement and potential alternative to detrimental effects of puddling and transplanting. Although DDSR seems potential and sustainable replacement of TPR, the success of DDSR is dependent on proper management of DDSR crop. Several challenges confront the wide-scale adoption of DSR by farmers (Nguyen and Ferrero, 2006), among which high weed infestation is the major bottleneck in DSR especially in dry fields (Rao *et al*., 2007). In absence of effective weed control measure the yield penalty in DDSR was found very high often leading to no yield at all (Rashid *et al*., 2012). The experiment was conducted to address the effective and sustainable weed management by determining the effects of seed bed preparation and weed management practices on the weed density, weed control efficiency, productivity and economics of dry direct seeded rice.

METHODOLOGY

The experiment was conducted in the Agronomy Research Block of Agriculture and Forestry University (AFU), Rampur, Chitwan from May to October, 2014 during the rainy season. The soil of experimental plot was sandy loam in texture. All other chemical properties such as soil organic matter (3.18%), total nitrogen (0.16%), available phosphorus (36.18 kg/ha) and available potassium (139.92 kg/ha) were found medium except soil pH (5.5) which was slightly acidic.The treatments consisted of two methods of seed bed preparation (stale seedbed and normal seedbed) in main plot and six weed management practices (weedy check, weed free check, pendimethalin @ 1 kg a.i./ha at 1 DAS followed by

Table 1. Grain yield, total weed density at harvest, total weed dry weight harvest, net returns and B:C Ratio as influenced by seed bed preparation and weed management practices in DDSR

Treatments	Grain yield (kg/ha)	Total weed density (no./m^2) at harvest	Total weed dry weight (g/m^2) harvest	Net returns NRs/ha (‘000)	B:C Ratio
Seed bed preparation					
Stale seed bed	3293.39	12.08^b (150.87)	8.61(96.77)	45.79	1.97
Normal seed bed	3280.62	12.69^a (171.82)	9.00(115.87)	45.20	1.99
SEm±	130.21	0.12	0.17	3.44	0.07
LSD (P=0.05)	NS	0.57	NS	NS	NS
Weed management practices					
Weedy check	318.51^c	17.40^a(305.23)	18.98^a(363.59)	-25.08^c	0.29^c
Weed free check	4171.10^a	9.03^d(81.42)	2.47^d(5.73)	59.68^{ab}	2.12^b
Pendimethalin fb 2,4-D EE	3862.49^{ab}	13.05^b(170.95)	8.62^b(77.38)	61.22^{ab}	2.42^a
Bispyribac Na	3355.55^b	12.73^b(163.09)	9.33^b(89.03)	53.03^b	2.34^{ab}
Pendimethalin fb Bispyribac Na	4157.11^a	10.81^c(117.85)	4.69^c(21.82)	68.73^a	2.55^a
Sesbania co-culture+1 HW	3857.28^{ab}	11.32^c(129.52)	8.75^b(80.37)	55.43^b	2.15^b
SEm±	169.10	0.43	0.40	4.03	0.08
LSD (P=0.05)	488.4	1.26	1.17	11.66	0.25

Data subjected to square-root ($\sqrt{X+0.5}$) transformation; figures in parentheses are original data; Treatments means followed by common letter(s) within column are not significantly different among each other based on DMRT at 5% level of significance. Note: HW: hand weeding, Na: sodium, NS: non-significant

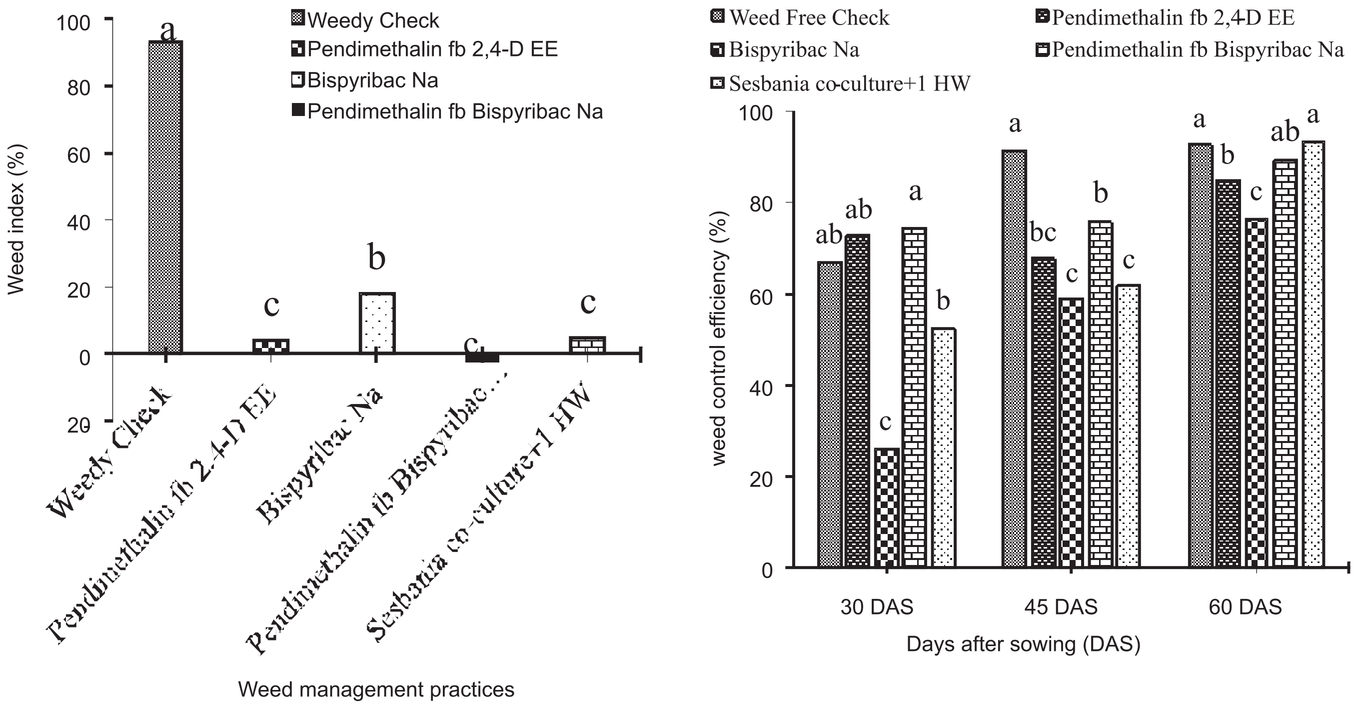

Fig. 1. Weed index and weed control efficiency as influenced by weed management practices

2,4-D @ 0.5 kg a.i./ha at 28 DAS, sole application of bispyribac sodium @ 25 g a.i./ha at 22 DAS, pendimethalin @ 1 kg a.i./ha followed by bispyribac sodium @ 25 g a.i/ha at 22 DAS, Sesbania co-culture followed by 1 hand weeding at 45 DAS) in sub plot arranged in split plot design with four replications.

RESULTS

There were non-significant differences between normal and stale seed bed in grain yield, weed dry weight, net returns, benefit cost ratio weed index and weed control efficiency except weed density (Table 1) because first land preparation in both stale and normal bed was done at the same time, and there was rainfall few days after application of irrigation to stale seed bed which germinated some of weed seeds in the normal seed bed as well. However, weed management practices significantly influenced all these parameters. There was 92.8% reduction in yield in weedy check compared to the yield of weed free plot.Higher weed control efficiency, statistically at par with weed free check was observed in the plots where pendimethalin was applied as pre-emergence and least in sole application of bispyribac Na (Fig. 1). Sequential application of pendimethalin followed by bispyribac Na recorded the yield statistically at par with weedy free check along with the highest net returns and benefit cost ratio compared to other treatments (Table 1).

CONCLUSION

Although method of seed bed preparation did not show significant differences in most of the parameters but stale seed bed recorded lower weed dry weight and produced slightly higher yield than normal seed bed. Among different weed management practices, sequential application of herbicides and sesbania co-culture followed by one hand weeding significantly reduced the weed density and weed dry matter compared to weedy check, but sequential application of pendimethalin fb bispyribac Na was found to be the best option for effective control of weeds producing higher grain yield, economic returns and benefit cost ratio.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Evolving profitable integrated farming system model for irrigated upland of Kancheepuram district of Tamil Nadu

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Kancheepuram district of Tamil Nadu is dominated by rice–rice mono cropping system under wet land condition and vegetables–groundnut cropping system under irrigated upland conditions. The need for diversification in this area is clearly evident since the income of farmers dependent solely on agriculture is decreasing due to narrow margin of profit and changed food consumption habits (Channabasavanna *et al.,* 2014). Hence, there is an imperative need for development of location specific profitable integrated farming system model (IFS) to enhance the farm productivity, soil fertility, income from unit area of land and sustainability.

METHODOLOGY

Field experiments were conducted to identify and optimize the component linkages in integrated farming systems for irrigated upland of Kancheepuram distirct at Krishi Vigyan Kendra, Tamil Nadu Veterinary and Animal Sciences University, Kattupakkam. Field experiments to evolving the best combination of integrated farming system with conventional cropping alone, improved cropping system + dairy + vermicompost, improved cropping system + dairy + vermicompost + turkey, improved cropping system+ dairy + vermicompost + Japanese quail, improved cropping system + fish + rhodo white chicken layers was carried out during 2013–14 in non-replicated trial. Cropping sequences tried were Bhendi–groundnut in 0.4 ha in conventional cropping system and (*i*) Maize + fodder cowpea–groundnut and (*ii*) Bhendi–sunflower each in 0.123 ha and (*iii*) Perennial cumbu napier grass (COCN-4) + hedge lucerne in 0.124 ha in integrated farming system. The remaining area of 0.029 ha was allotted to other allied components in the farming system. Out of 0.029 ha, dairy unit (2 cows + 2 calves), vermicompost unit (3.0 tonnes production capacity), turkey unit (100 nos per annum), Japanese quail unit (2,500 nos per annum) and fish pond unit (160 fingerlings stocking density) were allotted with an area of 0.004 ha, 0.003 ha, 0.004 ha, 0.002 ha and 0.016 ha, respectively. The system productivity, economic returns and employment generation of different farming system were evaluated.

RESULTS

Experimental results revealed that integration of improved cropping system, viz. Maize + fodder cowpea–groundnut, Bhendi–sunflower and Perennial cumbu napier grass (COCN-4) + hedge lucerne and allied components, viz. dairy, vermicompost and Japanese quail recorded higher system productivity by means of groundnut pod equivalent yield of 10,168 kg 0.4/ha than conventional cropping system alone during the study (Table 1). Higher net return of ₹ 228,855 0.4/ha/year and benefit cost ratio of 2.48, the higher per day return of ₹ 627 and highest employment opportunity of 392 man days from 0.4 ha for farm family were recorded in improved cropping system with dairy + vermicompost + Japanese quail during 2013–14, whereas the lowest net return, benefit cost ratio and employment generation was registered with conventional cropping system alone. The recycling of manure produced in the system through integration of dairy components reduced the investment on vermicompost and also contributed to increased nutrient availability leading to a decrease in cost of cultivation and increased the net return

Table 1. System productivity (Groundnut pod equivalent yield), economic returns and employment generation of integrated farming system during 2013–2014

Farming system	System productivity (kg 0.4/ha)	Net return (₹ 0.4/ha)	B : C ratio	Per day return	Employment generation (man days 0.4/ha)
FS_1	2,023	34,848	2.12	174	194
FS_2	7,765	167,658	2.42	459	370
FS_3	10,013	184,539	2.34	505	390
FS_4	10,168	228,855	2.48	627	392
FS_5	5,158	115,423	2.47	316	251

Data not statistically analysed.
FS_1- Conventional cropping system with crop alone – 0.4 ha
FS_2- Cropping system (CS) + Dairy + Vermicompost – 0.4 ha
FS_3- CS + Dairy + Vermicompost + Turkey – 0.4 ha
FS_4- CS + Dairy + Vermicompost +Japanese Quail – 0.4 ha
FS_5- CS + Fish + Rhodo white chicken (Layers) – 0.4 ha

and benefit cost ratio during both the years of study. Thus, crop and livestock compatibility influenced the productivity and sustainability of the integrated farming systems. Higher biomass production of cropping systems and fodder crops in the farming system might have led to higher productivity and greater residue addition which in turn added more nutrients thereby enhancing the soil fertility.

CONCLUSION

Based on the study, it could be concluded that for enhancing and sustaining the productivity, net returns, per day return, employment generation and soil fertility with effective recycling, integration of improved cropping system with allied components, viz. dairy, vermicompost and Japanese quail for the irrigated upland of Kancheepuram district of Tamil Nadu having 0.4 ha farm can be recommended.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Effect of weed competition and establishment methodsin direct seeded rice

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Rice is the most important staple food crop of India grown over an area of 42.2 million hectares with a production of 84.74 million tonnes. Many rice farmers in Southeast Asian countries shift from transplanting to direct-seeding in rice crop due to paucity of water. Direct production system is subject to greater weed pressure than conventional production systems (Mahajan and Chauhan, 2013). Studies to evaluate the effect of critical period of weed interference in direct seeded rice in wet and dry method of establishment are very meager. Thus, this study was carried out to find the effect of weed competition indirect seeded rice with two different establishment methods in coastal ecosystem of Karaikal, Puducherry UT, India.

METHODOLOGY

A field experiment was conducted under puddled irrigated condition from September, 2014 to January, 2015 at Pandit Jawaharlal Nehru College of Agriculture and Research Institute, Karaikal, Puducherry U.T. The experiment was laid out in split plot design with two crop establishment methods and four weed competition periods inthree replications. The main plot has crop establishment methods *viz.*,dry and wet sowing. Sub plots are assigned with various weed competition periods for 15, 30, 45 and 60 days after sowing (DAS) of crop growth.The data on weed density and dry weight was transformed using $\sqrt{x+0.5}$ to normalize their distribution before analysis. The weed index was calculated by using the standard formulae. The experimental data were subjected to statistical scrutiny as per the procedures given by Panse and Sukhatme (1967).

RESULTS

Major weeds observed in experimental field were: *Echinochloa crusgalli* L., *Echinochloa colona* L., *Cyperus iria* L., *Cyperus difformis* L. among monocots, *Eclipta alba* L., *Marselia quadrifolia* L., and *Bergia capensis* L. among dicot weeds. The total weed density and dry weight was not significantly influenced by either wet or dry sowing of seeds in puddled condition. However, weedy competition periods significantly influenced the weed density and dry weight (Table 1). Higher density of weeds was recorded when the weedy condition was maintained up to 60 DAS and then weed free. Critical period of crop-weed competition varied from 15 to 60 DAS when weeding resulted in highest economic returns in wet seeded rice (Mukherjee *et al*., 2008). Highest grain yield of 4.98 t/ha was recorded where the plots were maintained weed free throughout the crop period except the initial 15 DAS. It was followed by the weedy condition maintained for early 30 and 45 days of crop growth (4.61 and 4.23 t/ha, respectively). However, significantly lower

Table 1. Effect of method of establishment and weed competition on weed and direct seed rice

Treatments	Total weed density (no./ m^2)	Total weed dry weight (g/ m^2)	Productive tillers/m^2	Grainyield (t/ha)	Weed index
Method of establishment					
Wet	6.4(49.5)	4.3(18.6)	374.8	4.44	–
Dry	8.3(71.8)	5.1(25.2)	359.8	4.01	9.7
CD (P= 0.05)	NS	NS	NS	NS	NA
Weedy competition					
Weedy condition up to 15 DAS and then weed free	3.4(11.3)	2.4(4.7)	399.0	4.98	–
Weedy condition up to 30 DAS and then weed free	6.5(46.0)	4.0(13.8)	384.2	4.61	7.4
Weedy condition up to 45 DAS and then weed free	8.7(76.7)	4.9(21.0)	362.0	4.23	15.1
Weedy condition up to 60 DAS and then weed free	10.7(108.7)	7.4(48.2)	324.0	3.08	38.2
CD (P= 0.05)	3.67	1.51	51.0	0.36	NA

Data subjected to Öx+0.5 transformation. Figures in parentheses are original values. DAS- Days after sowing; NA- Statistically not analyzed.

grain yield (3.08 t/ha) was recorded in the plots maintained weedy for initial 60 days of crop growth. However, yield loss increased linearly with period of weedy condition existed from sowing to maturity.

CONCLUSION

It is inferred from the results that maintaining weed free environment during critical weed competition period resulted in higher rice yield under coastal ecosystem of Karaikal, Puducherry UT.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Impact of salinity on physiological and biochemical traits in pearl millet

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Salinity is one of the most severe environmental factors limiting the productivity of agricultural crops in arid and semi-arid regions. Accumulation of excess salts in the rhizospheric environment results in disturbed metabolic processes which commonly manifested in nutrient imbalance, reduced nutrient uptake including K^+, specific ion toxicity, distinctly changed concentrations of key biomolecules, inhibited plant growth to osmotic stress and ultimately poor productivity. Salinity management through improved irrigation techniques is viable option but quite expensive one. Therefore, crop improvement could be less expensive and a more sustainable solution for agricultural use of salt affected soils (Krishnamurthy *et al.,* 2007). Pearl millet (*Pennisetum glaucum*) is a warm season coarse grain cereal generally considered as fairly tolerant to salinity. Salt tolerance has been identified as a developmentally regulated, stage-specific phenomenon. Variation in whole-plant reaction to salinity provides the most efficient initial screening for salinity tolerance. The present investigation was carried out to explore the genotypic variability in pearl millet and to identify the key physiological and biochemical traits influencing crop growth and development during the stress periods.

METHODOLOGY

A set of twelve pearl millet hybrids was procured from ICRISAT, Hyderabad and CCS HAU, Hisar. Five hybrids from ICRISAT involved high biomass pollinator germplasm and were earlier identified for having high green/dry biomass for forage purpose, while seven hybrids from CCSHAU Hisar were dual purpose hybrids (bred for both grain yield and fodder purpose). ICRISAT hybrids reported 45–55 tonnes/ha of green biomass and 15–20 tonnes/ha of dry biomass at 80-90 days after planting, based on multi-location evaluation in 2014 in India (Gupta *et al.*, 2015). This set of hybrids was sown in clay/porcelain pots of 20 kg capacity filled with 16 kg saline soil (EC_e 7.9 dS/m) having field capacity 28% (v/v), bulk density 1.45 g/cc and porosity 40% at ICAR-Central Soil Salinity Research Institute (CSSRI), Karnal during *Kharif* 2015 in a randomized complete block design replicated thrice. Nine seeds of each hybrid were sown in three equally spaced hills in each pot and irrigated with deionized water to field capacity previously estimated for the soil. Osmotic stress was imposed by applying saline irrigation water of EC_{iw} 3, 6 and 9 dSm^1 along with best available water (BAW) having EC_{iw} 0.6 dS/m (control). The data on physiological and biochemical parameters by taking fully expanded leaves separately for measurement of chlorophyll content, total soluble sugars, proline and protein content. Ionic (Na^+ and K^+) content were determined from well ground plant material using di-acid mixture (HNO_3 : $HClO_4$ 3 : 1) onflame photometer (PFP7, Jenway, Bibby Scientific, UK).

RESULTS

At final harvest, the resultant soil salinity (EC_e) withsaline irrigation water treatments was found to be 6.36, 7.96 and 9.68 dS/m at EC_{iw} of 3, 6 and 9 dS/m as against the EC_e of 4.4 dS/m in the BAW treated pots (control). Pearlmillet hybrid ICMA 01888 × IP 6140 and HHB 272 maintained their RWC content more than 80% at EC_{iw} 9 dS/m closely followed HHB 226 and ICMA 00444 × IP 13150 (Table 1). Maximum reduction (42.6%) in RWC was noticed in ICMA 03222 × ICMV 05777 at EC_{iw} 9 dS/m. Membrane injury increased with the increase in saline irrigation level. However, a gradual decrease was recorded in chlorophyll content. Overall, ICRISAT hybrids showed lower per cent injury (< 30%) and higher chlorophyll concentration (>35 µg/ml) at EC_{iw} 9 dS/m. Increased proline accumulation was observed in all the test hybrids with increasing irrigation water. Highest proline content (7.29 mg/g FW) was observed in ICMA 00444 × IP 6202 while lowest (5.34 mg/g FW) was recorded with HHB 67 IMP. The proline accumulation was more in CCSHAU hybrids compared to ICRISAT hybrids (Table 1). Mean yield reduction of 16.0, 37.1 and 64.4 per cent was recorded when saline irrigation water of 3, 6 and 9 dS/m was applied in comparison to BAW (14.43 g/plant). The performance of CCSHAU hybrids was relatively better with increasing irrigation water salinity. The mean per cent reduction in grain yield of pearl millet hybrids collected form CCSHAU hybrids was 15.0, 30.3 and 58.5 EC_{iw} of 3, 6 and 9 dS/m, respectively while the corresponding values were 17.5, 47.8 and 67.5 per cent, respectively for ICRISAT hybrids. Pearl millet hybrids HHB 223, HHB 272, HHB 146, ICMA 004444 × IP 13150 and ICMA 03222 × ICMV 05777 were found to the promising ones showing lesser yield reduction and lower Na/K ratio in the shoot with the increasing irrigation water salinity.

Table 1. Effect of irrigation water salinity on the physiological and biochemical parameters in pearl millet hybrids

Hybrid	Relative water content (%)		Membrane injury (%)		Chlorophyll (µg/ml)		Proline (mg/g FW)	
	Control	EC_{iw}9 dS/m	Control	EC_{iw}9 dS/m	Control	EC_{iw}9 dS/m	Control	EC_{iw}9 dS/m
ICRISAT								
ICMA 00444 × IP 6202	90.35	70.33	2.73	32.11	52.43	37.15	1.71	7.29
ICMA 03222 × ICMV 05777	95.75	42.57	6.63	26.81	54.38	39.99	1.49	5.36
ICMA 00999 × IP 6202	89.32	75.40	7.39	31.89	54.03	34.92	1.35	5.95
ICMA 01888 × IP 6140	89.10	80.14	6.84	31.41	52.21	36.08	1.37	6.44
ICMA 00444 × IP 13150	93.04	75.44	7.31	31.23	53.70	33.75	1.07	6.57
Mean	91.51	68.78	6.18	30.69	53.35	36.38	1.40	6.32
CCSHAU								
HHB 67 IMP	88.82	69.55	8.08	32.53	53.64	36.66	0.87	5.44
HHB 146	96.76	73.03	8.42	31.35	53.66	28.37	1.73	7.17
HHB 197	87.51	68.90	5.84	29.33	53.66	31.50	1.31	6.55
HHB 226	91.56	76.68	5.45	42.66	53.68	34.73	1.22	6.34
HHB 223	92.66	72.60	9.53	34.96	53.72	29.52	1.41	7.12
HHB 234	90.05	64.08	10.63	41.08	53.69	35.64	1.61	7.13
HHB 272	92.49	78.87	7.12	38.35	61.56	35.06	0.64	5.74
Mean	90.85	72.23	7.71	37.28	55.26	33.29	1.24	6.58

CONCLUSION

Substantial variation for salinity tolerance exists in between pearl millet hybrids owing to variable physiological and biochemical response under different salinity irrigation water. These can be used as useful selection criteria for identifying salt tolerant hybrids for improving the adaptation as well as yield potential of this crop under arid and semi-arid climatic conditions.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Management of sweet corn for multiple purposes in southern Lao PDR

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In the lowlands of southern Lao PDR, the farming system is based on rainfed rice production in the wet season (May–October), with land usually left fallow in the dry season (November–April). Where supplemental irrigation is available, farmers often add a cash crop into their system in the dry season (Vote *et al*., 2015). Increasing the cropping intensity by introducing cash crop cultivation in the dry season has several potential impacts; it can improve farmers' incomes, provide a risk management strategy, contribute to the nutrient balance for wet season rice productivity, and forms a key link in the integrated farming system by providing a source of animal feed in the dry season. Alternative management options for the dry season crop can impact on these different factors. This paper describes the effect of staggered planting time of sweet corn on cob production and the interaction with stover production for animal feed.

METHODOLOGY

Staggered planting of sweet corn was tested in on-farm trials in Savannakhet and Champassak provinces in southern Laos in the dry seasons of 2015 (10 farms) and 2016 (7 farms). Farmers were provided with good quality seed, and managed their plots according to their normal practice apart from time of planting. Cob and stover fresh weight were weighed at harvest. A combined analysis of data was performed for five main average planting times (8th December, 22nd December, 31st December, 7th January and 17th January).

RESULTS

Mean cob and stover fresh weight was highest for the first planting date in early December, and subsequently declined after that for all dates (Fig. 1). There was homogeneity of variances, as assessed by Levene's test for equality of variances ($p = 0.5$ and 0.67 for cob fresh weight and stover fresh weight respectively). The production of cob and stover fresh weight was significantly different for different planting times; for cob fresh weight, $F(4, 77) = 3.26$, $p = 0.016$, and for stover fresh weight, $F(4, 77) = 2.8$, $p = 0.032$. There was a significant decrease in cob fresh weight between the first planting date (8th December) and the second ($p<0.05$) and fifth ($p<0.1$) planting dates. Similarly for stover fresh weight, there was a significant decrease in production between the first planting and the second ($p<0.05$), third ($p<0.05$) and fifth plantings ($p<0.1$). This is likely due to later plantings experiencing high temperatures at crop maturity; when harvest is delayed until later in February or March, plants mature at the hottest time of the year. Water availability is also lower at the end of the dry season if farmers are using ponds or shallow groundwater (Vote *et al*. 2015), and farmers risk running out of water by the end of the dry season. However, staggered planting of sweet corn means that animal feed (stover) is available more regularly at the end of the dry season over a

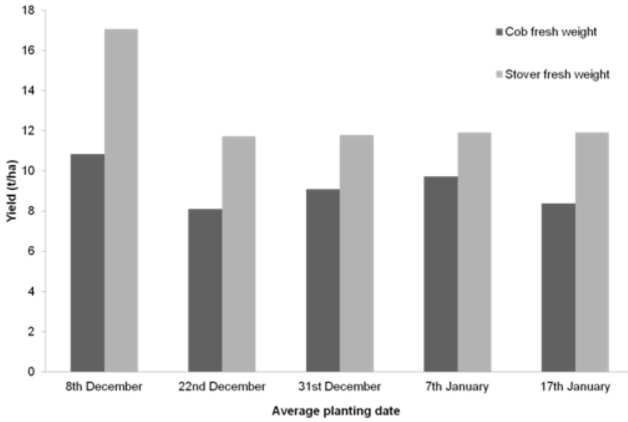

Fig. 1. Mean cob and stover fresh weights for staggered planting dates

period of around one month, when alternative feed resources are very low. Based on general feed requirement recommendations of fresh matter equivalent to 15% of bodyweight (Nampanya *et al*., 2014), a 200 kg animal requires around 30 kg fresh stover/day if being exclusively fed maize stover. Based on production rates in Fig. 1, this requires around 18–26 m^2 land area per day, or 123–169 m^2/week, with a larger area required as the season progresses. As farmers use stover as a supplementary feed, with supplementation usually equating to around 25–30% of a daily diet, this land area could potentially maintain around four animals at the end of the dry season, contributing to improved animal health and body condition compared to animals without a supplementary feed source.

CONCLUSION

Dry season crop production offers farmers an additional income stream, and if managed suitably can also contribute to livestock production. Managing sweet corn planting times by spacing planting dates by 7–14 days was found to have a significant effect on both cob and stover yield, with early December planting dates giving the highest yields. This is due to high temperatures at the end of the season when planting dates are delayed. However, this method offers a livestock feed source at the end of the dry season when other feed resources are scarce, and so farmers may benefit by maintaining animal health and condition at this critical time of the year.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

A farming system approach to address under nutrition

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Agricultural interventions in India from the 1960s till early 1990s were focused on increasing food grain production and productivity to attain self-sufficiency. However, increasing food production alone cannot address the issue of under-nutrition, unless there is a nutrition focus and the poorest have access to a diversified basket of nutritious foods. Therefore, agricultural interventions in the development paradigm need to be more nutrition-sensitive, with a greater focus on nutrient-dense foods with high levels of bioavailability, i.e. the proportion of micronutrients capable of being absorbed by the body (Das *et al.* 2014). According to M.S. Swaminathan, farming system for nutrition can be the answer and he has defined it as 'the introduction of agricultural remedies to the nutritional maladies prevailing in an area through mainstreaming nutritional criteria in the selection of the components of a farming system involving crops, farm animals and wherever feasible, fish' (Nagarajan *et al*., 2014). The proposed Farming system for Nutrition

(FSN) is an interventional approach that includes a combination of sustainable agricultural remedies involving improved crop production practices, bio-fortification, promotion of backyard and community nutrition gardens of fruits and vegetables, livestock and poultry development and setting up of small-scale fisheries, accompanied by nutrition literacy, as stimulant for rendering consistent output of higher income and better nutrition. The underlying assumption is that nutritional outcomes in a rural population improves through production and own consumption of nutrition-rich diverse diets or alternatively through higher incomes from sale of agricultural produce which is in turn used for addition or enrichment of diet with multi-nutrition-rich foods to often consumed staples as the pathways to connect agriculture and nutrition. Further, attention has to be paid to women's work in agriculture and the gender aspects (Gillespie *et al.*, 2012).

METHODOLOGY

The study is underway in Koraput District (18.80 to 18.82°N and 82.70 to 82.72°E) of Odisha and in Wardha District (20° 18′ to 21° 21′ N. and 78° 4′ to 79° 15′ E) in the Vidarbha region of Maharashtra. The locations were purposively selected due to their character contrast in agro-climatic and socio-economic condition, size of landholdings, agricultural practices and consumption pattern. Although agro-ecologically the two study intervention locations are different, both of them are characterized by rain-fed farming and high levels of malnutrition. Seven villages from one block of Koraput District (658 households with population of 2,845) and five villages from two blocks of Wardha District (556 households with population of 2,254) were identiûed as core villages for the study starting from the year 2013. Detailed baseline survey of households was undertaken to understand the socio-economic profile, pattern of agriculture and nutrition status in the project villages through well-structured questionnaires, participatory rural appraisal (PRA) and focus group discussions. Technology platform of local research institutions and stakeholder platform of government and civil society organizations have been constituted at both locations to leverage knowledge and intervention partnerships.

RESULTS

The baseline survey highlighted lack of dietary diversity and high levels of under nutrition including anaemia. With the baseline survey results in hand the core interventions to increase availability of nutrient dense food, were identified in discussion with the community. *Crop Husbandry interventions:* The crop based interventions under FSN basically focus on promotion of nutrient dense crops like millets and pulses, crop diversification through varietal substitution and crop intensification for landholders. Varietal substitution through introduction of nutrient dense improved varieties of predominant crops at both the study sites was carried out with improved package of practices in order to increase the production and productivity, thereby increasing nutrient availability per farm household (Table 1). Similarly,

Table 1. Details of crop based FSN interventions (2015–16)

Component	Area (ha)	Improved variety	Yield (kg/ha)	±Additional nutrient harvested (kg/ha)	Total expenditure (₹/ha)	Gross return (₹/ha)	Net return (₹/ha)	B : C ratio
Koraput								
Pre summer								
Green gram	5	SML-668	486	15	12,587	27,360	14,773	2.17
Black gram	3	TK94-2	351	12	11,500	24,570	13,070	2.14
Kharif								
Finger millet	4.4	GPU-67	2067	35	20,800	34,110	13,310	1.64
Maize + Pigeon pea	4.4	NHM-51 (maize) NTL-724 (pigeon pea)	7,729	3,669	27,600	77,303	49,703	2.80
Wardha								
Kharif								
Sorghum	16.4	CSV-20	330	34	17,655	6,600*	-	0.37
Red gram	8.8	NTL-900	1533	16	25,070	1,22,600	97,530	4.89
Rabi								
Wheat	35	AKAW-4210	1560	28	22,980	28,080	5,100	1.22
Chick pea/gram	8	Jackie-9218	898	20	23,123	49,363	26,240	2.13
Onion	2	Bhima super	6320	55	21,500	94,800	73,300	4.41

± Additional nutrients harvested (mainly in terms of protein) indicates the additional amount farmers will get from cultivation of improved varieties as compared to the traditional varieties

*crop loss due to dry spell during germination phase crop intensification through intercropping systems such as maize-pigeon pea intercropping aimed at increasing land use efficiency as well as greater monetary income. *Nutrition garden interventions:* The basic principle of nutrition garden intervention is to create awareness about importance of consuming fruits and vegetables as well as promotion of nutrition literacy among both producers and consumers. Seed kits consisting of different leafy, fruit and root vegetables based on a seasonal calendar along with planting materials of tubers and plants of fruit bearing plants were distributed at household level. Where backyard land is limited, some households grow the vegetables on their farm land. A leaflet on preparation of nutrition garden, nutritional value of different nutri-garden produce along with their recipes was distributed to households. Data on production and consumption from the nutrition gardens is collected on regular basis for analysis. Produce from school nutrition gardens in the villages goes into the midday meal prepared for the school children. *Animal husbandry interventions:* Regular animal health camps to improve health and productivity of livestock and fodder for livestock are an important component of the approach. Further, poultry farming has been introduced for landless and marginal farmer households as a means to enhance nutrition and provide livelihood support in Wardha; in Koraput, household and community based fish farming is being promoted based on availability of farm ponds. *Nutrition awareness interventions:* Underlying the entire approach is creating awareness in the community on leveraging their main source of livelihood, i.e. agriculture to improve their nutrition status along with attention to aspects of WASH and health of women and children in particular. This is a continuous effort being undertaken at individual, household and institutional levels. Currently, a participatory research is underway to train champions at the community level to make the effort sustainable.

CONCLUSION

The present study of area specific FSN approach offers an opportunity to capture the extent of productivity and profitability enhancement in the farming system coupled with greater nutrition awareness contributing to more intake of nutritionally rich food, and enhanced spending by the household towards balanced diet. This is expected to lead to greater dietary diversity and improved nutrition outcomes. Efforts are underway to build necessary linkages to ensure sustainability of the approach. The study is on-going and emerging evidence on effectively linking agriculture to nutritional outcomes could be the basis for replication in other agro-ecological regions of the country.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Promising genotypes of maize suitable for varying irrigation regimes and fertilizer management in maize-wheat cropping system

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High-yielding varieties of crops and the increased use of fertilizers and irrigation have collectively contributed to Green Revolution in India. However, the excessive and indiscriminate use of water and fertilizers has often resulted in adverse effect on the soil health, environmental pollution and productivity of crop. Rapid population increase in synergy with factors such as low soil fertility and climate variability are putting enormous pressure on natural resource, i.e. land, water, nutrients etc. The issue of water management has been a key factor to bring about steady progress in agricultural production. Maize as a gross feeder requires substantial amount of soil nutrients especially nitrogen (N) for growth and development. Nitrogen is an essential macronutrient required by cereals and it is a major yield determining nutrient required for maize production. It also enhances and facilitates the utilization of other nutrients like phosphorus, potassium and other elements. Nitrogen is the most vulnerable of all the plant nutrients in the soil; it is highly volatile and readily leached. Developing plant varieties that are better users of available nutrients coupled with appropriate soil management practices remains a reliable method of combating problems of nutrient deficiencies in the tropics. One most efficient way of replenishing and reversing soil nutrient depletion is through the application of mineral fertilizer. Maize genotypes differ in the rate of nitrogen absorption and utilization. Efficient use of nitrogen fertilizer in maize production enhances increased grain yield, appreciable economic return and reduced ground water pollution. The study was carried out to investigate the response of maize to five maize genotypes, The objective of this study was to evaluate the responses of five maize varieties under different fertilizer and irrigation levels as well as their interactions with a view to understand their performances under the varying fertility environments.

METHODOLOGY

The field experiment was conducted during *Kharif* (June-November) season of 2015 at Research farm, ICAR-Indian Agricultural Research Institute, New Delhi. The experimental field is situated at 28°35′ N latitude and 77°12′ E longitude. The altitude is of about 228.61 m above mean sea level (MSL). It comes under semi-arid and subtropical climate with very hot dry summers and cold winters. The total rainfall during the period of experimentation was 395.3 mm. The soil of the experimental site was sandy loam, low in OC (0.41%) and available N (176.7 kg/ha), medium in P (11.6 kg/ha) and K (178.5 kg/ha), having pH (7.4) and EC (0.31 dS/m). The experiment was conducted using factorial SPD with three replications. There were four factors for the study. First factor was irrigation x crop establishment methods in main plots and Fertiliser x varieties in sub plots. Total 80 treatments are formed by combination of above four factors.

RESULTS

Results showed that grain yield of maize genotypes were affected by different irrigation regimes and nutrient levels. The yield obtained with 50% RDF was less compared with the yield obtained with 100% RDF. However, the highest grain yield of (4.27 t/ha) was recorded in genotype, AWLH2 with 100% of RDF followed by HPQM-9 (3.67 t/ha) and obtained yield was 16.35% higher. An overall variation ranging from 14.5 to 46% was recorded with increased nutrient level from 50% to 100%. Amongst different irrigation regimes studied, assured irrigation (25% DASM) recorded the highest grain yield in all genotypes of maize followed by 50% DASM, 75% DASM and rainfed. An overall reduction of 54%, 51%, 44%, 37.5% and 31.0% was recorded as the irrigation level varied from 25% DASM to, 50% DASM, 75% DASM and rainfed in five genotypes PEEHM 5, HPQM-9, AH-7002, AH-7005 and AWLH 2 respectively. Water stress changed the relation between leaf water potential and relative water content of all genotypes so that stressed plants had lower water potentials than control at the same leaf relative water content (Atteya, 2003). Canopy development is sensitive to water deficit. It affects not only the production of the grains but also the whole process of growth of all organs of the plants and metabolism. Plant growth and development are affected by water stress affecting physiological and biochemical processes, for example, ion uptake, photosynthesis, respiration and translocation.

Table 1. Yield (t/ha) of different maize genotypes as affected under varying irrigation and fertiliser levels

Variety	25% DASM	50% DASM	75% DASM	Rainfed (lifesaving)	50% RDF	100% RDF
PEEHM 5	4.02	3.10	2.82	2.61	2.93	3.35
HPQM-9	4.33	3.68	3.13	2.87	3.33	3.67
AH-7002	4.61	4.53	3.79	3.20	3.73	4.27
AH-7005	3.74	3.15	2.97	2.72	3.01	3.28
AWLH2	3.59	3.47	3.00	2.75	3.15	3.55
Mean	4.06	3.59	3.14	2.83	3.23	3.65

CONCLUSION

It could be concluded that there was comparatively less reduction in grain yield in AH-7005 (37.5%) and AWLH 2 (31.0%) genotypes compared to other genotypes due to water stress (rainfed) and amongst the nutrient response, PEEHM 5 and AWLH2 were highly responsive to 100% RDF as resulted in higher yield increase.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Resource use efficiency in yam production in Ekiti State, Nigeria

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The study examined the resource use efficiency in yam production in Ekiti State, Nigeria. A multistage simple random sampling technique was used to select 120 respondents using a well structured questionnaire. The study examined the socio-economic characteristics of the farmers, the system of land ownership, the constraints the yam farmers faced as well as the technical efficiency of the farmers. Descriptive statistics such as frequency counts and percentage was used while the inferential statistics used was stochastic frontier function to estimate the technical efficiency. The findings revealed that the study area is dominated by age, male, married, experienced and small holder farmers who mostly attained secondary school level of education. The mean and maximum technical efficiency was 0.87 and 0.99, respectively. The study recommended that government should provide adequate extension and supportive services with a view of improving farming techniques with technological innovation and farm inputs should be made available at highly subsidized rates through adequate and efficient distribution to the farmers.

Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Weed wiper–A tool for drudgery reduction of hill farmer and resource conservation

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In the North-Western Himalayas, fingermillet, horsegram (during *kharif*), wheat and lentil (during *rabi*) are the most important rainfed crops. Weed infestation is a major problem in these crops which lead to reduction in productivity In addition, broadcasting method of sowing, non-availability of specific herbicides and negligible use of post-emergence herbicides in these crops makes the situation more challenging. In general, weeding is done manually by women in hills, which is time consuming and labour intensive. Effectiveness, efficiency and economics broadly make chemical weed control methods more advantageous than cultural and physical methods. The prevalent herbicide application equipments are very expensive and needs to be carefully calibrated. Thus to reduce the labour and drudgery of farm women, save time and control a variety of weeds, non-selective herbicide application in between the crop rows and in a protected way through small tools without any injury to crop plants can be a good option. Keeping these points in view, a simple, low-cost, light weight hand-held weed wiper was developed, which applies herbicide solution in between crop rows by direct contact with an impregnated absorbent surface without damaging the crops. The objective of the study was to calibrate the weed wiper for herbicide dose with volume of water and see the weed control efficiency, yield and economics in fingermillet, horsegram, wheat and lentil crops.

METHODOLOGY

The field experiment was conducted during 2013–14 and 2014–15 at the Experimental Farm of ICAR-Vivekananda

Table 1. Weed control efficiency and labour required in different weed control treatments

Crop	Weed control efficiency (%)		Labour requirement (man hours/ha)		Labour reduction in WW over
	WW	MW	WW	MW	MW
Finger millet	39	93	55	1602	96.6
Wheat	64	95	41	558	92.7
Horsegram	60	90	34	866	96.1
Lentil	62	91	45	885	94.9
Average	56	92	44	978	95.5

Table 2. Yield, cost and benefit ratio under different weed control treatments in different crops

Crop	Grain yield (kg/ha)			Cost of weed control (% of total cost of cultivation)		B : C ratio		
	WC	WW	MW	WW	MW	WC	WW	MW
Finger millet	517	2,051	2,965	9.9	60.3	0.53	1.61	0.91
Wheat	1,684	2,583	2,955	8.4	36.5	1.5	1.99	1.52
Horsegram	761	1,337	1,586	6.6	43.2	2.12	3.12	2.1
Lentil	607	807	923	9.0	48.9	1.05	1.22	0.75
Average	892	1,695	2,107	8.5	47.2	1.30	1.99	1.32

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 three weed control treatments, i.e. weedy check (WC), weed control through weed wiper (WW) and manual weeding (MW). In weed wiper treatment, non-selective herbicide, glyphosate 41% SL, was applied for post-emergence weed control through the newly developed prototype while in manual weeding, one manual hoeing was done to control the weeds. The weed wiper and manual weeding treatments were applied at 25, 55, 30 and 60 days after sowing in fingermillet, wheat, horsegram and lentil, respectively. All the four crops were sown as per recommended package of practices.

RESULTS

In weed wiper treatment, the herbicide dose used was 1.975, 1.792, 1.692 and 2.013 l/ha in fingermillet, wheat, horsegram and lentil, respectively with corresponding values for volume of water used being 395, 358, 338 and 403 l/ha, respectively. The capacity of weed wiper was 0.018, 0.024, 0.031 and 0.024 ha/h in fingermillet, wheat, horsegram and lentil, respectively with 55, 41, 34 and 45 man hours/ha labour requirement. Although the weed control efficiency was higher in manual weeding (92%) than weed wiper (56%) but the former required huge labour (978 man hours/ha) (Table 1). In contrast, use of weed wiper reduced the labour requirement by 95.5% as compared to manual weeding. Stroud and Kempen (1989) had tried wick/wiper applicators to control weedy rice in rice crop by applying glyphosate. Manual weeding recorded highest grain yield in all the crops and use of weed wiper resulted into 297, 53, 76 and 33% higher yield than control in fingermillet, wheat, horsegram and lentil, respectively (Table 2). On an average there was 90% increase in grain yield due to weed wiper over control. Although manual weeding recorded 24% higher yield than weed wiper but it incurred very high cost of cultivation. For weed control, manual weeding contributed 47.2% of the total cost of cultivation as compared to only 8.5% in case of weed wiper. The cost of weeding in these crops with wiper was found 89.9% less as compared to manual weeding. Thus, weed wiper proved very economical in terms of weed control and gave highest B : C ratio (1.61, 1.99, 3.12 and 1.22 in fingermillet, wheat, horsegram and lentil, respectively). Proportionately more increase in cost of cultivation than increase in grain yield resulted into low B : C ratio (1.32) in manual weeding.

CONCLUSION

Relatively simple, low-cost, light weight hand-held weed wiper appears to be new tool for drudgery reduction saving labour and time. It was also found to be effective in terms of yield with favourable economics for weed control. The prospect warrants accelerated investigation and follows up.

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Productivity of wheat under preceding legumes and cereals cropping with organic and inorganic nutrition

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In wheat growing zones of India continuous cereal based cropping system and heavy application of inorganic fertilizers deteriorating soil conditions to a great extent. The maize-wheat system in northern plain zoneis becoming less productive due to continuous use of N, P and K anddecline in soil organic carbon, available nutrients and micronutrient. Excessive use of fertilizers and intensive cropping system have led to a substantial decrease in soil organic content and therefore resulted in decline in soil productivity. Use of available organic sources, viz. FYM, vermicompost, leaf manure, biofertilizers etc. improve productivity, grain quality, profitability, soil health and sustainability of wheat based cropping system. Besides including a legume crop in sequence with a cereal crop (wheat) and use of available organic sources may prove beneficial for long-term productivity and sustainability of the system. There are various *kharif* crops (soybean, pearl millet, maize, green gram etc.) suitable for wheat based cropping system. Inclusion or replacement of either of cereal components with suitable pulse crop can help in sustaining the productivity of the system as pulse crop have extensive root system which explores soil mass more thoroughly and are capable of enriching soil resource through leaf litter and symbiotic nitrogen fixation (Kundu*et al.* 2002). Hence the experiment was conducted to study the effect of organic and inorganic sources of nutrient on productivity of wheatgrown after maize and soybean.

METHODOLOGY

A field experiment was conducted at ICAR-IARI during 2009–10 and 2010–11 to evaluate the effect of maize, soybean and maize + soybean on succeeding wheat applied with various fertilizers and organic sources of nutrients. The experiment was conducted in split plot design with three replications. The treatment consisted of three cropping systems–maize–wheat, soybean–wheat and maize + soybean-wheat in main plots and five nutrient levels – control, recommended dose of fertilizers (RDF) (120 kg N, 60 kg P and 40 kg K/ha), 75% nitrogen equivalent through FYM, vermicompost and leaf compost in subplots. Maize, soybean and maize + soybean were sown in July-end with recommended dose of nutrients. Wheat crop received nutrients through various sources as per the treatments.

RESULTS

Grain yield and yield attributes of wheat significantly affected by previous crops and due to application of various fertilizers and organic sources of nutrients (Table 1). Significantly higher yield and yield attributes were obtained when wheat crop grown after soybean in comparison with maize pure and it was at par with maize +soybean. Significantly higher wheat yield and yield attributes were obtained from 50% N equivalent through FYM + 50% recommended dose through fertilizers over RDF and control. This treatment was at par with the application of 75% N equivalent through FYM, vermicompost or leaf compost. Application of 50% N equivalent through FYM + 50% recommended dose through fertilizers to wheat grown after maize + soybean produces significantly higher yield over RDF and 75% N equivalent through leaf compost when wheat

Table 1. Grain yield of wheat (t/ha)

Treatment	Maize–wheat	Soybean–wheat	Maize + soybean–wheat	Mean
Control	3.60	3.87	3.68	3.72
RDF (N,P,K)	4.32	4.77	4.63	4.58
FYM (75% N equivalent)	4.61	4.93	4.87	4.80
Vermicompost (75% N equivalent)	4.70	4.89	4.66	4.75
Leaf compost (75% N equivalent)	4.17	4.42	4.49	4.36
FYM (50% N equivalent) + 50% RDF	4.89	5.08	4.76	4.91
Mean	4.38	4.66	4.51	
CD (P=0.05)				
Cropping system	0.27			
Nutrient level	0.32			
Interaction	0.68			

grown after maize pure and control treatment irrespective of previous crops.

CONCLUSION

Highest grain yield of wheat can be obtained when it isapplied with 50% N equivalent through FYM + 50% recommended dose through fertilizers and grown after soybean.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Conservation tillage influenced the system yields, soil properties and economics of maize based system in *terai*, Nepal

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Agricultural intensification from intensive tillage-based production systems generally has a negative effect on the quality of many of the essential natural resources such as soil, water, terrain, biodiversity and the associated ecosystem services provided by nature (Friedrich *et al*, 2012). Nepalese agriculture is facing a severe problem of land fragmentation, declining labor availability due to out-migration (Karki *et al.* 2015). It has led to the emergence of Conservation Agriculture (CA) as an alternative sustainable agriculture system. Inclusion of legumes with cereals reduces soil erosion increases soil organic matter and available nitrogen content and also smothers weed growth (Giller and Wilson, 1991). However, both of the components have not been reported yet under the maize based system of Nepal. Therefore, to identify the appropriate tillage method with or without residue and intercropping system an experiment was carried out at Rampur, Chitwan, Nepal.

METHODOLOGY

A two seasons experiment was carried out during the summer season of 2014 and completed on winter season of 2015 at National Maize Research Program, Rampur, Chitwan. It was tested in split-split plot design with three factors, of which tillage as main factor having two levels with CT (Conventional tillage) and NT (No tillage), residue as sub factor with RR (Residue removed) and RK (Residue kept) and cropping system as sub-sub factor MS-W (maize + soybean-wheat), M-W (maize–wheat) and S-W (soybean-wheat) replicated three times. In sole maize, planting was done at 75X25cm spacing and in intercropping crop geometry was maintained at 100cm between rows and 50cm between hills and in each hill 2 plants were planted. Soybean was planted at the spacing of 33cm between rows and 10cm between plants i.e 3 rows of soybean in between two rows of maize. Wheat was planted at 20cm between rows and continuous seeding. ANOVA was performed for data analysis using GENSTAT Discovery version.

RESULTS

The system yield was only affected by different cropping systems and the highest yield was found in maize+soybean-wheat and the least was recorded in maize-wheat cropping system. Benefit cost ratio was significantly the highest in no-tilled and residue kept field (Fig 1 and 2). The effect of tillage, residue and soybean was obvious in improving the soil organic matter, total nitrogen and available P_2O_5. Soil organic matter, total nitrogen content and available P_2O_5 were higher in no tilled, residue retained and intercropping of

Table 1. Effects of cropping system on system yield and BC ratio in maize based system, 2014-2015

Treatments	System yield (kg/ha)	BC ratio
Maize+Soybean-Wheat	26808.1	2.35
Maize-Wheat	13282.2	1.25
Soybean-Wheat	20173.2	1.91
F-test	**	**
CD (P=0.05)	2,668.2	0.25

Table 2. Soil properties as affected by tillage, residue and cropping systems at Rampur, 2015

Treatment	SOM%	N%	P_2O_5 (kg/ha)
Tillage method			
Conventional Tillage	3.493	0.157	33.25
No Tillage	3.578	0.167	33.27
F test	**	**	*
CD (P=0.05)	0.006	0.008	0.012
Residue level			
Residue removed	3.502	0.159	33.23
Residue kept	3.571	0.165	33.29
F-test	**	**	**
CD (P=0.05)	0.006	0.008	0.008

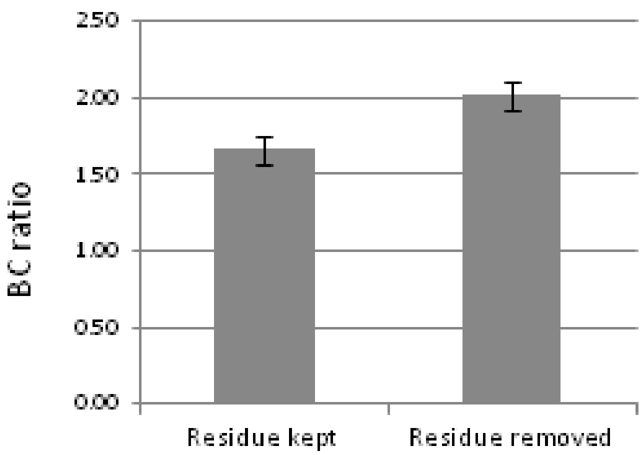

Fig. 2. Effects of cropping systems on benefit cost ratio in maize based system

soybean with maize (Table 2). It might be due to the effect of continuous retention of the maize and wheat residues, since the experiment was carried-out with the same treatments since 2012. Effects of residue retention and inclusion of soybean as an intercrop was obvious in improving the soil organic matter and thereby nutrient status in the experiment. Similar study carried-out by Tsuboa *et al.* (2001) under maize–soybean intercropping compared with maize and bean sole cropping systems, the radiation intercepted was higher in intercrop than the sole crop. Therefore, when it is considered that both maize and beans would be planted in a

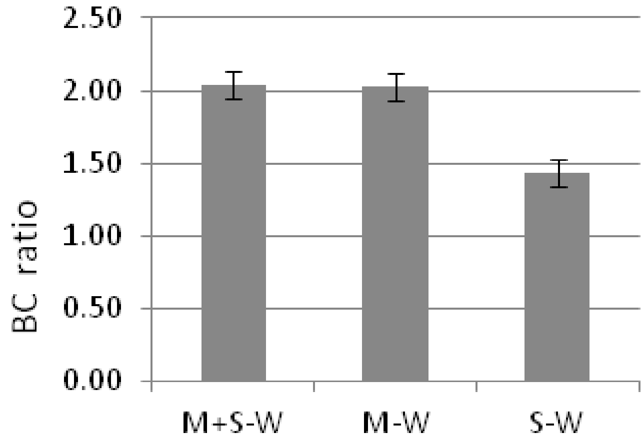

Fig. 1. Effects of residue on benefit cost ratio in maize based system

given area of land, intercropping has more efficient radiation harvests than sole cropping.

CONCLUSION

Intercropping of soybean with maize under not tillage with residue retention tillage) (Conservation agriculture) seems promising technology in maize based systems of Nepal. Integration of other leguminous species with maize under conservation agriculture is the further areas of studies in Nepal. The CA technologies along with various intercropping combinations need to be further verified across the maize growing ecologies.

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Biotic stresses in crops with special reference to weed management

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ABSTRACT

Among the biotic stresses, weeds are major one, which cause around 37% of yield losses. Field studies were conducted at the ICAR-National Institute of Biotic Stress Management, Raipur, with the objectives 1) to minimize the weed severity with agronomic measures and 2) to reduce the yield loss on rice caused by weeds. Under these various experiments were conducted where green manuring with *Sesbania* (*Dhaincha*), weed competitive cultivars, nutrient management and herbicides were tested separately. It was noticed that *Dhaincha* incorporated plots suppressed the weed emergence by 57% of density and 37% of dry weight. Tall varieties suppressed 29.2% of broad leaved weeds, whereas, dwarf stature varieties reduced the grassy weeds by 16.7%. Omission of nutrients significantly increased the weed density and dry weight. Similarly, the highest weed control efficiency (88.5%) was noticed with two hand weeding, whereas, application of herbicides also controlled the weeds considerably resulting in improved crop yield. The results suggest that integrated use of *dhaincha*, competitive cultivars, optimum nutrients and herbicides can help to minimize weed menace and increase rice grain yield.

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.

MATERIALS AND METHODS

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 × 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 h 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 AND DISCUSSION

Effect of Dhaincha on weeds and yield attributes

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. 1a & b).

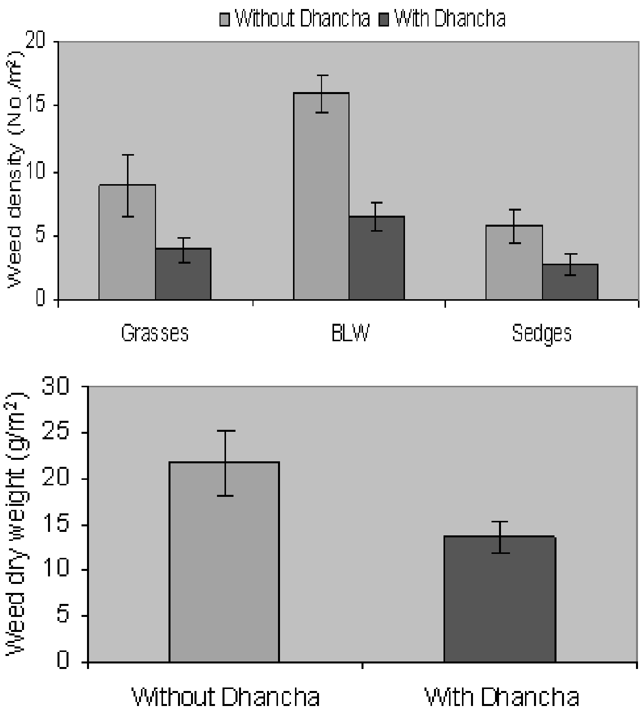

Fig. 1. With and without *Dhaincha* influence the density of weeds (a), and Weed dry weight (b)

Weed suppressing rice cultivars

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% of broad leaved weed suppression over Mahamaya and only 4% suppression with short stature varieties.

Primary nutrients on productivity and weed suppression

Applications of RDF N100$P_2O_5$60K_2O40 hereafter 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).

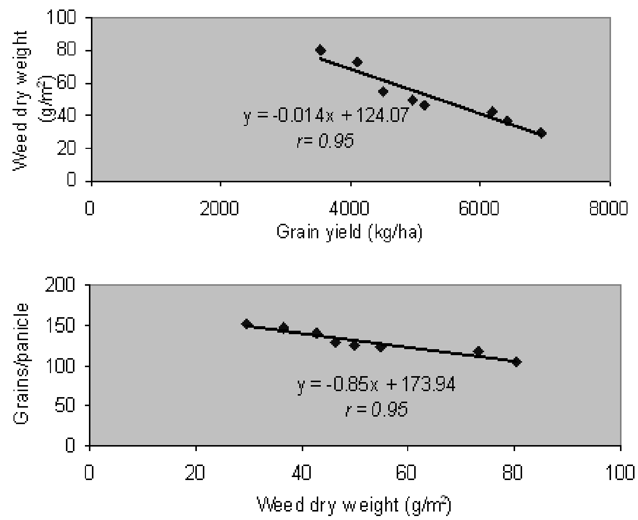

Fig. 2. The relationship between weed dry weight and a) grain yield, and b) grains/panicle in rice

Chemical weed management on productivity and weed dynamics in rice

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).

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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Deficit irrigation improves water productivity of wheat in hot arid region

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To sustain the rapidly growing world population, agricultural production will need to increase (Howell, 2001), yet the portion of fresh water currently available for agriculture (72%) is decreasing (Cai and Rosegrant, 2003). Therefore, sustainable methods to increase crop water productivity (WP) are gaining importanceparticularly in arid and semiarid regions (Debaeke and Aboudrare, 2004). To cope with scarce water supplies, deficit irrigation is an important tool to achieve the goal of reducing irrigation water use and improving crop WP. The nutrient and water interact to influence yield and water productivity of crops. Nitrogen is most limiting nutrient in soils of hot arid region. Drawing on these insights, a 3-year experiment was conducted to assess the effect of different irrigation and N application rates on yield attributes, yield and water productivity of *Triticum aestivum* L.

METHODOLOGY

The experiment was conducted at ICAR-Central Arid Zone Research Institute, Regional Research Station, Bikaner, Rajasthan during *Rabi* 2011–12, 2012–13 and 2013–14. The treatments consisted six irrigation (ETm: ETc 1.0, ETd_1: ETc0.9, ETd_2: ETc 0.8, ETd_3: ETc 0.7, ETd_4: ETc0.6, ETd_5: ETc 0.5) and four nitrogen application (N_1: 0 kg/ha, N_2: 40 kg/ha, N_1: 80 kg/ha, N_1: 120 kg/ha) rates. The experiment was laid out in split–plot design with three replications. The water application rate was assigned to main plot and N application rate was assigned to sub-plots. To compute yield the plants from net plot excluding border rows were harvested and threshed separately. The soil moisture was determined by thermo-gravimetric method. The water productivity was calculated as the ratio of yield to water applied and evapotranspiration. Data were analysed using analysis of variance (ANOVA) (Gomez and Gomez, 1984). In case of significant *F* test in ANOVA with 5% significance level ($P < 0.05$), the means were compared using the least significant difference (LSD) test at á = 0.05.

RESULTS

Irrigation (I), N application (N) ratesand their interaction (I × N) had significant influence ($P < 0.05$) on yield attributes of wheat. Averaged across years and N application rates the spike m^{-2} varied from 171 to 241. The ETd_1 had greatest spike number followed by ETm, ETd_2, ETd_3, ETd_4 and ETd_5. The difference in spike number among ETm, ETd_1 and ETd_2 were non-significant. Application of N significantly increased number of spike. The application of N @ 40, 80 and 120 kg/ha recorded 28, 48 and 52% more spike number compared to no application of N. Number of grain/m^2 showed significant reduction at ETd_3 compared to ETm. Application of N @ 40, 80 and 120 kg/ha had 1.5, 1.9 and 2.1-fold higher grain/m^2 compared to no application of N. The 100-seed weight varied from 3.05 to 3.92 g. The 100-seed weight decreased with an increase in water deficit. Application of N improved weight, however the difference in 100-seed weight between 80 and 120 kg N/ha was non-significant. The differences in yield attribute between N application @ 80 and 120 kg/ha were significant with higher rate of irrigation (ETm, ETd_1 and ETd_2). Seed yield showed significant response (P< 0.05) to I, N and their interaction (I × N). Seed yield (SY) had range: 1,694–3,522 kg/ha. The SY decreased with decreasing water application at ETd_2. Seed yield obtained with ETd_2, ETd_3, ETd_4were 19, 36 and 47% less compared to full irrigation (ETm). Nitrogen application significantly improved seed yield. Seed yield recorded with application of N @ 40, 80, 120 kg/ha had 1.7, 2.3, and 2.4-fold higher seed yield compared to no application of N. The seed yield response to N was modified with the irrigation rate, the difference in seed yield between 80 and 120 kg/ha was significant at ETm and ETd1. However at deficit level (ETc ≤0.7) of irrigation the difference in seed yield between higher levels of N application (80 and 120 kg/ha) were non-significant. The I, N and I × N effects were detected significant for WP. WP measured as ratio of seed yield to total water applied varied from 0.63 to 0.93 kg/m^3. Averaged across N application rates, ET d_2 had highest WP, followed by ET d_1 and ETd_3. The WP recorded with ETd_2 and ETd_3 were significantly higher compared to WP obtained with ETm. Application of N significantly influenced WP. Application of N @ 40, 80, 120 kg/ha had 65, 118 and 127% higher WP compared to no application of N.

CONCLUSION

The results of study suggest that nitrogen and water application rates interact significantly to determine yield attributes yield and water productivity of wheat. The water application @ 80% of full ET demand with N application helps to achieve higher water productivity in hot arid agro ecological conditions of north western Rajasthan.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Priority of inputs in *rabi* sorghum under resource constraints

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Rabi sorghum is an important grain and fodder crop of the country which occupies 4th place after rice, wheat and maize. It is a drought hardy crop of rainfed areas and can be grown on stored soil moisture. The *rabi* sorghum grown with all recommended package of practices (quality seeds, fertilizer, plant protection chemicals, protective irrigation, weed management, thinning and seed treatment with biofertilizer) can help in getting the maximum yields which may not be possible with poor farmers. Hence priority of these inputs based on yield will help farmers to select and use the critical inputs under resource constraints to get possible maximum yield. With this objective in view, the present investigation was planned.

A field experiment was carried out during *rabi* seasons of 2014–15 and 2015–16 at Main Agricultural Research Station, UAS, Dharwad, Karnataka, India to prioritise the critical inputs for *rabi* sorghum under resource constraints. The experiment was laid out in completely randomized block design comprising nine treatments and three replications. The pooled data for two years indicated that yield and yield parameters along with economics differed significantly due to different treatments. The crop grown with full package (all inputs) recorded significantly higher grain yield (46.85 q/ha), fodder yield (8.93 t/ha) and net returns (₹ 76,800/ha) as compared to others. The higher grain yield was mainly due to higher 100-seed weight (2.9 g) over others. The lowest grain yield (23.16 q/ha) was recorded in control plot(without inputs). The percent grain yield reduction in control plot, without inputs, viz., fertilizer, weedicides, plant protection, protective irrigation/thinning and seed treatment with biofertilzers is 28, 18, 14, 13 and 8 respectively. Thus, it could be concluded that the priority inputs are fertilizer, weedicides, plant protection, protective irrigation/thinning and seed treatment with biofertilzers for getting maximum yield and net returns in *rabi* sorghum.

Key words: *Rabi* sorghum, priority, inputs, constraints, resource

Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Thermal image classification of wheat crop to derive Leaf Are Index

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Thermal imaging cameras determine the temperature of the object by non-contact measurements. They work with the same principle of spot pyrometers,as they detect infrared radiation and convert it into a temperature reading. However, thermal cameras give temperature reading for each pixel of the image.Thus the thermal image directly gives the temperature of the crop canopy (Krishnan, 2014) and provides a better distinctibility between the two classes i.e., leaf and soil using image classification techniques. Supervised method of image classification provides a better opportunity to classify whole image into corresponding class unit (Lillesand *et al.*, 2014). Thus thermal imaging can be used for determining the canopy coverage. Leaf area index (LAI),is an important biophysical parameter that determine extent of solar radiation, a plant can absorb for photosynthesis and thus biomass (Bréda *et al.*, 2003). Leaf area coverage over the ground varies with the applied moisture stress and has been regarded as one of the important parameter to monitor crop status index (Banerjee *et al.*, 2015). Direct LAI measurement is time taking, labor intensive, destructive and produce error in its estimation. It has observed that by Image classification, accurate estimation of LAI can be obtained from digital images in a non-destructive mode (Liu *et al.*, 2013). The objective of this study is to determine LAI of a wheat crop grown under different moisture stress condition usingthermal image analysis with different ENVI supervised classification methods and compare the results with those obtained from digital image and classical instrument values.

METHODOLOGY

Wheat crop were grown under four different level of moisture stresses I_1, I_2, I_3, I_4 (based on the IW/CPE ratio of 1.0, 0.8, 0.6 and 0.4 respectively) in the experimental farm of Indian Agricultural Research Institute, New Delhi.

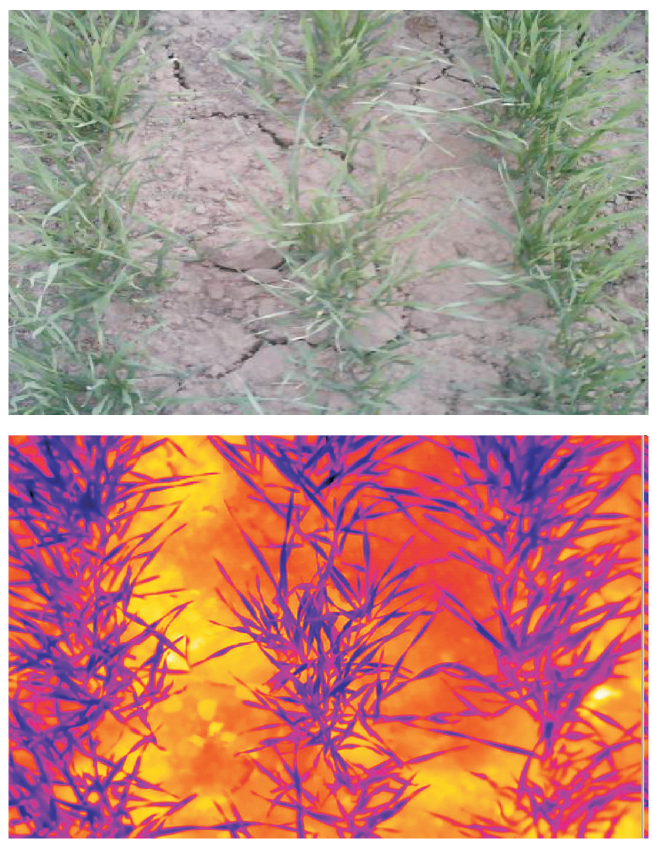

Fig. 1. Image analysis: (a) Optical Image (b) Thermal Image

Instrumental value of LAI for wheat crop grown under different stress condition was obtained using LAI-2200 (LICOR inc.,Nebraska).Thermal and digital images were obtained at different growth stages of the crop. Five different methods of supervised image classification (Support vector machine, Maximum likelihood method, Minimum distance method, Parellepiped method, Mahalanobis method) were performedand LAI was estimated from both thermal and digital image.The number of pixels for each class in the classified image was multiplied with the area of each pixel to get the area covered by each class. LAI was obtained by dividing leaf area to total ground area. This image classification based LAI was compared with instrumental LAI to get modelling efficiency (ME) for each supervised image classification method. Classification accuracy of each image classification methods in terms of overall accuracy, user's accuracy, producer's accuracy and Kappa coefficient (K) was also found out.

RESULTS

Thermal image classification based LAI performed best in predicting LAI as compare to digital image classification based LAI. In both the cases Support vector machine (SVM) method performed well in predicting LAI with R^2, 0.9157 and 0.814 for thermal and digital image respectively (Fig 2). Parallelepiped method was found to be the poor performer in prediction efficiency for both thermal and digital image classification for LAI with R^2, 0.797 and 0.606 respectively. Similarly, modelling efficiency was found to be highest for SVMand least for parallelepiped method for both thermal and digital image classification for LAI estimation. The methods used in this study for image processing are widely

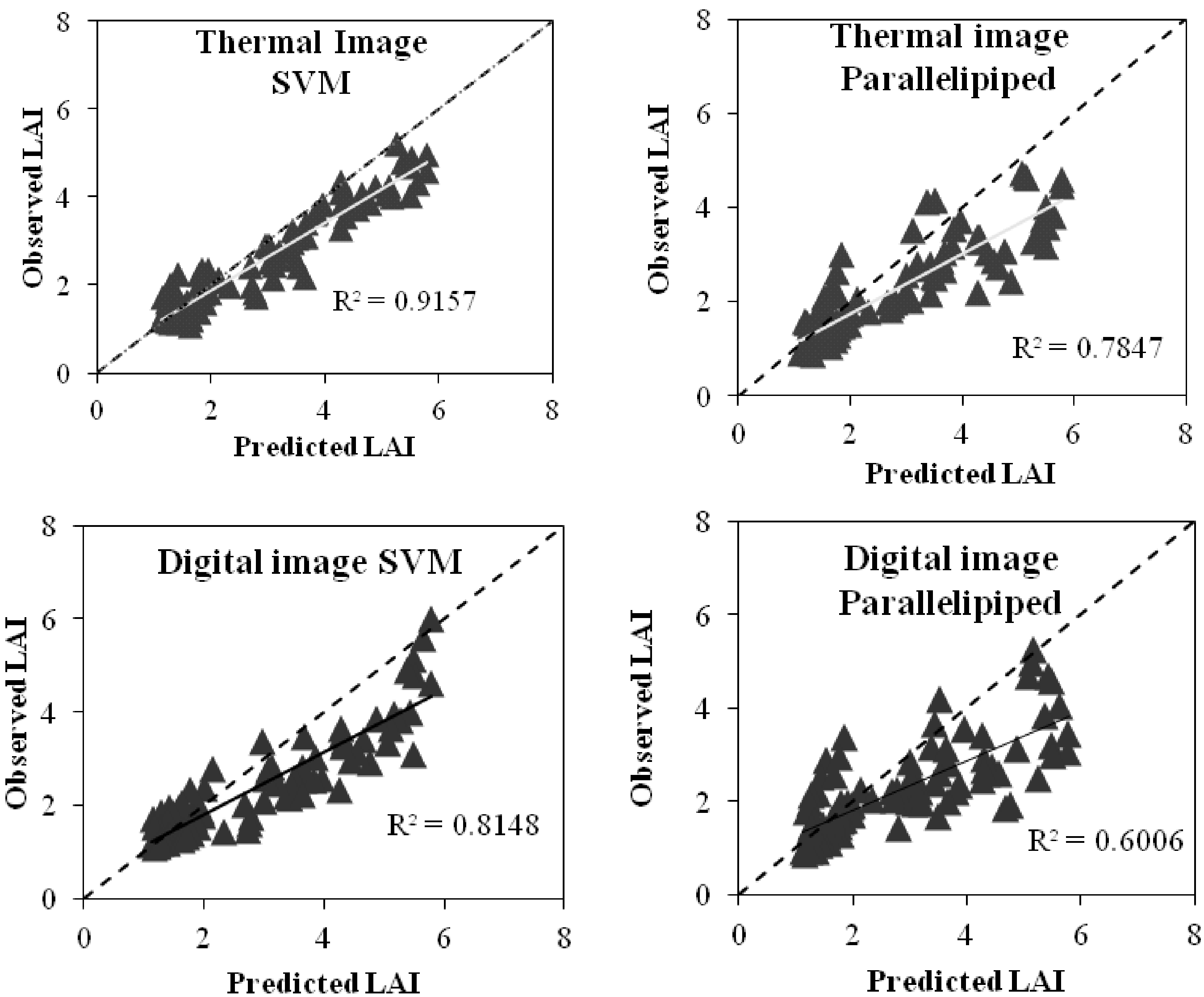

Fig. 2. Observed verses predicted LAI from thermal and digital image for SVM and parallelipiped method

used in, image analysis studies (Lillesand *et al.*, 2014), however they are rarely applied in field based studies (Liu *et al.*, 2013). Although, classification accuracy for different classification methods was found to be statistically at par but maximum overall accuracy and Kappa coefficient were found for SVM method and least for parallelepiped method for both thermal and digital image. So, as a non-destructive, less laborious, less erroneous and accurate estimation of LAI, ENVI supervised thermal image classification using Support vector machine method can be used for large scale application. Therefore instead of spot pyrometer, thermal imaging can be used not only for canopy temperature determination (Krishnan, 2014) but also for LAI estimation in wheat crop grown under different moisture stress conditions.

CONCLUSION

Thus the results clearly showed that the best estimation of LAI was possible using Support Vector Machine method, due to its higher overall classification accuracy and Kappa coefficient. This is further supported by the statistical analysis based on the observed LAI. In general Support Vector Machine method estimated the wheat crop LAI from the thermal image meaningfully with high R^2 value and low values of RMSE and MBE than those derived from the digital image. Thus the present study clearly showed that thermal image analysis could be applied as a non-destructive, rapid, less erroneous technique to characterise the crop canopy temperature and also estimate the LAI of the wheat crop grown under moisture stress conditions.

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Extended Summaries Vol. 3 : 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India

Productivity, water use and profitability of chickpea as influenced by land configurations and irrigation scheduling

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Chickpea (*Cicer arietinum* L.) is one of the most important food legume or 'pulse crop' in the world with production of 14.24 million tons from an acreage of 14.80 million hectares with the productivity of 962 kg/ha (FAOSTAT, 2014). India is world's leading producer of chickpea accounting for nearly 55.74 and 57.47 per cent of the total area (8.25 million hectares) and production (7.33 million tons), respectively, with the average productivity of 889 kg/ha (DAC, 2015). In Rajasthan, it covers an acreage of 1.26 million hectares with the production of 0.91 million tonnes and average yield 725 kg/ha.

Crop productivity is low in India in comparison to most developed countries as it is cultivated following traditional way of cultivation and planting system.In India, cultivation of chickpea mainly confined under rainfed conditions or un-irrigated soils led to low levels of its productivity. Moreover, these areas are inherently low in native fertility status. Although chickpea is a hardy plant, a poor supply of water or moisture along with nutrient deficiencies in soil are leading stresses aggravates yield loss.Chickpea is also susceptible to water stagnation due to flood irrigation or rainfall even for a shorter period during the crop growth. To overcome the problem of water logging due to flooding or aberrant weather with higher precipitation, the novel strategy is to sow the crop on raised beds. The enhancement in input use efficiency in respect of critical inputs is also due to lesser requirements for seed, fertilizers and irrigation water under FIRB in comparison to planting in flat land. The advantages of sowing of chickpea on raised bed over flat bed in terms of seeds and fertilizer saving has been noticed to the extent of 25–30% following flat sowing (Kumar *et al.*2015). On the other hand enhancing water use efficiency is also a concern. As applying irrigation to the plant at scheduled time is important factor influencing grain yield. The translocation of photosynthates are greatly dependent on timing or scheduling of water to the plant. Chickpea needs at the most 2 irrigations coinciding with pre-flowering and pod development stages. There is still a gap in optimum combination(s) of critical requirements of irrigation and optimum or efficient land configuration for sowing in chickpea. Therefore, the current investigation was undertaken to fulfill the twin objectives of (1) Finding optimum land configuration method for sowing and irrigation scheduling and (2) Evaluating effects on yield, water use efficiency and economics.

METHODOLOGY

A field experiment was conducted during two consecutive *rabi* seasons (2012–13 and 2013–14) at Agricultural Research Station, Ummedganj, Kota with the objective to find out the best land configuatation and irrigation scheduling for higher productivity, profitability and water use by chickpea under irrigated conditions. The soil of experimental site was clay loam having pH 7.53 to7.71 and organic carbon 5.65–5.69 (g/kg). Available N, P, K and S content in the experimental soil was 367.4–368.6, 23.8–23.9 and 310.6–311.4 and 16.8–16.8 kg/ha, respectively.The twelve treatment combinations consist of four land configurations. (*i*) Flat bed (FB) (*ii*) Ridge furrow (RF) (*iii*) Broad bed furrow (BBF) (*iv*) Broad bed furrow + one row of linseed intercrop allocated in main plot and three irrigation scheduling (*i*) Irrigation at branching (*ii*) irrigation at pod development stage (*iii*) irrigation atbranching and pod development allocated in sub plot were laid out in split plot design with three replications. The recommended dose of fertilizers were applied to chickpea through di ammonium phosphate (N and P), muriate of potash (K) and bentonite (S) at the time of sowing as basal. The amount of nitrogen was adjusted through urea.Ridge furrow and Broad bed furrow were prepared by using tractor drawn ridger and bed planter, respectively. Single row of chickpea was sown on the ridges (Ridge furrow) while as two rows of chickpea were sown on 67.5 raised beds (Broad bed furrow). Other agronomic practices followed as per the standard package of practices of Kota Division.

RESULTS

Effect of land configurations

Among the various land configuration systems Broad bed furrow + one row of linseed as intercrop produced significantly higher chickpea equivalent yield (2,098 kg/ha) followed by broad bed furrow (1,907 kg/ha), ridge furrow (1,863 kg/ha) and flat bed (1,636 kg/ha). Likewise, sowing of chickpea on BBF also improved water use efficiency over ridge furrow and flat bed sowing. Further, intercropping of linseed with chickpea under BBF method had highest water use efficiency (13.18 kg/ha mm) over ridge furrow and flat bed sowing. This could be attributed to more uptake of water from the root zone by the crops and its efficient utilization by both the main (Chickpea) and intercrop (Linseed). As the same amount of applied water was utilized by two crops under the system. The improvement in root and shoot weight under raised bed and ridge planting over flat bed led to enhanced grain yield mainly due congenial soil environment and better soil depth. Raised bed also encourage initial root and shoot growth of plant (Pramanik *et al.*, 2009). The higher water use efficiency under broad bed furrow (BBF) system was mainly because of less application of irrigation water and higher yield than flat bed planting. The irrigation water requirement was lower in BBF followed ridge planting over that in flood irrigation applied under flat bed system. Similar findings were also reported by Pramanik *et al.* (2009).

Sowing of chickpea on BBF and intercropping with linseed fetched highest net return (₹ 47,789) and B : C ratio (3.57). Further, sowing of chickpea sole on BBF also fetched higher net return and B : C ratio over ridge furrow and flat sowing techniques. Higher economics returns fetched due to higher grain yield under the system. Thus, the overall performance of chickpea was superior in broad bed furrow (BBF) system over other planting systems.

Effect of irrigation scheduling

Irrigation scheduling at pod development stage had significant improvement on chickpea equivalent yield, water use efficiency and profitability in terms of net return and B : C ratio (Table 1). Application of two irrigations at branching and pod development being on par with one irrigation at pod development only. However, irrigation at pod development stage markedly enhanced chickpea equivalent over irrigation scheduled at branching stage. However, irrigation scheduled at branching and pod development stage had highest water use efficiency over single application of irrigation either at pod development or branching only. Further, irrigation once at pod development fetched significantly higher net return (₹ 41,199) and B : C ratio (3.27) over irrigation at branching. Irrigation scheduled at pod development stage might efficiently utilize the applied water and translocated to the other plant parts. This is the reason behind higher more productivity. Moreover, due to more hardiness nature of the crops applying irrigation at critical stage resulted in higher grain yield thereby equivalent and profitability (Mishra *et al.* 2012).

Nodulation

Significant improvement in nodule/plant and nodules fresh

Table 1. Effect of land configuration and irrigation scheduling on chickpea equivalent yield, water use efficiency and economics of chickpea

Treatments	Chickpea Equivalent yield (kg/ha)	WUE (kg/ha mm)	Net Return (₹/ha)	B : C ratio
Land configurations				
Flat bed	1,636	9.48	35,078	2.88
Ridge furrow	1863	11.70	40,612	3.17
Broad bed furrow (BBF)	1,907	11.76	41,421	3.29
BBF + one row of Linseed	2,098	13.18	47,789	3.57
CD (P=0.05)	149	1.15	4,526	0.24
Irrigation scheduling				
Branching	1,749	9.98	37,776	3.04
Pod development stage	1,907	11.12	41,199	3.27
Branching and pod development stage	1,973	12.17	44,702	3.35
CD (P=0.05)	119	0.92	4,018	0.21

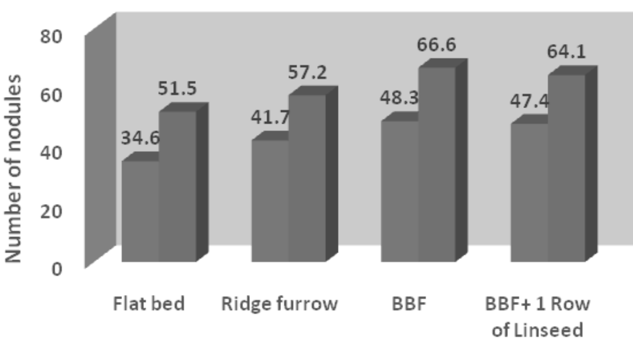

Fig. 1. Nunmber of nodules in chickpea

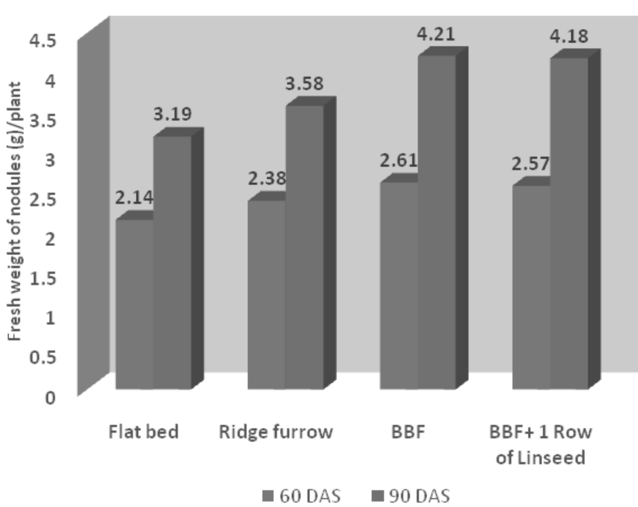

Fig. 2. Fresh weight of nodules in chickpea

weight/plant was recorded under both ridge furrow (RF) and broad bed furrow (BBF) planting systems over conventional flat bed (FB) method of chickpea sowing (Figs 1 and 2). The increase in nodules number/plant at 60 and 90 DAS was maximum under BBF (48.3 and 66.6) followed by ridge furrow planting (41.7 and 57.2) and least under flat bed planting system. Similarly, significantly higher nodule fresh weight/plant has also been noticed under BBF following ridge furrow and flat bed sowing condition at both the stages of crop growth (60 and 90 DAS). However, intercropping of chickpea with linseed failed to improve nodulation (number and fresh weight) under BBF over sole chickpea sown in BBF system. BBF and ridge furrow facilitated better nodulation due to more favorable rhizospheric conditions for plant growth. As there was a greater depth of surface soil with furrows enabling good drainage, rapid re-aeration of the root-zone occurred following an irrigation or rainfall event (Pramanik *et al.*, 2009; Kumar *et al.*, 2015). Relatively lower bulk density (26–28%) and higher infiltration rate (5–6%) under BBF and ridge furrow system in comparison to flat bed could also be attributed to enhanced nodulation under BBF/RF planting.

CONCLUSION

The study concludes that sowing of chickpea on broad bed furrow with one row of linseed as intercrop gave highest chickpea equivalent yield (2898 kg/ha), water use efficiency (13.18 kg/ha mm), net return (₹ 47,789/ha) and B : C ratio (3.57). Further, irrigation scheduling at branching and pod development stage fetched highest water use efficiency (12.17 kg/ha mm). However, irrigation scheduling at pod development stage fetched significantly higher chickpea equivalent yield, gross return and B : C ratio. Likewise, sowing of chickpea on broad bed furrow (BBF) was superior in terms of nodule number and nodule fresh weight over flat and ridge sown chickpea.

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