Journal of Farming Systems Research and Development

Volume 17 **January - December 2011** **Number 1&2**

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Short Communication

J. Farming Systems Research & Development **17** (1&2) : 1-15 (2011)

BALANCED FERTILIZATION FOR MAXIMIZING THE RICE-WHEAT SYSTEM PRODUCTIVITY UNDER TYPIC USTOCHREPT SOILS OF WESTERN INDO-GANGETIC PLAIN

B.S. Dwivedi[2], V.K. Singh[1] and Vinod Kumar

[1]*Project Directorate for Farming Systems Research, Modipuram, Meerut 250 110, India*
[2]*Division of soil Science and Agricultural Chemistry, Indian Agricultural Research Institute, New Delhi 110012*

ABSTRACT

Rice (*Oryza sativa* L.)-wheat (*Triticum aestivum* L.) cropping system (RWS) in the Indo-Gangetic Plains (IGP) of India is under stress due to wide spread multi-nutrient deficiencies and far low replenishment of plant nutrients compared to their removal. We, therefore, evaluated nine treatment combinations having three fertility levels (i.e. F_1 = 120 kg N: 26 kg P and 33 kg K/ha, F_2 = 150 kg N: 32.5 kg P and 41.5 kg K/ha, and F_3 = 180 kg N: 39 kg P and 49.5 kg K/ha) to both rice and wheat each and three zinc application rate (i.e. 0, 5 and 10 kg/ha) to rice crop only in a randomized block design with four replications. Two years results show that it is possible to realize 13-15 t/ha/annum rice equivalent yields (REY) from rice-wheat cropping system by restoring to heavy fertilization along with micronutrient use i.e. zinc. Use of 25% higher fertilizer dose (F_2) out yielded to recommend NPK (F_1) and the magnitude of increase was 11-12% in different years. Increasing NPK doses beyond (F_3) did not bring any significant ($P<0.05$) yield improvement. The Fertilizer and Zn interaction were also significant, and in Zn skipped plots, REY tended to be low, when F_2 or F_3 doses of NPK were applied to rice and wheat. Also, the use of graded doses of zinc (5 to 10 kg/ha) had additive effect on partial factor productivity (PFP_N). The balanced NPKZn use had significant influence on total uptake of these nutrients in rice and wheat crop and maximum uptake was noticed at highest rate of application. Although the NPK rates did not influence the available N content in soil but at higher doses of fertiliser NPK (25% and 50%), use of 5 or 10 kg Zn had synchronized effect on buildup of available P, exchangeable K , DTPA-Zn and soil OC content in the soil.

Keywords: Rice- wheat system; Balance fertilization; Zinc application; Indo-Gangetic Plains; Soil fertility; Partial factor productivity

INTRODUCTION

The rice-wheat system (RWS) is one of the largest agricultural production systems of the world, occupying 24 million hectares of cultivated land in the Indo-Gangetic Plains (IGP) in South Asia, and in china. In South Asia, the area under the RWS is 10 m ha in India, 2.2 m ha in Pakistan, 0.8 m ha in Bangladesh and 0.5 m ha in Nepal. The RWS represents 32% of the total rice area and 42% of the wheat area in these countries (Ladha et al., 2000). Intensively-cultivated RWS is fundamental for employment, income generation and livelihood security of about 100 million of rural and urban people of South Asia and about 8% of the world's population. The fertilizer use ($N+P_2O_5+K_2O$) in Indo Gangetic Plain (IGP) remained not only highly variable (ranging from 258 kg/ha in Lower Gangetic Plain (LGP) to 444 kg/ha in Trans-Gangetic Plain) but also unbalanced (Sharma, 2003). In many of such areas, particularly in TGP and UGP, sharp yield declines and decelerations in factor productivity have been noticed in RWS (Yadav, 1998; Singh et al., 2005). A RWS yielding 10 t of grain ha/ yr may remove 315 kg nitrogen (N), 281 kg phosphorus (P) and 333 kg potassium (K) /ha along with significant amount of micronutrients (Hegde and Dwivedi, 1992). Since both rice and wheat are extensive feeders of nutrients, a high annual productivity results in removal of nutrients in substantial amounts that often exceed replenishments through fertilizer and manures, leading ultimately to deterioration in soil fertility and emergence of multi-nutrient deficiencies (Duxbury et al., 2000; Dwivedi et al., 2006). The extent of nutrient mining further aggravated at higher annual productivity levels say 15 t/ ha of rice+wheat (Tiwari et al., 2004). On the other hand, surveys conducted in UGP and TGP revealed that farmers apply greater than recommenced doses of N and P, but ignore the replenishment of other nutrients (Dwivedi et al., 2001; Singh et al., 2005). Such unbalanced use of fertilizers not only aggravates the deficiency of potassium (K), secondary and micronutrients in the soils (Duxburry et al., 2000; Ladha et al., 2003), but also proves uneconomic and environmentally unsafe (Dwivedi et al., 2003).

For tailoring fertilizer requirement of crop and field specific needs, the optimization of fertilizer use is necessary to further improve farm productivity and profitability. Experimental evidences suggest the productivity on high fertility soil is often greater than that obtained on low fertility soil despite nutrient use in optimum quantities on both the soils (Tiwari, 2002). Maintaining soil at high level through careful appraisal and judicious use of nutrient is an assured way to attain and sustained maximum yield. On station studies conducted in RWS under the aegis AICRP-CS revealed that balance fertilization using the all deficient nutrients could enhance the annual productivity of the system up to 2-2.5 times over the prevailing ad-hoc nutrient management adopted by the farmers (Singh et al., 2008). In fact, pragmatic information on the benefit of balance fertilization involving micronutrient such as zinc on crop yields, nutrient uptake and soil fertility for high yield target is scarce. We, therefore, conducted on-station field experiment at PDFSR (Earlier PDCSR) Research Farm in order to: (i) determine attainable yields of rice and wheat with gradient doses of NPK and Zn (ii) examine the effect of balance N, P, K and Zn fertilizer use on factor productivity of nutrients and their uptake in RWS; and (iii) to study the effect of balance fertilization on soil fertility status under RWS.

Material and Methods

The experimental site

The experiment was done during 1990-91 and 1991-92 growing seasons at Project Directorate for Cropping Systems Research Modipuram, Meerut, India Meerut, located at 29°4' N latitude, 77° 46' E longitude and at an elevation of 237 m above mean sea level, representing irrigated, mechanized and input-intensive cropping areas of Upper Gangetic Plain zone of IGPR. The climate of Meerut is semi-arid sub-tropical with hot summers and cold winters. The average annual rainfall is 810 mm and potential evapo-transpiration 1500 mm. Nearly 80% of the rainfall is received from north-west monsoon during July to September. The averages monthly minimum and maximum temperatures fluctuate from 6.7 to 7.5 ^{0}c and 17.9 to 21.7 ^{0}c in January (the coolest month) and from 23.4 to 25.2 ^{0}c and 38.1 and 40.9 ^{0}c in May (the hottest month), respectively.

The soil of experimental site was a

sandy loam (15% Clay, 18.5% Silt, 64.5 % Sand) of Gangetic alluvial origin (Typic Ustochrept), very deep (>2 m), well drained, flat (about 1% slope), and represented one of the most extensive soil series i,e, Sobhapur series of north west India.

Treatments and crop culture

The nine treatment combinations having thee Fertility levels (i.e. F_1 = 120 kg N: 26 kg P and 33 kg K/ha, F_2 = 150 kg N: 32.5 kg P and 41.5 kg K/ha, and F 3 = 180 kg N: 39 kg P and 49.5 kg K/ha) to both rice and wheat each and three zinc application rate (i.e. 0, 5 and 10 kg/ ha) to rice crop only, were tested in a randomized block design with four replications during 1990-91 and 1991-92.

The rice and wheat crops were transplanted/sown in first week of July and November, respectively in both the years. The plant population density for rice was 25 hill/m^2 and 100 kg seed of wheat was kept during the study. At maturity, 5 x 4 m net plot area of both crops was harvested manually just above ground level. After sun drying in the field, the total biomass of rice and wheat was weighed, threshed with plot-thresher and grain yield weighed. The above ground matter was removed from the plots and underground stubbles ware incorporated into the soil by ploughing. Both rice and wheat crops received fertilizer N as urea in three equal splits; at transplanting/sowing and 20 and 60 days after transplanting/sowing. All P and K were applied as basal through single super phosphate and muriate of potash, respectively. The rice crop received irrigation at 2 days after disappearance of pounded water during whole crop period, while wheat received five irrigation's at 7.5 ha-cm water and each irrigation on 22, 55, 75, 95 and 115 day after sowing in both years of study.

Soil and plant analysis

Before commencement of the experiment in 1990-91 soil samples were collected from 0-15 cm profile depth at four places in the experimental field using a core sampler of 8 cm diameter. Samples were thoroughly mixed and bulked, and a representative samples was drawn for chemical analysis. Soil samples (0-15 cm profile depth/were again drawn from each plot after completion of every annual crop cycle i.e., after harvest of wheat during 1990-91 and 1991-92. The initial and post-harvest soil samples were pulverized a using wooden pestle-mortar and sieved through a 100-mesh sieve. The processed samples were analyzed for pH, electrical conductivity (EC), organic carbon (Walkley and Black method), available N (Alkaline $KMNO_4$ method), available P (0.5 M $NaHCO_{3,}$ pH 8.5 extraction) and available K (1N NH_4OAC, pH 7.0 extraction and Available Zn (DTPA method) following Page *et al.* 1982. The soil of experimental field at the start of experiment was non-saline (EC 0.35 dS/ m) and mildly alkaline (pH 8.4), and contained 0.28% organic carbon, 92 mg/ kg available N, 8.1mg/kg extractable P, 56 mg/kg exchangeable K and 0.65 mg/ kg DTPA zinc.

At final harvest, representative grain and straw samples of rice and wheat were drawn from the bulk produce of net plot. These were washed thoroughly with top water, 0.05 M HCl solution and de-ionised water in succession and dried at 70 ^{0}C in a hot air oven, ground in a stainless steel Wiley mill. The ground samples wet digested in a 4:1 mixture of nitric and per-chloric acid and aqueous extract prepared for the determination of total P (Spectro-photomatrically using vanadomohybdate yellow color method), and of total K content (flame photometrically), while the ground material was digested separately and analyzed with micro- kjeldahl method (Jackson 1973) for the determination of total N. The Zn content in grain and straw samples was determined on atomic absorption spectrophotometer (Lindsay and Norvell, 1978).

Computations method and statistical analysis

The overall system productivity under each treatment was compared by calculating their rice equivalent yield (REY) using the following formula:

REY for wheat = Economic yield of wheat crop (tonne/ha) x Economic value (Rupees/tonne) / Price of rice grain (Rupees/t) (1)

For this, the values of rice and wheat economic produce were taken Rs. 5500 and 6100/ tonne, respectively. The REY of wheat was added to rice yield in their respective treatments and system yield in the treatment was calculated.

In order to quantify the effect of different fertilizer, input and zinc doses on the nutrient use efficiencies in rice and wheat, computation was made using following equation:

$PFP_N = G_Y / F_N$ (2)

Where PFP_N is the partial factor productivity of nutrient, G_Y is the grain yield and F_N is the total sum of nutrient applied i.e. N+P+K+Zn. All these quantities are expressed in kg/ha.

The data of each crop season were statistically analysed using F-test, following the procedures of factorial randomized block design (Cochran and Cox, 1957).

RESULTS

Effect on crop productivity

In rice, application of 25% higher NPK i.e. 150 kg N, 32.5 kg P and 41.5 kg K (F_2) significantly ($P<0.05$) out yielded recommended NPK dose i.e. 120 kg N, 26 kg P and 33 kg K/ha (F_1) during both the years of experimentation (Table 1). Increasing further NPK dose up to F_3 brought 0.14 and 0.07 t/ha extra yield during 1990-91and 1991-92, respectively. The crop response to graded zinc application was noted up to 10 kg/ha application rate, where it was significantly greater ($P<0.05$) by 1.05 and 1.28 t/ha during 1990-91 and 1991-92, respectively over no-fertilizer zinc treatment (control). Such yield response to zinc at 5 kg/ha application rate was computed as 12% and 12.5% greater over no- Zn (control) during first and second year of experimentation, respectively. Response of rice to Zn has been reported by several workers in India and elsewhere (Shihua and Wenqiang, 2000; Shivay et al., 2008a). Crop response to zinc application was increased with increasing NPK dose and the magnitude of increase was highest at F_3 level of NPK application. The enhancement in yield under F_2 plots with 5 kg Zn/ha application rate was 11% and 15% over no- Zn (control), respectively during 1990-91 and 1991-92. Such yield advantages under F_3 plots were 16% and 24%, and 16% and 25% in different years. These results adequately confirmed the findings of Singh et al., 2011 that balanced fertilization not only increases the crop productivity but also helped mitigating other nutrient stress in plants by way of increasing the uptake of the nutrients.

Significant highest wheat yield (5.27 and 5.16 t/ha) was obtained with 25% higher NPK (150: 32.5: 41.5) kg/ha fertilization treatments (F_2), which was 14% and 12% greater than recommended NPK dose i.e., 120 kg N, 26 kg P and 33 kg K/ha (F_1) during 1990-91 and 1991-

92, respectively (Table 1). Further enhancement in fertilizer dose (F_3) had negative effect on wheat yield (-0.28 t/ha) during first year, while an additional yield of wheat (0.28 t/ha) was noted during second year of experimentation. Such yield increase and improved nutrient use efficiency in wheat with balanced nutrition is well established by earlier researchers (Yadav, 2003; Tiwari, 2002; Singh et al., 2008). Use of graded zinc doses had significant positive effect on wheat yield over no-zinc (control), during both year of experimentation and zinc fertilization at 5 kg and 10 kg/ha did produced 0.46 to 0.66 t/ha, and 0.85 to 0.92 t/ha, respectively extra yield during different year of experimentation (Table 1). The F x Zn interaction was also statistically significant ($P<0.05$) during both the years, as heavy NPK fertilized crop accrued greater yield advantages (19-40%) due to 5-10 kg Zn application compared with crop receiving no- zinc (control). The considerable response to Zn could be explained in the light of wide spread deficiencies of this nutrients in Indian soils (Dwivedi et al., 2006).

Changes in partial factor productivity of nutrients (PFPN)

The fertilizer use efficiency was computed in term of partial factor productivity (PFP_N) of rice and wheat were significantly ($P<0.05$) affected by fertility levels and zinc doses (Table 2). The increasing doses of fertilizer NPK brought a significant decrease in PFP_N under both rice and wheat crop during both the year of experimentation, and the extent of decrease was 37.3 to 28.2 and 38.2 to 28.5 kg grain/kg nutrient for

Table 1. Grain yield (t/ha) of rice and wheat as effected by fertilizer NPK dose and Zn application rate

NPK dose	Rice				Wheat			
	Zn rate (kg/ha)				Zn rate (kg/ha)			
	0	5	10	Mean	0	5	10	Mean
				1990-91				
F_1	6.54	7.01	7.05	6.87	4.36	4.71	4.76	4.61
F_2	6.98	7.75	8.01	7.58	4.81	5.45	5.56	5.27
F_3	6.82	7.93	8.43	7.72	4.11	5.12	5.74	4.99
Mean	6.78	7.56	7.83	-	4.43	5.09	5.35	-
S.E. (24 D.F.)	F=0.20	Zn=0.20	FxZN= 0.34	-	F=0.14	Zn=0.14	FxZn=0.24	-
				1991-92				
F_1	6.56	7.18	7.36	7.03	4.30	4.73	4.54	4.62
F_2	7.02	1.86	8.34	7.74	4.68	5.29	5.52	5.16
F_3	6.88	1.97	8.59	7.81	4.76	5.65	5.92	5.44
Mean	6.82	7.67	8.10	-	4.58	5.22	5.43	-
S.E. (24 D.F.)	F=0.23	Zn=0.23	FxZn=0.40	-	F=0.15	Zn=0.15	FxZn= 0.27	-

Table 2. Partial factor Productivity (kg grain/kg nutrient) of rice and wheat as effected by fertilizer NPK dose and Zn application rate

NPK dose	Rice				Wheat			
	Zn rate (kg/ha)				Zn rate (kg/ha)			
	0	5	10	Mean	0	5	10	Mean
				1990-91				
F_1	36.5	38.1	37.3	37.3	24.4	26.3	26.6	25.8
F_2	30.0	32.6	33.0	31.9	20.7	23.4	23.9	22.7
F_3	25.4	29.0	30.3	28.2	15.3	19.1	21.4	18.6
Mean	30.6	33.2	33.5	-	20.1	22.9	24.6	-
S.E. (24 D.F.)	F=0.79	Zn=0.79	FxZn=1.37	-	F=0.73	Zn=0.73	FxZn=1.27	-
				1991-92				
F_1	36.6	39.0	38.9	38.2	24.0	26.4	27.0	25.8
F_2	30.2	33.1	34.4	32.6	20.1	22.7	23.7	22.2
F_3	25.6	29.1	30.8	28.5	17.7	21.0	22.0	20.2
Mean	30.8	33.7	34.7	-	20.6	23.4	24.2	-
S.E. (24 D.F.)	F=1.03	Zn=1.03	FxZn=1.79	-	F=0.78	Zn=0.78	FxZn=1.35	-

rice, and 25.8 to18.6 and 25.6 to20.2 kg grain/kg nutrient for wheat during 1990-91 and 1991-92, respectively. Contorary to this, use of graded doses of zinc (5 to 10 kg/ha) had additive effect on PFP_N and the corresponding mean values for two crop season of each rice and wheat across the fertility doses were 33.5, 34.1 and 23.1 and 24.4, respectively (Table 2). Using 5 or 10 kg zinc /ha had significant effect on arresting the decline of PFPN caused by higher fertiliser NPK dose. The rice crop being highly responsive to fertilizer zinc, such advantages of zinc nutrition was more apparent in rice than in wheat crop.

Effect on total N, P, K and Zn uptake by rice and wheat

Total N uptake

In rice, total N uptake (grain + straw) was significantly greater ($P< 0.05$) under 25% and 50% higher NPK applied plots than recommended NPK use (Table 3). The mean N uptake by rice under recommended NPK plots, across graded Zn application treatments was 113.5 kg/ha in 1990-91 and 116.7 kg/ha in 1991-92, which was increased to 135.7 and 141.0 kg/ha, respectively consequent to NPK application at F_2 i.e. 180 kg N, 39 kg P and 49.5 kg K/ha. The results thus revealed that adequate supply of nutrients ensured higher recovery of N and its efficient utilization, as also confirmed by positive NPK interactions in plants (Tiwari, et al., 1992). Compared with no-Zn (control) treatments, total N uptake by the crop was significantly greater in the treatments receiving 5 kg Zn/ha (by 9.7% and 12.9%) and at 10 kg Zn/ha (by 14.4% and 17.6%) during

Table 3. Total N, P, K and Zn uptake of rice as affected by fertilizer NPK dose and Zn application rate

NPK	Zn rate (kg/ha)				Zn rate (kg/ha)			
dose	0	5	10	Mean	0	5	10	Mean
	1990-91				1991-92			
				N uptake (kg/ha)				
F_1	106	115	119	113	107	122	117	115
F_2	120	131	136	129	123	140	147	137
F_3	125	138	145	136	128	142	153	141
Mean	117	128	133	-	119	135	139	-
S.E. (24 D.F.)	F=3.62	Zn=3.62	FxZn=6.26	-	F=3.65	Zn=3.65	FxZn=6.34	-
				P uptake (kg/ha)				
F_1	23	25	26.2	25	21	25	25	24
F_2	29	33	34.2	32	29	34	37	33
F_3	31	35	37.9	35	34	40	46	40
Mean	28	31	33	-	28	33	36	-
S.E. (24 D.F.)	F=0.79	Zn=0.79	FxZn=1.37	-	F=0.75	Zn=0.75	FxZn=1.29	-
				K uptake (kg/ha)				
F_1	121	134	135	130	122	132	135	130
F_2	128	154	150	144	146	149	163	153
F_3	138	151	152	147	145	160	175	160
Mean	129	146	146	-	138	147	158	-
S.E. (24 D.F.)	F=3.94	Zn=3.94	FxZn=6.83	-	F=4.00	Zn=4.00	FxZn=6.92	-
				Zn uptake (kg/ha)				
F_1	278	376	422	359	275	387	436	366
F_2	273	381	442	365	257	380	443	360
F_3	249	370	421	347	239	356	428	341
Mean	267	376	428	-	257	374	436	-
S.E. (24 D.F.)	F=10.72	F=10.72	FxZn=18.57	-	F=10.34	Zn=10.34	FxZn =17.91	-

1990-91 and 1991-92, respectively. Use of Zn (5 or 10 kg/ha) in combination with different NPK doses resulted higher N uptake in rice, the extent of increase was more spectacular in the treatments receiving 25% or 50% higher NPK dose. These results are in close conformity with findings of Tiwari et al., 2006.

The total N uptake by wheat was influenced significantly ($P < 0.05$) by fertilizer NPK dose and Zn input (Table 4), whereas use of 25% and 50% higher NPK dose accounted for 19.15 kg and 24.5 kg, respectively higher mean N uptake dose over and above recommended NPK (120: 26: 33 kg/ha), across the year. The magnitude of increase due to Zn ranged between 14-20% over no-Zn (control). Fertilizer Zn application not only increased N uptake as compared to that under no-Zn (control) plots, but also augmented the magnitude of response to NPK application dose. Such yield increase and improved nutrient use efficiency in wheat with balanced nutrition is well established by earlier researchers (Yadav, 2003; Tiwari, 2002; Singh et al., 2008).

Total P uptake

The mean P uptake by rice in different years varied from 23.7 to 25.0 kg/ha under recommended NPK (120: 26: 33 kg/ha) dose and 32.0 to 33.3 kg/ha, 34.6 to 40.0 kg/ha under 25% and 50% higher NPK treated plots (Table 3). Averaged across the fertilizer NPK doses, total P uptake by rice crop was greater by 11.5% to 17.9% at 5 kg Zn and 18% to 28.6% at 10 kg Zn application over no-Zn (control) treatments. Interaction of Zn with F was also significant ($P <0.05$) in terms of total P uptake and the use of Zn at higher fertility doses (NPK 25% or 50%) had spectacular increase over recommended $NPKZn_0$.

Compared with rice, subsequent wheat crop removed less P from the soil, irrespective of treatments (Table 4). Nonetheless, total P uptake by wheat, as influenced by fertilizer NPK dose or Zn rates exhibited a pattern similar to rice.

Total K uptake

The mean K uptake values under F_2 plots were 130.0 kg/ha in 1990-91 and 129.7 kg/ha in 1991-92, which was increased by 10.5% and 17.7% with 25% higher dose (F_2) increase and by 13.1% and 23.4% with 50% higher dose (F3). The significant response in total K uptake due to Zn dose was up to 10 kg in second year, while this response was confined up to 5 kg applied rate in first year of study. The P and Zn interaction followed a trend similar to N and P uptake.

The total K uptake by wheat was influenced significantly ($P < 0.05$) by fertilizer NPK dose and Zn input (Table 4), whereas application 25% and 50% extra NPK dose accounted for 22 kg and 27.6 kg more K uptake over recommended NPK applied plots, irrespective of the year of experimentation. The magnitude of increase in K uptake due to Zn in wheat ranged between 14.2% to 19.4% in 1990-91 and 12.4% to 17.2% in 1991-92 at 5 and 10 kg Zn application rates over no-Zn (control), respectively. The significance of Zn application was also noted at higher (25% or 50%) NPK fertilizer dose.

Total Zn uptake

Compared to no-Zn plots, application of 5 kg Zn brought 40.9% and 45.6% greater Zn uptake in first and second year of experimentation, respectively. The corresponding values for 10 kg Zn application rate were 60.5% and 69.5%. Similar zinc enrichment of rice grain

Table 4. Total N, P, K and Zn uptake of Wheat as affected by fertilizer NPK dose and Zn application rate

NPK dose	Zn rate (kg/ha) 0	5	10	Mean	Zn rate (kg/ha) 0	5	10	Mean
	1990-91				1991-92			
				N uptake (kg/ha)				
F_1	98	106	104	103	80	91	93	92
F_2	116	128	032	125	95	106	110	110
F_3	102	127	142	124	101	118	127	117
Mean	105	120	126	-	92	105	110	-
S.E. (24 D.F.)	F=2.61	Zn=2.61	F x Zn =4.53	-	F=2.60	Zn=2.60	FxZn =4.50	-
				P uptake (kg/ha)				
F_1	15	17	17	11	14	16	17	14
F_2	18	20	22	13	18	21	22	18
F_3	17	19	22	12	19	22	23	18
Mean	17	19	20	-	17	20	21	-
S.E. (24 D.F.)	F=0.74	Zn=0.74	FxZn= 1.27	-	F=0.54	Zn0.54	FxZn =0.93	-
				K uptake (kg/ha)				
F_1	98	106	103	68	96	106	107	90
F_2	116	128	132	81	114	126	132	109
F_3	102	127	142	76	121	140	149	115
Mean	105	120	126	-	110	124	129	-
S.E. (24 D.F.)	F=2.55	Zn=2.55	FxZn= 4.42	-	F=3.14	Zn=3.14	FxZn= 5.44	-
				Zn uptake (kg/ha)				
F_1	154	188	215	114	140	173	208	154
F_2	171	212	237	128	142	199	231	167
F_3	138	195	236	111	143	196	221	158
Mean	154	198	229	-	142	189	220	-
S.E. (24 D.F.)	F=6.03	Zn=6.03	FxZn= 10.45	-	F=3.23	Zn=3.23	FxZn= 5.61	-

consequent to Zn fertilization is reported elsewhere (Shivay et al., 2008a; 2008b; Tiwari and Dwivedi, 1994). Similar to rice, subsequent wheat also showed the significant response to Zn application (Table 4). The fertility doses (NPK) and its interaction with Zn could not produce significant effect on Zn uptake to both the crops. Thus, result indicates that balanced fertilization with the inclusion of Zn in fertilization schedule, not only increased the rice yield, but also helped mitigating other macro and micronutrient deficiency stress in plants by way of increasing the uptake of the nutrients. Also increased Zn concentration in rice and wheat straw is of importance from the viewpoint of cattle nutrition, as rice and wheat straw are the major feed for farm cattle in Asian countries (Prasad, 2006). The results of our research show that balanced fertilisation involving Zn application under RWS could help in this direction.

Effect on soil fertility

Changes in soil organic carbon and available N content

When compared with initial organic carbon (OC) content (0.28%), the OC of soil (0-15 cm soil profile depth) measured after second crop cycle i.e. 1991-92 was increased with increasing fertility level, zinc application rates (Table 5). Increasing fertility level had significant positive effect on soil OC content and the values ranged from 0.31 to 0.34% in different NPK fertility levels. With graded doses of zinc application, soil OC content increased by 18-24% after two crop cycle over initial soil OC status. The significant ($P<0.05$) advantage of Fx Zn interaction on OC content was more spectacular at higher NPK dose.

The available N content of surface soil (0-15 cm) was significantly ($P<0.05$) greater in 25% or 50% higher NPK applied plots than plot receiving recommended ones i.e. 120 : 26: 33 kg/ha NPK dose (Table 5). At these NPK doses, after two crop cycles, available N contents of soil were higher by 8.6 and 9 mg/kg, over normal NPK application, respectively. Compared to initial value (92 mg kg), available soil N contents were higher by 2.5% and 4.3% the plots receiving 25% (F_2) and 50% (F_2) more NPK dose, respectively, while in F_1 plots a decline of (-4.7%) available N content was noted. The F x Zn interaction could not bring considerable build up of available N content.

Effect on available P, K and Zn content of soil

Available P content of the soil profile (0-15 cm depth) increased over the initial content at all the fertility levels, and the magnitude of increase was greater at over and above recommended fertilization rates after two crop cycle (Table 5). The plots receiving 25% and 50% extra NPK doses had 1.6 and 2.4 mg/kg higher available P content than at recommended NPK (120:26:33 kg/ha) application dose, respectively. On contrary, a concomitant depletion of available P content was noted with zinc application and the extent of decrease was up to 1.3 mg/kg at 10 kg/ha Zn application rate. At higher doses of fertiliser NPK (25% and 50%) use of 5 or 10 kg Zn had synchronized effect on buildup of available P content in the soil.

Initial soil available K status was declined in all the fertility treatments except plot fertilized with 50% higher NPK (180:39:49.5 kg/ha) in 0-15 cm soil layer. The magnitude of decline was 15% and 5% at recommended and 25% higher NPK doses, respectively over initial K status (56 mg/kg). The increasing zinc dose had also negative effect on soil

Table 5. Soil organic carbon and available N, P, K and Zn rates as affected by fertilizer NPK dose and Zn application rate

NPK dose	Zn rate (kg/ha)			
	0	5	10	Mean
		Organic carbon %		
F_1	0.30	0.32	0.31	0.31
F_2	0.34	0.33	0.35	0.34
F_3	0.34	0.33	0.36	0.34
Mean	0.33	0.33	0.34	-
S.E. (24 D.F.)	F=0.002	Zn=0.002	FxZn=0.003	-
		Available N (mg/kg)		
F_1	86	88	89	87.7
F_2	99	96	94	96.3
F_3	99	97	94	96.7
Mean	95	94	92	-
S.E. (24 D.F.)	F=0.76	Zn=0.76	FxZn=1.31	-
		Available P (mg/kg)		
F_1	87	8.3	7.9	8.3
F_2	10.4	102	9.0	9.9
F_3	11.4	11.0	9.8	10.7
Mean	10.2	908	8.9	-
S.E. (24 D.F.)	F=0.083	Zn=0.083	FxZn=0.145	-
		Available K (mg/kg)		
F_1	48	45	45	46
F_2	52	52	50	51.3
F_3	55	56	52	54.3
Mean	52	51	49	-
S.E. (24 D.F.)	F=0.74	Zn=0.74	FxZn=1.27	-
		Available S (mg/kg)		
F_1	0.60	0.65	.073	0.66
F_2	0.58	0.61	0.68	0.62
F_3	0.52	0.59	0.65	0.59
Mean	0.57	0.62	0.69	-
S.E. (24 D.F.)	F=0.009	Zn=0.009	FxZn=0.016	-

exchangeable K content but use of Zn at 5 kg/ha application rate along with 50% extra NPK dose showed a build up of 3.7% K content in the 0-15 cm soil profile.

The DTPA Zn content in soil showed inverse relation with increasing fertility dose and it was declined by 0.04 and 0.07 mg/kg at 25% and 50% higher fertilizer NPK dose (Table 5). Application of graded doses of zinc (5 to 10 kg/ha) brings significant ($P<0.05$) increase in DTPA extractable Zn status. After two crop cycle, 10 kg zinc application rate had an increase of 6.2% extractable zinc over initial (0.65 mg/kg) soil status. The F x Zn interaction was also significant ($P<0.05$), and it had positive effect on soil Zn status at 10 kg zinc rate in conjunction with different fertility doses.These findings corroborate the earlier findings (Dwivedi et al., 2001; Singh et al., 2006; Tiwari et al., 2006), where inclusion of deficient micro-nutrients (such as Zn in present case) with NPK increased their availability over the initial content under RWS. The improvement in soil fertility parameters with increasing doses of nutrients may be envisaged as increase in root/ shoot biomass due to balanced nutrition, which ultimately induces more recycling of their bi- products (root+shoot) to the soil and led to fertility buildup.

Effect on system performance

Two years results show that it is possible to realize 13-15 t/ha/annum rice equivalent yield from rice-wheat cropping system by restoring to heavy fertilization along with micronutrient use i.e. zinc (Fig. 1). During both year of experimentation, use of 25% higher fertilizer dose (F_2) out yielded to recommended NPK (F_3) kg/ha. The magnitude of increase was 12% and 11% in 1990-91 and 1991-92, respectively. Increasing NPK doses beyond this (F_3) did not bring any significant ($P<0.05$) yield improvement. Similarly, use of 5 kg zinc/ha had marked influence on system REY and 1.6 t/ha additional REY was noted over no-Zn (control) during both year of experimentation. Although the application of Zn at 10 kg/ha was not

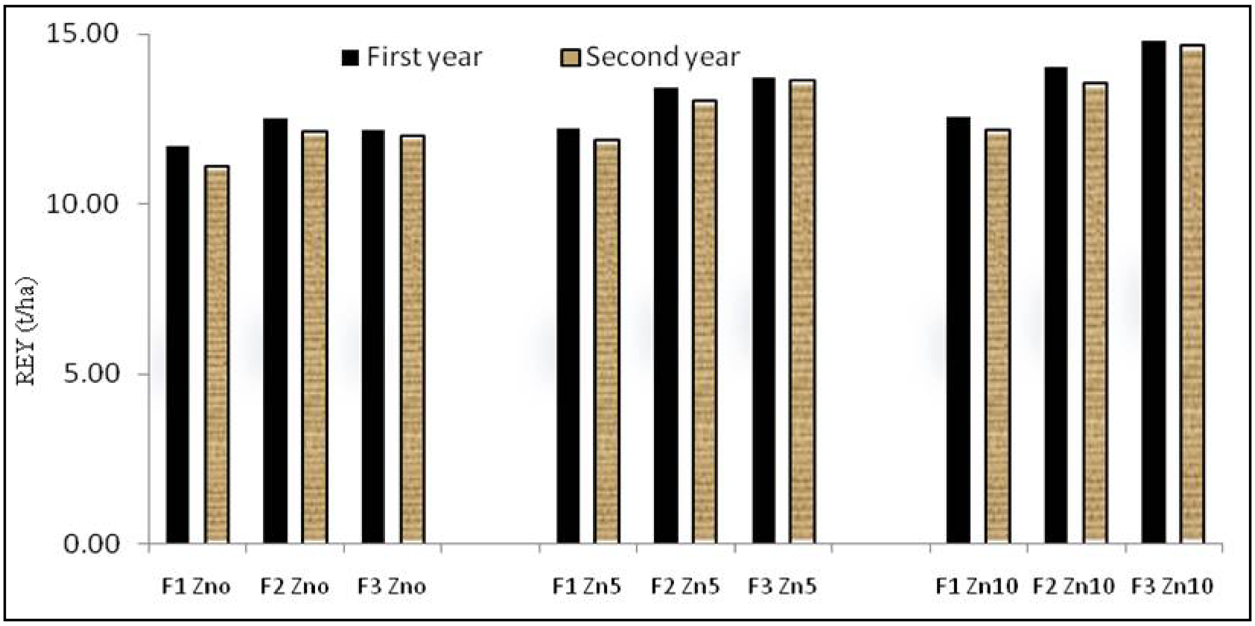

Fig.1. Rice equivalent yield (REY) as influenced by balanced nutrition

significantly differ from its 5 kg application rate, but an extra yield of 2.1 and 2.3 t/ha was noted in these plots over no-Zn (control). The Fertilizer and Zn interaction were also significant, and in Zn skipped plots, REY tended to be low, when F_2 or F_3 doses of NPK were applied to rice and wheat. The higher REY with balanced fertilization clearly indicates that high yield potential of modern varieties can never be exploited with inadequate and unbalanced fertilization. Site-specific balance nutrient management appraoch is a strategy that may provide sustained high yields on one hand, and assure restoration of soil fertility on the other.

Conclusion

The most dominant rice-wheat system of India which contributes 78 per cent of the total food grain production is showing a sign of fatigue mainly due to inadequate and unbalanced fertilization. The results of the present study clearly established the significance of improved balanced fertilizer management including Zn. Study further underline that not only the yield gains are higher with conjoint use of NPK and Zn but their application also enhanced net profits. Site specific balanced fertilization in addition to maintaining food security will help to sustaining soil health and environment with improved nutrient use efficiency. Further, there is need to study in detail different quality parameters in grain and straw of rice and wheat so as to establish the significance of balanced fertilization in augmenting crop quality and thus helping to overcome malnutrition in humans and animals.

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J. Farming Systems Research & Development **17** (1&2) : 16-35 (2011)

CONSERVATION AGRICULTURE FOR IMPROVING FOOD SECURITY THROUGH INTEGRATED CROP AND RESOURCE MANAGEMENT IN THE RICE-WHEAT SYSTEM IN NORTH WEST INDIA

R.K. Naresh[1], Prem Singh[2], Raj K. Gupta[3], R.S. Rathore[4], H.L. Singh[5] and Vineet Kumar[6]

[1]Department of Agronomy, [5]Department of Agricultural Economics, [6]Department of Soil Science
Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut (U. P.), India
[2]Project Directorate For Farming Systems Research, Modipuram, Meerut-250110
[3]CIMMYT India office, NASC complex, Todapur Road, Pusa, New Delhi-11001
[4]Uttar Pradesh Council of Agricultural Research,Lucknow

ABSTRACT

Resource conserving technologies (RCTs) with double no-till practices represents a major shift in production techniques for attaining optimal productivity, profitability and water use in rice-wheat system in north west India. Conventional tillage and crop establishment methods such as puddled transplanting in the rice–wheat (Oryza sativa L.–Triticum aestivum L.)system in north west India require a large amount of water and labor, both of which are increasingly becoming scarce and expensive. We attempted to evaluate alternatives that would require smaller amounts of these two inputs.A field experiment was conducted in the juricdiction of Sardar Vallabhbhai Patel University of Agriculture & Technology,Meerut (U.P.) in North West India for 02 years to evaluate various tillage and crop establishment systems for their efficiency in labor, water, and energy use and economic profitability.The soil physical properties (bulk density, mean weight diameter of aggregates and infiltration rate) improved significantly compared to puddled transplanted rice-conventional till wheat system. The wide beds and double no-till with flat layouts in rice-wheat system is under evaluation in different scenario of soil, climate, crop cultivars and seeding/crop establishment techniques (direct seeding, transplanting) and showed non consistent results. Systematic information on various aspects of narrow/wide beds is lacking.The productivity of rice with wide beds was at par compared to reduced tillage transplanted rice layouts but, the wheat productivity was reverse as it was highest under wide beds. The RW system productivity was highest with wide raised beds does differ significantly with other tillage and crop establishment techniques except with mulch crop establishment techniques. The water productivity of both rice and wheat was markedly improved with wide beds compared to other tillage and crop establishment techniques. The study showed that the conventional practice of puddled transplanting could be replaced with no-tillage-based crop establishment methods to save water and labor. However, the occurrence and distribution of rainfall during the cropping season had considerable influence on the savings in irrigation water.

Key words: Resource conservation technologies, productivity enhancement, profitability

INTRODUCTION

Resource conservation technologies through integrated crop and resource management is a system that maintains a soil cover through surface retention of crop residues, reduced or zero tillage and the use of cover or green manure crops in rotations. In India this concept of farming has found favour in the states of Punjab, Haryana and western parts of Uttar Pradesh and as estimated about 40000 to 50000 hectares of land particularly under rice-wheat system has been brought under conservation agriculture involving primarily reduced or zero tillage, bed planting and crop residue mulching. As experienced world-wide conservation agriculture leads to the buildup of soil organic carbon and thereby arrests the decline in total factor productivity of the applied inputs; helps saving the top fertile soil from wind and water erosion, enhances the nutrient use efficiency by creating conducive rhizosphere for soil micro-flora and fauna; reduces water requirement of the crops by effectively cutting the evaporation losses; checks non-point pollution of nearby water bodies and helps sequestering the green house gasses in the soil. The farmers adopting this system have reaped good benefits and gained confidence for saving their lands from deterioration and getting higher returns. A positive effect of this system of agriculture has also been reported on saving of inputs like nutrients, water and energy. These benefits of conservation agriculture need to be reaped in other input intensive cropping systems such as rice-wheat system.

Traditionally in this region, farmers grow rice in the wet (monsoon) season after intensive dry and wet tillage (puddling), followed by wheat in the dry (winter) season after intensive dry tillage. But the traditional tillage and crop establishment methods create problems in timeliness of wheat seeding, maintenance of soil structure, and management of irrigation, weeds, and other pests, fertilizers, and crop residues (Rao et al 2007, Pathak et al 2003) reported yield losses of 35 to 60 kg d^{-1} ha^{-1} from the north western to eastern IGP due to delayed wheat planting. Soil quality degradation has occurred because soils for both crops are managed differently. For rice, soil is puddled (wet tillage) and kept under continuous submergence. In contrast, wheat is grown in upland well-drained soils having good tilth. Puddling reduces weed competition and water losses but destroys soil structure and creates a hard pan at shallow depth and consumes a large quantity of water (Sharma et al 2002,Naresh et al.,2010). Poor tilth, restricted drainage, and inadequate soil aeration caused by puddling are the major limitations for wheat to express its yield potential in postrice soils. Conventional practices have further led to (1) a decline in soil carbon to as low as 0.2, (2) an increase in soil compaction, and (3) creation of a hard pan (Sharma et al 2002). Rice is the largest user of fresh surface water bodies and has led to an increase in tubewells of 480% in the past four decades in the region (Central Groundwater Board,Northwestern Region,).Poor-quality irrigation systems and a greater reliance on ground water have led to problems of waterlogging, salinity, sodicity, hydraulic imbalance, and water-table decline of 0.1 to 1.0 m y^{-1} in the western IGP, resulting in a scarcity and higher cost of pumping water (Harrington et al 1993, Sondhi et al 1994). Moreover, timely labor availability and increasing labor costs are becoming a serious concern for the timely planting of crops (Ladha et al 2003). In the changing climatic conditions, increased night temperature at the flowering stage causes spikelet sterility in rice and a reduction in yield of about 5% per degree Celsius rise above 32^0C(Peng et al 1999). The luxurious environment of excessive nitrogen and moist conditions provides a paradise for insect pests and diseases in the region and also decreases input-use efficiency. Evaluation and promotion of integrated crop and resource mnagement in the rice-wheat system in north west India . Total factor productivity (TFP) has declined by 50% in the region, and a shift in weed flora and herbicide-resistant weeds are some of the major causes of the decline in TFP (Ladha et al 2003).

Problems in the RWCS have been further intensified by planners and policy makers who have provided high subsidies for power, fertilizer, and irrigation. This has not only led to an overuse of these resources, but has also discouraged voluntary crop diversification. Despite the ecological damage, farmers continue to grow rice and wheat due to government support in terms of an assured minimum price for crops, ever-increasing demand, mechanization of the system, and assured irrigation. But concerns are growing about the sustainability of the RWCS as the growth rates of rice and wheat yields are either stagnant or declining.

RCTs involving no or minimum tillage with direct seeding, and bed planting; innovations in residue management to avoid straw burning; and crop diversification need to be advocated as alternatives to the conventional rice-wheat system for improving productivity and sustainability (Gupta et al 2003). Alternative methods have been proven effective to sustain soil health and reduce water demand in the rice crop in on-station trials in different agroecological regions by many scientists (Ladha et al 2003). But the application of these new tillage and crop establishment methods needs to be tested on a wider scale for water, labor, and energy efficiency in farmer-managed trials. Therefore, systematic studies were conducted with a wider approach of on-station and farmer participatory trials to (1) develop and accelerate productivity-enhancing, input (water, labor, and energy)-efficient, soil- and environment-friendly, and profitable RCTs in the North West India; (2) promote diverse crop rotations attractive to farmers and that help improve system ecology.

MATERIALS AND METHODS

Biophysical, demographic, and socioeconomic profile

Initially, a baseline survey of randomly selected farmers from different villages was conducted to understand their social, economic, and educational status in addition to input use (seed, irrigation, tractor, labor, fertilizer, and pesticide use) and outputs (grain and straw yield) in conventional farmers' practices (CTTPR-CTBCW), that is, conventional-tilled, puddled transplanted rice (CT-TPR) and conventional till broad casting wheat(CTBCW) (Table 1). The study was conducted for two years from June 2009 to May 2011 in 20 farmers' fields at Sardar Vallabhbhai Patel University of Agriculture &Technology, Meerut sites in the North West India. The area has a subtropical climate highly influenced by south west monsoon. Average annual rainfall was around 805 mm, more than 85% of which is received in June to September.Out of 20 farmers 57% had landholdings of <2 ha, 31% had 2 to 4 ha, and 12% had more than 4 ha (Fig. 1a). About 75% of the farmers were literate, out of which 32% were middle-school pass, 52% were high-school pass, and 21% were college pass (Fig. 1b). The literacy rate was higher for large farmers than for small farmers. The average family size was 6.4 family members for evaluation and promotion of integrated crop and resource mnagement in the rice-wheat system in northwest India per household. The large farmers usually lived in joint families, where as medium and small farmers had a separate nucleus family. Out of 128family members of the 20 households surveyed, 39% were fully engaged in agriculture and 51% partly engaged, whereas 35% were students who also helped with

Table 1. Description of cropping practices

Treatment Code	Rice	Wheat	Rice		Wheat	
			Tillage	Transplanting	Tillage	Drill
T_1	CT-TPR	ZT-HS	Dry and wet tillage (puddling)	Transplanting (TPR)	Zero-tillage(ZT)	Drill seeding (DSW) by HS
T_2	WBed-DSR	WBedZTDSW +M	Wide raised beds(WBed)	Drill seeding(DSR)	Zero-tillage in wide Beds (WbedZT)	Drill seeding (DSW)+M
T_3	WBed-TPR	WBedZTDSW – M	Wide raised beds(WBed)	Transplanting (TPR)	Zero-tillage in wide Beds (WbedZT)	Drill seeding (DSW) -M
T_4	NBed-DSR	NBedZT-DSW+M	Narrow raised beds(NBed)	Drill seeding(DSR)	Zero-tillagein narrow Beds (NBedZT)	Drill seeding (DSW)+M
T_5	NBed-TPR	NBedZT-DSW - M	Narrow raised beds(NBed)	Transplanting (TPR)	Zero-tillage in narrow Beds (NBedZT)	Drill seeding (DSW)-M
T_6	ZTDSR	ZT-DSW CT + M	Zero-tillage(ZT)	Drill seeding(DSR)	Zero-tillage with controlled traffic (ZTCT)	Drill seeding (DSWCT) +M
T_7	ZTTPR	ZT-DSW CT - M	Zero-tillage(ZT)	Transplanting (TPR)	Zero-tillage with controlled traffic (ZTCT)	Drill seeding (DSWCT) -M
T_8	RTDSR	ZT-DSW PR + M	Reduced tillage(RT)	Drill seeding(DSR)	Zero-tillage with paired row (ZTPR)	Drill seeding (DSWPR) +M
T_9	RT(UP)TPR	ZT-DSW PR - M	Reduced tillage unpuddled(RTUP)	Transplanting (TPR)	Zero-tillage with paired row (ZTPR)	Drill seeding (DSWPR)-M
T_{10}	CTDSR	ZT-DSW + M	Conventional tillage(CT)	Drill seeding(DSR)	Zero-tillage(ZT)	Drill seeding (DSW)+M
T_{11}	CTBCR	ZT-DSW – M	Conventional tillage(CT)	Broad-casting sprouted seeding (BCR)	Zero-tillage(ZT)	Drill seeding (DSW) -M
T_{12}	CT-TPR	CT-BCW	Dry and wet tillage (puddling)	Transplanting (TPR)	Dry conventional tillage(CT)	Broad-casting

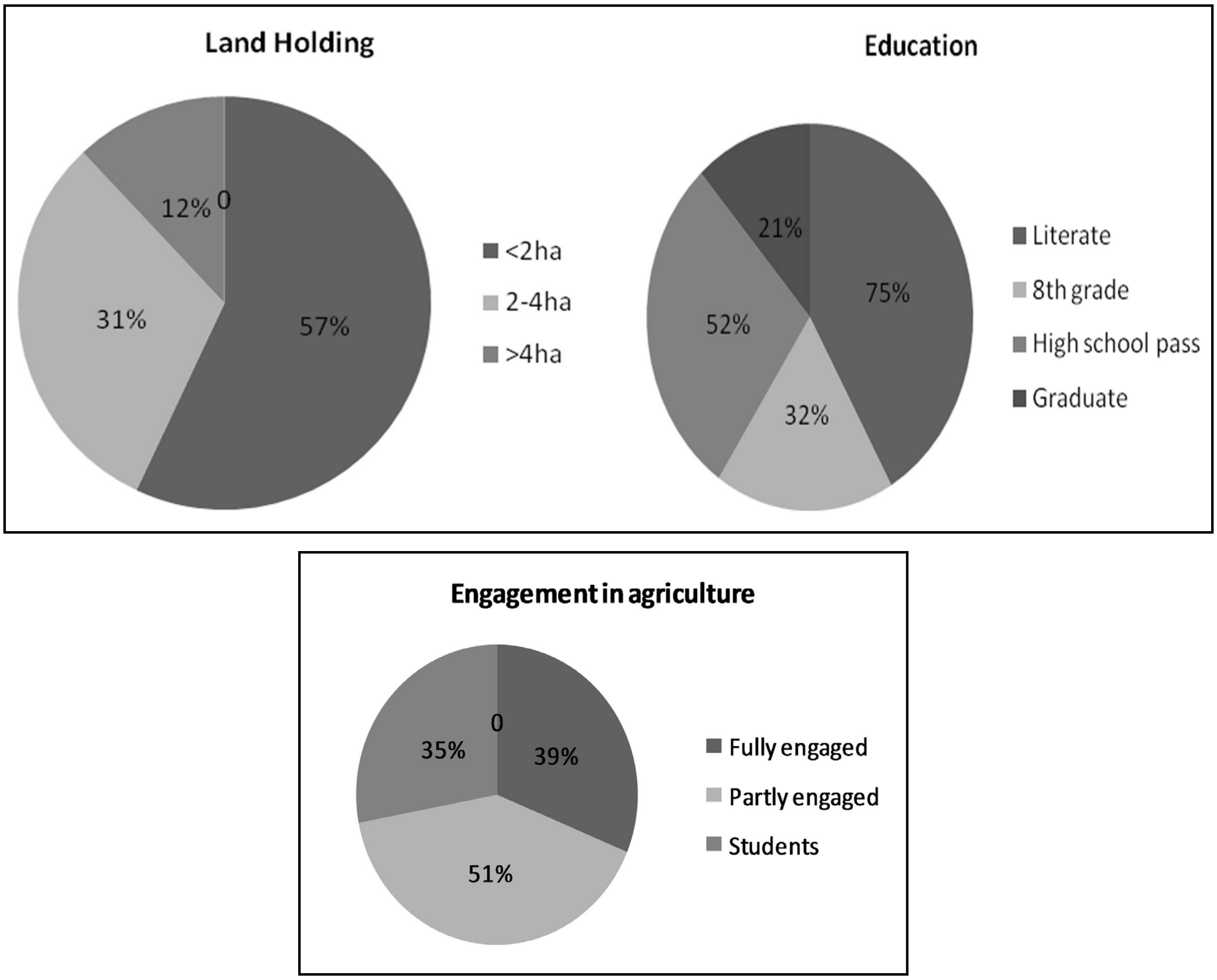

Fig. 1. Socio economics and demographics of project sites(a) land holding ,(b) education and (c) engagement in agriculture of Uttar Pradesh, India

agricultural activities during vacation and/or leisure periods (fig 1c). 38% of the farmers were members of different cooperatives existing in the area. Rice and wheat were the major source of income for 55% of the farmers, followed by sugarcane (30%), vegetables (15%), and oilseeds(7%).

Site characteristics

Twenty farmers were selected to conduct on-farm demonstrations of RCTs in four districts (Meerut, Ghaziabad, Muzaffarnagar and Saharanpur) of western Uttar Pradesh (UP),India (28 402 073 Nto 29 282 113 N ,77 282 143 E to77 442 183 E) (Fig.1).The climate of the area is semiarid, with an average annual rainfall of 805 mm (75–80% of which is received during July to September),minimum temperature of 4^{0}C in January, maximum temperature of 41–45^{0}C in June, and relative humidity of 67–83% during the year. The soils are generally sandy loam to loam in texture and low to medium in organic matter content. Groundwater pumping is the predominant method of irrigation. Western UP has a diversified cropping system, with RW as the dominant cropping system. Wheat is grown by broadcasting after three to four dry-tillage operations and rice seedlings (3–4 weeks old) are transplanted in puddled fields after three to four dry-tillage operations.

Experimental layout and treatments

Two set of experiments on different tillage and crop establishment techniques involving permanent beds were conducted under researcher managed trials at the research farm ($29^0 01'$ N, $77^0 45'$ E, and 237 m above mean sea level) of Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut (Uttar Pradesh), India, and farmer managed trials in Meerut district of Uttar Pradesh in western Gangetic Plain during 2009-10 & 2010-11. .The experimental soil (0–15 cm) was silty loam in texture, with a bulk density of 1.48 Mg m^{-3}, weighted mean diameter of soil aggregates 0.74 mm, pH =7.9, total C = 8.3 g kg-1, total N = 0.83 g kg-1, Olsen P = 28 mg kg-1, and K = 128 mg kg-1.

Experiment–I: An experiment on different tillage and crop establishment techniques involving permanent beds were conducted under farmers participatory researcher managed trials at the Farmers field of district Meerut, Ghaziabad, Muzaffarnagar and Saharanpur of Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut (Uttar Pradesh), India juridiction ($29^o 4'$N, $77^o 46'$E, 237 m above sea level) during 2009-10 to 2010-11 by UPCAR,Lucknow funded project.The water table was deep at all sites (23–35 m) with very good quality ground water which was used for irrigation.In general the soils of the farmers' fields were sandy loams with medium fertility.The particle size distribution of the 0–20 cm soil layer is 69.2% sand, 16.1% silt and 14.9% clay.A randomized block design (RBD) was used in the study.A combination of twelve tillage and crop establishment techniques [1. Conventional tilled Puddled transplanted rice (CT-TPR) - zero till wheat planted by turbo happy seeder-ZTHS), 2. direct seeded rice on wide raised beds (WBed DSR)- zero till wheat on permanent wide raised beds with mulch (WBedZT-DSW +M),3. transplanted rice on wide raised beds(WBedTPR)-zero till wheat on permanent wide raised beds without mulch (WBed ZT-DSW-M), 4. direct seeded rice on narrow raised beds (N Bed DSR)- zero till wheat on permanent narrow raised beds with mulch (NBed ZT-DSW+M), 5. transplanted rice on narrow raised beds(NBedTPR)- zero till wheat on permanent narrow raised beds without mulch (NBed ZT-DSW-M), 6. zero till direct seeded rice(ZTDSR)-zero till wheat in controlled traffic with mulch (ZT-DSWCT +M),7. zero till transplanted rice(ZTTPR)-zero till wheat in controlled traffic without mulch (ZT-DSWCT -M),8.reduced till direct seeded rice(RTDSR)-zero till wheat in paired row with mulch (ZT-DSWPR +M),9. reduced till unpuddled transplanted rice(RT(UP)TPR)-zero till wheat in paired row without mulch (ZT-DSWPR -M),10. conventional till direct seeded rice(CTDSR)-zero till wheat with mulch (ZT-DSW +M),11.conventional till sprouted broad casting rice(CTBCR)-zero till wheat without mulch(ZT-DSW -M),12. Conventional puddled transplanted rice (CT-TPR)-Conventional till broad casting wheat (CT-BCW) in RW system]. The changes in soil physical properties were recorded using standard techniques. The soil samples were taken at 0-15 cm soil layer from top of the beds in permanent beds and within the row in flats.

Seeding and Seed Rate

Pusa Sugandha- 4 (1121) rice variety was seeded on 1st and 3rd June in direct-seeded plots, where as transplanting was done on 22nd and 24thJune in 2009 and 2010, respectively. Rice was seeded in flat beds as well as in raised beds after seed priming (soaking seeds in water for 12 hr's followed by air drying). A seed rate of 25 kg and 20 kg ha^{-1} was used for direct-seeded rice on flat and raised beds, respectively. 'PBW 343' wheat was seeded on 7th and 9th Nov. 2009 and 2010, respectively. A seed rate of 80 kg ha^{-1} was used in treatments where wheat was seeded on beds, and 100 kg ha^{-1} was used in the rest of the treatments. The multi crop zero till cum raised bed planter with enclined plate seed metering device machine was calibrated every time before seeding to adjust the seeding rate.

Fertilizer Application

For rice, 120 kg N, 60 kg P_2O_5, 40 kg K_2O, and 20 kg $ZnSO_4$ ha^{-1} and for wheat 150 kg N, 60P_2O_5, 40 kg K_2O ha^{-1} was applied. Half dose of N and full doses of P, K, Zn was applied as basal and remaining N was applied in two equal splits in rice and in wheat, 80 per cent N was applied as basal and remaining N was applied at full bloom stage.

Weed Management: The crop was maintained weed free using following practices-

Rice: Weeds that germinate prior to seeding of rice and wheat in zero till plots were killed by spraying glyphosate @ 900 g a.i. ha^{-1}. The plots are then kept weed-free throughout the growing season. Butachlor @ 1300 g a.i. ha^{-1} at 2 days after transplanting (DAT) in case of transplanted rice followed by a spray application of bispyribac sodium(Nomne gold) @ 25 g a.i. ha^{-1} at 25-30 DAT for narrow and broad leaf weeds, and pendimethalin @ 1000 g a.i. ha^{-1} at 2 DAS in direct seeded rice were applied for controlling grassy weeds followed by a spray application of bispyribac sodium(Nomne gold) @ 25 g a.i. ha^{-1} at 25-30 DAS for narrow and broad leaf weeds. Additionally, 1 hand-weeding in transplanted rice and 2 hand- weeding in direct seeded rice was done to keep the plots weed-free.

Wheat: grassy weeds were controlled by spraying of sulfosulfuron @ 35 g a.i. ha^{-1} at 30-45 DAS, and broad leaf weeds using 2,4-D @ 500 g a.i. ha^{-1} at 35 DAS.

Water application and productivity

Irrigation water was applied using 5-cm-diameter pipes and the amount of water applied to each plot was measured using a flow meter. The quantity of water applied and the depth of irrigation were computed using the following equation:

Depth of water applied (mm) = ((I/ 1,000)/A)/1,000 [1]

where I is the amount of irrigation water (L) applied to each plot during each irrigation and

A is the area of the plot (m^2).

Rainfall data were recorded using a standard rain gauge installed within the meteorological station The total amount of water applied was computed as the sum of water received through irrigations and effective rainfall considering 80% of the total precipitation during the cropping season. Irrigation water productivity (WPI) was computed as the ratio of average grain yield

Harvesting

At maturity, rice and wheat were harvested and the grain and straw yields were determined from an area of 71.4 m^2 in flat beds and 75.04m^2 in raised beds located in the center of each plot out of 120 m^2 gross plot area. The grains were threshed using a plot thresher, dried in a batch grain dryer, and weighed. Grain moisture was determined immediately after weighing. Grain yields of rice and wheat were reported at 14 and 12 per cent moisture content, respectively. Straw weight was determined after oven-drying at 70^{0}C to constant weight and expressed on an oven dry-weight basis.

RESULTS AND DISCUSSION

Crop yields: The various tillage and crop establishment techniques had a significant effect on rice yield (Table 2).Yield were similar when rice was conventionally puddled transplanted (CT-TPR) ,transplanted on wide raised beds (WBedTPR) unpuddled transplanted in slits after no tillage(ZTTPR) and unpuddled transplanted in normal spacing (RT UP TPR) in all techniques.This indicated that puddling of soil, for which normally a large amount of water and labour are required can be avoided without any penalty in rice.Treatments ZTTPR and RTUPTPR were at par with each other, however,they recorded higher grain yield over ZT-DSR and NBed-DSR treatments which recorded lowest grain yield (4.05&3.95 tha^{-1}).

The wheat grain yield t ha^{-1} resource conserving technologies when practiced as such which includes sowing earlier than conventional tillage resulted in higher wheat yield over conventional tillage over all treatments. Treatment WBedZT-DSW+M was found significantly superior to all the treatments, and

Table 2. Productivity of RW system under various tillage and crop establishment techniques

Crop establishment		**Grain yield (tonnes ha^{-1})**					
		Rice		**Wheat**		**RW System**	
Rice	**Wheat**	**2009**	**2010**	**2009-10**	**2010-11**	**2009-10**	**2010-11**
CT-TPR	ZT-HS	5.56	5.85	4.85	4.93	10.41	10.78
WBed-DSR	WBedZT-DSW +M	4.35	4.45	5.07	5.15	9.42	9.60
WBed-TPR	WBedZT-DSW – M	5.25	5.50	4.99	5.06	10.24	10.56
NBed-DSR	NBedZT-DSW +M	3.95	4.05	4.88	4.95	8.83	9.00
NBed-TPR	NBedZT-DSW - M	4.20	4.35	4.81	4.87	9.01	9.22
ZTDSR	ZT-DSW CT + M	4.05	4.20	4.72	4.78	8.77	8.98
ZTTPR	ZT-DSW CT - M	4.45	4.55	4.65	4.70	9.10	9.25
RTDSR	ZT-DSW PR + M	4.15	4.35	4.83	4.92	8.98	9.27
RT(UP)TPR	ZT-DSW PR - M	4.55	4.85	4.75	4.85	9.30	9.70
CTDSR	ZT-DSW + M	4.20	4.35	4.66	4.75	8.86	9.10
CTBCR	ZT-DSW – M	4.10	4.24	4.59	4.67	8.69	8.91
CT-TPR	CT-BCW	5.20	5.35	4.15	4.20	9.35	9.55
C D at 5 %		1.05	1.25	0.65	0.45	0.42	0.49

recorded maximum grain yield.Grain yield increased significantly within various resource conserving technologies with mulch.TreatmentZT-DSWPR+ M was significantly superior to the remaining treatments. ZTDSWCT+M, ZT-HS, ZT-DSW +M ZT-DSW-M and ZT-DSW –M were at par with each other, however, they recorded significantly higher grain yield over CT-BCW treatment which recorded lowest grain yield.ZT-DSWPR +M or –M (paired rows) seed yields for twin-row plantings were approximately 6 to 8 % greater for equal spacing conventional practices.This observation is similar to that reported by Mascagní et al.(2008),Naresh et al.,2011 and these data are similar to those reported by Ball et al. (2001), who observed increased soybean yields were related to increased plant densities which increased fertile nodes per m^{-2} and pods per m^{-2}.Under all the tillage and crop establishment techniques, there was yield advantage with surface residue retention compared to removal. The crop residues retained as surface mulch (partially anchored and partially loose) @ 6.0 Mg ha^{-1} that helped in regulating the soil temperature and moisture and more response was mainly due the aberration in weather conditions during the crop growth period.

Total system Productivity

Commonly,conversion from conventional tillage to reduced-till systems with straw retention requires several crop cycles before potential advantages or disadvantages become apparent (Phillips and Phillips,1984).In our trials straw retention increased productivity rapidly,starting from the second crop cycle.We believe this is an important findings because,if repeated on farmers fields,farmers will quickly realize the benefits and be more interested in adopting the technology.Total system productivity increased by 8-13% in residue retention with paired row planting,and zero tillage planting system over conventional (Table 2).Total system productivity of rice-wheat (R-W) was 10.60 t ha^{-1}yr^{-1}.For both crops the highest system yields occurred in full straw retained,but the differences between residue removal and full residue retained were always significant for both the crops.Lower system productivity also occurred from residue removal due to reduced crop growth.Yields tended to be lower in with lower levels of residue retention for both crops.Similar observations were made by Sayre etal,2005 in Mexico.

Profitability: Profitability of wheat was remarkably higher with double no-till practices(ZT-DSW PR and WBed-ZTDSW) due to higher productivity and less cost of production compared to conventional tillage practices(CT-BCW) (Table 3). Further, the profitability of wheat was remarkably higher with residue retention compared to residue removal and the difference was more under WBed-ZTDSW +M, ZT-DSWPR + M, compared to other practices.The maximum net income was recorded with Wbed –ZTDSW + M followed by ZT-DSW PR + M and the lowest being with conventional wheat system(CT - BCW).

CT-TPR - Conventional tilled Puddled transplanted rice,WBed DSR - direct seeded rice on wide raised beds, WBedTPR - transplanted rice on wide raised beds, N Bed DSR- direct seeded rice on narrow raised beds, NBedTPR - transplanted rice on narrow raised beds, ZTDSR - zero till direct seeded rice,ZTTPR - zero till transplanted rice, RTDSR -reduced till direct seeded rice, RT(UP)TPR- reduced till unpuddled transplanted rice, CTDSR - conventional till direct seeded rice,CTBCR -

Table 3. Profitability of RW system under various tillage and crop establishment methods

Crop establishment		Net returns (Rs ha^{-1})						B:C ratio	
		Rice		Wheat		RW System		RW System	
Rice	Wheat	2009	2010	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
CT-TPR	ZT-HS	18,955	19,950	24,695	25,100	43,920	45,050	1.87	1.92
WBed-DSR	WBedZT-DSW +M	17,800	19,880	27,380	27,295	45,180	47,175	1.98	2.07
WBed-TPR	WBedZT-DSW – M	19,025	20,300	25,450	25,810	44,475	46,110	1.85	1.96
NBed-DSR	NBedZT-DSW +M	15,010	17,010	24,880	25,240	39,890	42,250	1.70	1.81
NBed-TPR	NBedZT-DSW - M	15,540	17,400	24,050	24,395	39,590	41,795	1.68	1.78
ZTDSR	ZT-DSW CT + M	19,035	19,740	23,128	23,425	42,163	43,165	1.79	1.84
ZTTPR	ZT-DSW CT - M	18,690	19,110	22,785	23,025	41,475	42,135	1.76	1.79
RTDSR	ZT-DSW PR + M	18,260	19,140	24,150	24,600	42,410	43,740	1.83	1.90
RT(UP)TPR	ZT-DSW PR - M	17,745	18,915	23,275	23,765	41,020	42,680	1.78	1.86
CTDSR	ZT-DSW + M	15,120	15,660	20,510	20,900	35,630	36,560	1.40	1.43
CTBCR	ZT-DSW – M	14,350	14,840	19,275	19,615	33,625	34,455	1.32	1.35
CT-TPR	CT-BCW	16,160	16,585	16,600	16,800	32,760	33,385	1.30	1.31

conventional till sprouted broad casting rice,CT-TPR - Conventional puddled transplanted rice , ZTHS - zero till wheat planted by turbo happy seeder,WBedZT-DSW+M - zero till wheat on permanent wide raised beds with mulch,WBed ZT-DSW-M -zero till wheat on permanent wide raised beds without mulch,NBed ZT-DSW+M -zero till wheat on permanent narrow raised beds with mulch,NBed ZT-DSW-M -zero till wheat on permanent narrow raised beds without mulch,ZT-DSWCT+M -zero till wheat in controlled traffic with mulch, ZT-DSWCT–M -zero till wheat in controlled traffic without mulch,ZT-DSWPR+M -zero till wheat in paired row with mulch,ZT-DSWPR-M -zero till wheat in paired row without mulch,ZT-DSW+M-zero till wheat with mulch,ZT-DSW–M - zero till wheat without mulch,CT-BCW -conventional till broad casting wheat in RW system.

Irrigation water application and water productivity of rice

Studies of farmers-managed trials showed 9–27% (190–635 mm) lower irrigation water use in wide beds DSR than in flooded CT-TPR.The reduction in irrigation water use varied with type of DSR method, ranging from 190 mm (9 %) in wet seeding on puddled soil (CT-wet-seeding) to 375–460mm (16–21%) in dry seeding after tillage (CT-dry-seeding) or zero tillage (ZT-dry-seeding), and 635 mm (27 %) in dry seeding on raised beds (wide beds-dry-DSR).The relatively lower water use in Wet-DSR than in CT-TPR despite its longer main field duration may be because of fewer continuous flooded days in the main field (Fig. 2 A and B). In CT-TPR, the field is generally kept continuously flooded (Fig. 2 A). Whereas in Wet-DSR, during the first 10 days, very little or no irrigation is applied and then irrigation is either applied at 2- to 3-day intervals or relatively shallow flooding is maintained during the early part of vegetative growth to avoid submergence of young seedlings, thereby reducing seepage, percolation, and evaporation losses. Moreover, the Wet-DSR crop is harvested about 10–15 days earlier than CT-TPR; therefore, total duration from seed to seed is reduced in this method (Fig. 2 B). Another reason reported for lower water use in Wet-DSR is the shorter land preparation period than in CT-TPR. In some areas,for example, in the largest surface irrigation scheme in Central Luzon, called UPRIIS (Upper Pampanga River Integrated Irrigation System), because of a lack of tertiary field channels, the whole main

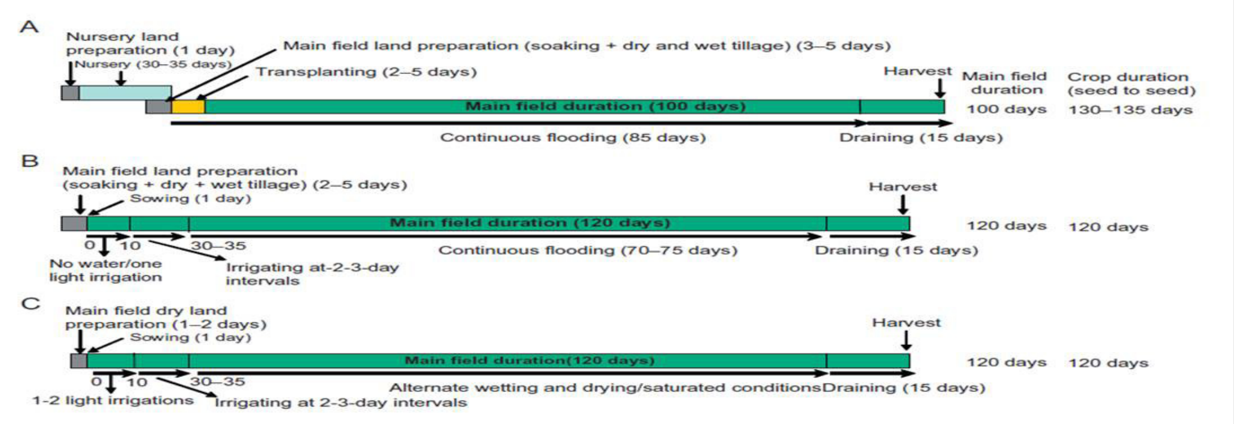

Fig.2. Various cultural activities, including irrigation schedules of puddled transplanting (A), direct wet seeding (B), and direct dry seeding (C). Modified from Tabbal et al. (2002).

field is soaked when the nursery is prepared and kept flooded during the entire duration of the nursery for CT-TPR. This results in a longer land preparation period and higher seepage, percolation, and evaporation losses (Tabbal et al., 2002).

In Wet-DSR, the main field is soaked, and the land is prepared 2–3 days prior to sowing. In Dry-DSR, lower water use than that in CT-TPR may be attributed to savings in water used for puddling in CT-TPR instead of continuous flooding in CT-TPR (Fig. 2 C).Although the overall trend is a savings in irrigation water application with alternative tillage and methods of rice establishment, some authors have reported higher irrigation water use (Bhuiyan et al., 1995; Hukkeri and Sharma, 1980), which could be due to (1) a longer crop growth period in the main field in DSR (Wet- and Dry-DSR) than in CT-TPR (Rashid et al., 2009; Fig.2), and (2) higher percolation losses, especially with Dry-DSR (Sudhir-Yadav et al., 2011a,b). Rainfall pattern and time of occurrence are another major deciding factor in irrigation water use and resulting savings (Saharawat et al., 2010,Naresh et al.,2010). If the onset of rain coincides with puddling and extends for a few days after CE, then irrigation water use declines drastically. Naresh et al.(2010), and Gathala et al. (2011) highlighted savings in irrigation water use in years with favorable and unfavorable rainfalls. There is a trade-off between savings of irrigation water during land preparation and increased water use during crop growth,which is highly influenced by rainfall pattern.

Effect of soil management on wheat irrigation and total water use

In our experiments there was a consistent trend for lower water input for beds on either soil in either the small plots or the large blocks.TTherefore, on average, a similar amount of water was applied to beds and flats (Fig.4).Our results are in accordance with many findings in the literature in both small plots and farmers' fields (Singh et al. 2002; Aggarwal and Goswami 2003; Balasubramanian et al. 2003;Sharma et al. 2004; Naresh et al.2010). In general,the reported irrigation water savings for wheat on beds seem to be larger in farmers' fields (45–54% in Haryana, Singh et al. 2002.However, Jehangir et al. (2007) found average irrigation water savings of 14–20% in nine farmers' fields in Pakistan.However,Naresh et al.2010 found average irrigation water saving of 15-26%.A possible explanation for larger savings in farmers' fields is the longer irrigation time, especially where levelling is poor or flow rates are low, leading to greater opportunity for deep drainage losses.

In many of the small plot studies the beds and flats were always irrigated on the same day, with less water applied to the beds because it takes less water to fill the furrows than to flood the flat plots. None of those studies compare what would have happened if the same irrigation amount applied to the beds had also been applied to CT-BCW. In the studies in farmers' fields, irrigation management is not known. In practical terms the lowest application rate that can be applied and provide full coverage of a 'flat' field will depend on how well the field has been levelled and on the flow rate Fig. 3a &b. Laser levelling in Western Uttar Pradesh, resulted in average wheat irrigation water savings of 21% in comparison with non lasered fields (Naresh et al. 2003). In Western Uttar Pradesh ,India,irrigation block size is relatively small (e.g. 0.25 acres) and lower application rates similar to those

Fig. 3a: First post-sowing irrigation of conventionally

Fig. 3b: First post-sowing irrigation of wheat on tilled wheat (CT-BCW) in small plots, fresh beds in small plots

applied to beds may be feasible given good levelling.Any savings in irrigation amount with beds are likely to be due to reduced deep drainage to the groundwater. Where groundwater can be used for irrigation, this is not a water saving but it is a highly beneficial saving of both energy and cost due to reduced pumping (Ahmad et al. 2007).More comprehensive experiments are needed in farmers' fields to rigorously test the hypothesis of lower irrigation requirement on beds, as well as studies to determine the optimum irrigation scheduling for wheat on beds. Such studies should include determination of soil water depletion in the root zone between sowing (or pre-irrigation) and harvest,evidence of whether or not there is significant deep drainage beyond the root zone, and estimates of total crop water use (ET) in addition to irrigation

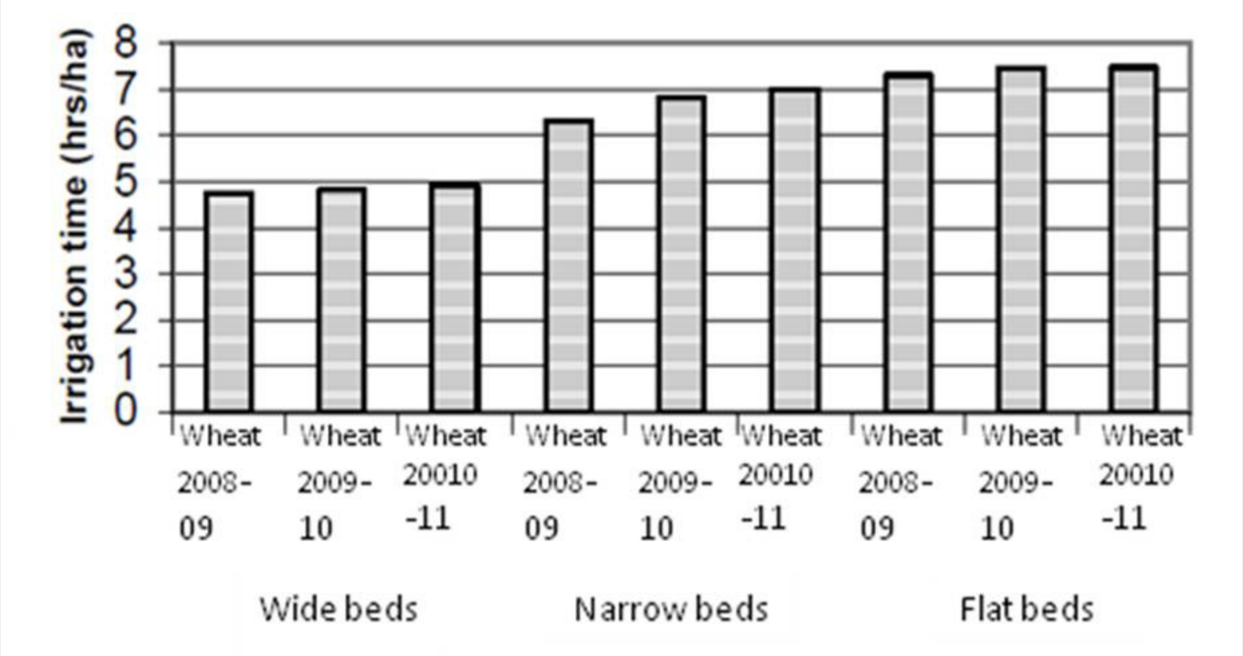

Fig.4: Wheat Crop Irrigation Times of Different Treatments on Farmers' Fields

and rainfall.It is only by doing a complete water balance that conclusions can be drawn about the magnitude and types of water savings on beds in comparison with flats.

Soil moisture conservation

Straw retention significantly influenced the soil moisture in wheat crops at 40 DAS. In the 0–30 cm soil layer the maximum soil moisture (18.6%) was in residue retention + permanent raised beds,more than double that (7.8%) of 0% without residue retention. Retention of straw improves soil water-holding capacity, and retention on the soil surface also reduces soil evaporation (Sanchez 1976). We visually observed more rapid and greater canopy development in the mulched treatments, presumably due to both greater water availability and more efficient use of fertiliser.In our trial we observed that the straw retention allows sufficient water to be saved (calculated at 30–135mm) to either reduce the number of irrigations by one or delay irrigation time by an average of 30%, or to increase yield in water limiting situations.Without straw retention at the ground coverage of the crop was far less (~30% at 40 DAS).As a result, soil moisture depletion from the soil was faster due to much greater exposure of the soil surface.Similar observations were made by Kumar and Goh (2000),Zaman and Choudhuri 1995; RWC-CIMMYT 2003).

Planting system and Soil quality

Soil from permanent raised beds with full residue retention had significantly higher mean weight diameter (MWD) compared to conventional tilled flat beds (Table 4). Permanent raised beds with full residue retention had a significantly higher MWD compared to those with residue removal.Permanent raised beds with full residue retention had a significantly longer time compared to the treatment with complete residue removal. The effect of plant residue removal on soil structure in permanent raised beds was very clear as the MWD decreased with decreasing amounts of residues retained. Aggregate breakdown is a good measure for soil erodibility,as breakdown to finer, more transportable particles and microaggregates, increases erosion risk (Le Bissonais 2003). Conventionally tilled flat beds and permanent raised beds without residue cover present as such a high erosion risk.Similar results were found for infiltration rates on top of the raised bed and in the furrow. Infiltration rates in the bottom of the furrow were significantly higher for conventionally tilled compared to permanent raised beds, but not on top of the raised beds.A lower aggregation results in a reduction of the infiltration and storage capacity of the soil by forming a relatively impermeable soil layer by sealing of pores (Le Bissonais 2003,Naresh et al.,2010). This corresponded with the higher time to confirm the results found in permanent raised beds with residue retention compared to permanent raised beds with residue removal.The standing stubble remaining on top of the permanent raised beds induces a 'vertical' mulching effect, resulting in bigger water infiltration than in fields without residue.The furrows in permanent raised beds are more compacted as all traffic is always concentrated in the furrows. However, in order to take advantage of the active water harvesting system by installing furrows and ridges it is probably more desirable to have slow infiltration rates in the furrow in order to let the water slowly infiltrate to the plant root zone, rather than let it escape to deeper layers

Table 4. Physical properties in different permanent tillage techniques after 2 years

Crop establishment		Field capacity (% Moisture)		Permanent wilting point (% Moisture)		Bulk Density (Mg m^{-3})	Infiltration rate (mm /hour)	Cone index	MWD (mm)
		0–5 cm	5–20 cm	0–5 cm	5–20 cm				
CT-TPR	- ZTHS	29	31	13	12	1.56	51.2	2.54	0.40
WBed-DSR	- WbedZT- DSW +M	30	33	12	12	1.54	77.6	2.44	0.46
WBed-TPR	- WbedZT –DSW -M	28	31	11	11	1.55	80.4	2.46	0.43
NBed-DSR	- NbedZT – DSW +M	31	33	12	12	1.55	81.3	2.49	0.45
NBed-TPR	- NbedZT – DSW -M	29	31	11	11	1.57	83.7	2.51	0.41
ZTDSR	- ZT – DSW CT +M	29	32	13	11	1.53	71.4	2.57	0.37
ZTTPR	- ZT – DSW CT -M	28	30	11	09	1.54	75.3	2.60	0.34
RTDSR	- ZT – DSW PR +M	29	32	13	11	1.55	68.5	2.59	0.42
RT(UP)TPR	- ZT –DSW PR –M	27	30	11	09	1.58	72.4	2.63	0.38
CTDSR	- ZT – DSW +M	29	32	13	11	1.59	55.7	2.78	0.29
CTBCR	- ZT – DSW - M	28	30	11	09	1.60	50.3	2.79	0.23
CT-TPR	- CT – BCW	28	30	11	09	1.63	36.4	2.83	0.24
Initial		-	-	-	-	1.50	-	2.26	0.32
C D at 5 %		-	-	-	-	0.09	10.62	0.17	0.06

due to cracks in the soil. However, ridges will help to actively keep water in the field, which otherwise would be lost as run off, and can compensate for the partial removal of residue.There is a need for further investigations concerning the critical threshold amounts of residue required for maintaining soil productivity. At initial time bulk density of surface layers remains lower under residue retained bed planting than under conventional tillage. This is because top of beds remains loose. The lower bulk density means more porosity especially in upper surface. The cone index was increased significantly under all the tillage and crop establishment techniques but the extent of increase was more under conventional tillage systems.With the passage of time the differences between soil physical parameters get narrowed (Aggarwal and Goswami 2003 ; Limon et al 2006) because height of bed gets reduced and become compacted. As a result of better physical environment (loose soil) under bed planting, higher root length density in upper 0-50 cm soil layer was observed than that of CT system, which was reflected in yield improvement. The adoption of permanent beds will led to controlled traffic thereby providing a healthy root environment. Fine tilth and better aeration causing less penetration resistance are responsible for better root development thereby producing higher yield attributes. Higher yield recorded in wide beds planting can be attributed to better soil environment in wide beds since prolonged ponding reduces yield (Tisdall and Hodgson,1990).

CONCLUSION

Use of permanent raised beds has been proposed as a means to increase the productivity, profitability and sustainability of RW systems, principally through improving soil structure and drainage for wheat, direct drilling of both crops, and reducing irrigation requirements for both crops through furrow irrigation. The benefits of growing wheat on beds compared with conventional tillage include similar or higher yields and reduced irrigation applications.Given the low organic matter status and coarse texture of the soils of NW India, long-term evaluation of permanent bed RW systems, including organic matter and stubble management, is urgently needed.The performance of rice on beds in NW India has been variable, but generally disappointing to date. Even with similar irrigation scheduling, yields of TPRB (transplanted on narrow raised beds) on permanent beds are generally 6–25% lower than CT-TPR despite similar soil water tensions at 10–15 cm depth. Yield loss with Nbed-DSRis even higher (22–30%), with serious problems of iron deficiency,weeds, variable sowing depth and sometimes nematodes. Strategies for overcoming all these problems are urgently needed, as is breeding and selection for rice grown in aerobic soil and for wide row spacings between beds. Irrigation and soil management strategies to reduce potential bypass flow losses through macropores such as rat holes and cracks may need to be included in designs for rice on permanent beds.

Retention of crop residues together with zero-till permanent bed soil systems offer an important soil restorative management strategy likely to have a long-term positive impact on soil quality and crop productivity in intensive wheat growing areas in India.Lignified residual straw and roots added more organic matter and nutrients into the soils under permanent raised beds, resulting in increased nutrient uptake by the crops. Crop yields on beds with straw retention rose by about 18% for wheat over a 2-year cycle compared with at the same N rate with conventional tillage on the flat beds. Retention of crop residues as a mulch reduced moisture depletion and increased SOM content over relatively short periods of time. Fertiliser use efficiency may be increased by implementing permanent bed management in addition to reducing crop lodging problems.Permanent raised beds will also help ameliorate the adverse effects of tillage on soil structure, which lead to waterlogging under excess water conditions and hamper establishment, growth and development of the crop.

Conservation agriculture offers an opportunity for arresting and reversing the downward spiral of resource degradation, diminishing factor productivity and decreasing cultivation costs making agriculture more resource use-efficient, competitive and sustainable. While, research and development efforts over the past decade have contributed to increasing farmer acceptance of zero tillage for wheat in rice-wheat cropping system, this has raised a number of institutional, technological and policy related questions related to technology generation, adaptation and further improvement, which must be addressed if CA practices have to be adopted on a sustained basis.Food production in India must increase by 2.5 per cent each year to meet the demand of the growing population and to reduce malnutrition.A significant part of it has to come from rice- wheat crop based production systems.This assumes special challenge as the data on rice- wheat yield trends indicate plateauing or progressive productivity decline in Punjab, Haryana, and Western Uttar Pradesh. For future productivity growth to keep pace with the increasing demand, it is necessary to address the problem at various levels. It will be important to make investment in developing appropriate technologies, and enable the farmers to take advantage of these in combination with their own ingenuity and ageold wisdom. Resource conserving technologies are a key to ensuring sustainable food production in South Asia in the next decade. Overcoming mindsets that hold traditional beliefs about excessive tillage and providing the enabling factors that allow exposure of the technology to all those involved in agriculture will be key factors for future success. This technology revolution is seen as one way to sustainably increase food production to meet future demands while conserving natural resources, improving farmer livelihoods and reducing the negative effects on the environment. Water is listed high on the list of natural resources and its use and productivity can definitely be improved with these new technologies.

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J. Farming Systems Research & Development **17** (1&2) : 36-43 (2011)

DRY AND WET SPELL PROBABILITIES BY MARKOV CHAIN MODEL FOR ITS APPLICATION TO CROP PLANNING IN NAVSARI

G.C. Sharma, K.K. Singh and S.K. Duhoon

Project Directorate for Farming Systems Research, Modipuram, Meerut-250 110 (U.P.)

Abstract

Probability analysis by Markov chain model for weekly rainfall data of Navsari from 1987 to 2008 has been carried out. The long term frequency behaviour of wet and dry weather spells has been extensively been studied. The probabilities of occurrence of two and three dry and wet weeks have been evaluated for appropriate crop production. Further forward and backward accumulation of rainfall has been worked out to determine the effective onset and termination of monsoon.

Key words: Markov chain model, transitional probability, forward and backward Accumulation

Our Indian Government has stressed upon optimum utilization of natural resource management for agricultural development to ascertain food and environmental security due to surmounting pressure of the population size. Till now agriculture development was confined to assured irrigation system. But in India, about 65% area is still rainfed (Kar and Singh, 2002). Therefore, for crop planning and its management, it is necessary to know in advance the dry and wet sequels and also rainfall pattern. It is well known that dry /wet spells coinciding with the crucial phonological stage of crop sometimes may be harmful or sometimes beneficial to the crop growth. Hence for the purpose of crop planning, it is desirable to predict in advance with certain degree of confidence the sequence of dry and wet periods (Pandarinath, 1991). Further, due to increase in agricultural inputs and optimum escalation in infrastructure cost, optimum utilization of rain water is a prime issue for sustaining agriculture, particularly in rain fed area. The projection of dry and wet spells is essential to plan agriculture which is the need of the day.

Markov chain probability model has extensively been used to work out the long term pattern of wet and dry spells (Victor and Sastry, 1979). Pandarinath (1991) and Panigrahi and Panda (2002) have exhibited practical utility of Markov chain model for studying the probability of dry or wet spells in terms of week periods. Besides, backward and forward accumulation of rainfall has been used to determine the onset and termination of the wet season. If for a longer period, the weekly rainfall is summed forward or backward from the peak of dry season until certain amount of rainfall is accumulated, then the requisite amount of rainfall at different stages with certain probability can be worked out. However, 75 mm and 200mm accumulation of rainfall are considered essential at the onset time for sowing of rainfed *kharif* crop and initiation of puddling time for *kharif* crop like rice. Likewise, the end of wet season is determined by backward summing of rainfall data to the level of 500 mm and 300 mm to sustain second short duration field crops (WMO,1982).

In the present study, weekly rainfall from 1987 to 2008 was obtained from Navsari Agricultural University, Navsari (Gujarat). The Navsari district is located in the south eastern part of Gujarat in the coastal lowland having $20^0$51'0" N and 72^0 55' 0" E latitude and longitude respectively. The average amount of rainfall is 1220 mm of which 80 % is received during last week of June to September. The maximum temperature of Navsari reaches 40^0 C during summer while the minimum temperature during the winters reaches around 10^0 C.

The Markov chain probability model (Pandarinath, 1991) has been used for drought and wet frequencies during rain periods. Robertson (WMO, 1982) has used the 30 mm or more rainfall in 10 days duration as the criterion for deciding the spell as wet and less than 30 mm rainfall as a dry spell . Pandarinath (1991) and Das and Senapati (1992) have taken 20 mm or more rainfall as a wet period and less than 20 mm a dry period. In the present study, based on Das and Senapati (1992), it is assumed that the week is wet if it receives 20 mm or more rainfall, otherwise dry. The formulae used in this study are:

$$P(d) = F(d) / N$$

$$P(w) = F(w) / N$$

Where P(d)= Probability of the week considered being dry (Initial dry probability)

F(d)= Frequency of dry weeks , N= total number of years of data being used.

P(w) = Probability of week considered being wet (initial wet probability)

F(w) = Frequency of wet weeks

$P(w) = F(w) /N$

The consecutive dry and wet probabilities are defined as under

$$P(2D) = P(dw1) . P(ddw2)$$

$$P(3D) = P(dw1) P(ddw2) P(ddw3)$$

Where P(2D) = Probability of 2 consecutive dry weeks

P(ddw1) = Probability of the first week being dry

P(ddw2) = Probability of the 2nd week consecutive dry week given the preceding week being dry

P(3D) = Probability of 3 consecutive dry weeks

P(ddw3) = Probability of 3rd week being dry given the preceding week being dry

In a similar way P(w/d), probability of wet week preceded by dry week ; P(d/ d), probability of dry week preceded by another dry week; P(d/ w), probability of dry week preceded by wet week; P(w/w), probability of wet week preceded by another wet week; P(2W), probability of 2 consecutive wet weeks; and P(3W), probability of 3 consecutive wet weeks have been estimated. Using the above formulae, initial probability for dry and wet weeks, conditional probability of wet week preceded by dry week and probability of consecutive two and three wet or dry weeks have been worked out. For the computation of forward and backward accumulation of rain water, the weekly rainfall are added from the week onward to evaluate the corresponding week number in which the cumulative rainfall has reached a sum total of 75 mm and 200mm. Likewise, the weekly rainfall from 52nd week is added backwards to evaluate 100 mm, 300 mm and 500 mm total rainfall and the corresponding week numbers are noted. Then the years are assigned with rank number. The probability of each rank is computed by

Table 1. Initial and Transitional Probabilities of rainfall at Navsari

Week	Initial Probabilities (%)		Transitional Probabilities (%)			
	P(w)	P(d)	P(w/w)	P(d/d)	P(d/w)	P(w/d)
1	0	100	0	95.45	0	0
2	4.55	95.45	0	86.36	4.55	4.55
3	0	100	0	95.45	0	0
4	0	100	0	95.45	0	0
5	0	100	0	95.45	0	0
6	0	100	0	95.45	0	0
7	0	100	0	95.45	0	0
8	0	100	0	95.45	0	0
9	0	100	0	95.45	0	0
10	0	100	0	95.45	0	0
11	0	100	0	95.45	0	0
12	0	100	0	95.45	0	0
13	0	100	0	95.45	0	0
14	0	100	0	95.45	0	0
15	0	100	0	95.45	0	0
16	0	100	0	95.45	0	0
17	0	100	0	95.45	0	0
18	0	100	0	95.45	0	0
19	0	100	0	95.45	0	0
20	0	100	0	95.45	0	0
21	0	100	0	95.45	0	0
22	13.64	86.36	0	68.18	13.64	13.64
23	22.73	77.27	0	50	22.73	22.73
24	45.45	54.55	22.73	31.82	31.82	22.73
25	54.55	45.45	31.82	18.18	22.73	22.73
26	72.73	27.27	45.45	4.55	22.73	22.73
27	86.36	13.64	68.18	0.00	13.64	13.64
28	77.27	22.73	54.55	4.55	18.18	18.18
29	81.82	18.18	59.09	0.00	18.18	18.18
30	68.18	31.82	50.00	9.09	18.18	18.18
31	77.27	22.73	50.00	0.00	22.73	22.73

32	86.36	13.64	72.73	0.00	9.09	9.09
33	63.64	36.36	36.36	9.09	22.73	27.27
34	77.27	22.73	54.55	4.55	18.18	18.18
35	59.09	40.91	36.36	13.64	22.73	22.73
36	59.09	40.91	27.27	9.09	27.27	31.82
37	63.64	36.36	40.91	13.64	18.18	22.73
38	63.64	36.36	40.91	13.64	18.18	22.73
39	36.36	63.64	9.09	31.82	27.27	27.27
40	27.27	72.73	9.09	50.00	18.18	18.18
41	4.55	95.45	0	86.36	4.55	4.55
42	4.55	95.45	0	86.36	4.55	4.55
43	9.09	90.91	0	77.27	9.09	9.09
44	4.55	95.45	0	86.36	4.55	4.55
45	0.00	100.00	0	95.45	0.00	0.00
46	0.00	100.00	0	95.45	0.00	0.00
47	4.55	95.45	0	86.36	4.55	4.55
48	0.00	100.00	0	95.45	0.00	0.00
49	0.00	100.00	0	95.45	0.00	0.00
50	0.00	100.00	0	95.45	0.00	0.00
51	0.00	100.00	0	95.45	0.00	0.00
52	0.00	100.00	0	95.45	0.00	0.00

P = (1/m +1) x 100 where m is the year number.

For forward accumulation the rank order and the probability level are arranged in ascending order and the corresponding week numbers are arranged similarly. For backward accumulation the rank order, probability level and the corresponding week numbers for 500 mm, 300 mm and 100 mm rain fall are arranged in descending order.

RESULTS AND DISCUSSION

The initial (45.45 -86.36 per cent) and conditional (22.73-72.73 per cent) wet probability was the highest from 24th to 38th weeks but it remained very low from 4.55 to 22.73 per cent and zero during 1st week to 23rd weeks respectively (Table-1). The good probabilities of good rainfall during 24th to 38th week indicate that it can be used for *kharif* rice crop cultivation in Navsari district. The probability of occurrence of dry week was very high (77.27 – 100 per cent) until the end of 23rd week. Besides, the conditional probability of dry week preceded by dry week was also very high (50 – 95.45 per cent). However, the probability of dry week ranged from 13.64 to 54.55 per cent during 24th week to 38th week and the conditional probability of dry week preceded by another dry week ranged from 4.55 to 31.82 per cent which were very low from those of 1st to 23rd weeks. It is in agreement with the findings of Singh and Bhandari (1998) and George and Kolappadan (2002). The probability of occurrence of dry week preceded by another wet week and that of dry week preceded by another wet week varied from 9.09 to 31.82 per cent and from 9.09 to 22.73 per cent, respectively.

The probabilities of getting two and three consecutive wet weeks during 24th to 38th weeks (Table-2) indicated the continuous rainfall was good for *kharif* crop. The analysis of dry week revealed

Table2. Consecutive Dry and Wet week Probability analysis of Navsari

Week	**Consecutive Dry Probabilities (%)**		**Consecutive Wet Probabilities (%)**	
	P(2D)	**P(3D)**	**P(2W)**	**P(3W)**
1	95.45	95.45	0	0
2	100	100	0	0
3	100	100	0	0
4	100	100	0	0
5	100	100	0	0
6	100	100	0	0
7	100	100	0	0
8	100	100	0	0
9	100	100	0	0
10	100	100	0	0
11	100	100	0	0
12	100	100	0	0
13	100	100	0	0
14	100	100	0	0
15	100	100	0	0
16	100	100	0	0
17	100	100	0	0
18	100	100	0	0
19	100	100	0	0
20	100	100	0	0
21	86.36	82.44	0	0
22	78.10	56.80	0.83	0.23
23	39.67	23.44	12.40	5.07
24	26.86	8.55	22.31	15.21
25	8.68	2.37	49.59	36.06
26	3.72	1.18	62.81	42.82
27	7.23	2.63	52.69	33.53
28	6.61	3.01	52.07	28.40
29	14.46	4.60	37.19	25.36
30	7.23	3.29	52.69	28.74
31	6.20	3.10	47.11	23.55
32	18.18	9.92	31.82	14.46
33	12.40	7.33	42.15	17.24
34	24.17	14.28	24.17	9.89
35	24.17	12.09	24.17	12.09
36	18.18	12.40	31.82	10.12
37	24.79	23.67	20.25	0.92
38	60.74	57.98	1.65	0.10
39	69.42	69.42	1.24	0.08
40	95.45	95.45	0	0
41	95.45	95.45	0	0
42	90.91	90.91	0	0
43	95.45	95.45	0	0
44	100.00	100.00	0	0
45	100.00	100.00	0	0
46	95.45	95.45	0	0
47	100	100	0	0
48	100	100	0	0
49	100	100	0	0
50	100	100	0	0
51	100	100	0	0
52	100	100	0	0

that there were 39.67 to 100 per cent chances that two consecutive dry weeks would occur within the first 23rd weeks of the year. Likewise, the probability of occurrence of three consecutive dry weeks was very high from 23.44 to 100 per cent within the first 23rd weeks.

The analysis of consecutive dry and wet spells indicated (Table2) that there were 39.67 to 100 per cent chances that two consecutive dry weeks would fall within the first twenty three weeks of the year. Likewise, the probability of occurrence of three consecutive dry weeks is very high C 23.44 to 100 per cent) in the first 23 weeks of the year. The corresponding values of 2 and 3 consecutive wet weeks from 1st to 23rd weeks were very low ranging from 0 to 12.40 and 0 to 5.07 per cent respectively. Further, there are chances of rain from 24th to 39h weeks ranging from 1.65 to

Table 3. Forward and backward accumulation of rain water

Year	**Forward**		**Backward**			**m**	**FM**	**Forward**		**m**	**FM**	**Backward**		
	75	**200**	**500**	**300**	**100**			**75**	**200**			**500**	**300**	**100**
	Week No.		**Week No.**					**Ranked**				**Ranked**		
1987	24	26	27	31	34	1	2.8	8	17	22	91.5	26	29	33
1988	24	24	24	37	39	2	4.2	9	22	21	90.4	28	30	34
1989	24	26	30	33	36	3	9.1	9	22	20	86.5	28	30	34
1990	24	26	33	37	39	4	13.5	10	23	19	81.5	28	30	35
1991	26	28	29	30	32	5	18.2	10	23	18	76.8	28	30	35
1992	28	29	35	36	36	6	23	11	23	17	74.4	31	32	35
1993	24	24	29	37	39	7	25.8	12	23	16	69.9	29	32	36
1994	24	24	30	33	36	8	30.1	14	23	15	65.4	30	32	36
1995	28	29	30	35	37	9	39.5	16	25	14	60.2	30	33	37
1996	25	27	30	34	40	10	41.6	17	25	13	57.5	30	33	37
1997	24	25	31	34	38	11	48.2	17	25	12	51.8	30	33	38
1998	26	27	37	38	40	12	53.2	18	25	11	48.8	30	33	38
1999	25	25	29	34	41	13	55.6	19	25	10	46.8	31	33	38
2000	23	27	28	32	34	14	65.7	19	25	9	41.5	31	35	38
2001	24	27	32	34	34	15	69.8	20	26	8	37.8	32	35	38
2002	25	26	32	34	36	16	72.5	20	26	7	32.6	32	35	39
2003	25	26	32	32	38	17	74.5	20	27	6	28.8	32	36	40
2004	24	25	31	37	39	18	78.5	20	27	5	23.5	33	36	40
2005	25	26	32	33	38	19	81.2	20	28	4	18.1	33	37	40
2006	22	26	31	36	37	20	86.2	21	29	3	13.5	35	37	41
2007	25	26	35	36	38	21	90.7	22	31	2	9.2	36	38	41
2008	24	26	33	37	38	22	95.8	23	33	1	4.5	36	39	42

62.81 and .08to 42.82 per cent during 2 and 3 consecutive wet weeks. The study further reveals that the last fourteen weeks of the year would remain under stress ranging from 69.42 to 100 per cent with 2 and 3 consecutive dry weeks.

The results of forward and backward accumulation of rainfall (Table 3) show that there was 73 per cent probability of getting 75 mm cumulative rainfall in 20th week and 51 per cent probability of getting 200 mm cumulative rainfall in the 25th week considering forward accumulation of rainfall into consideration.Thus,500 mm of rainfall is expected to occur in the 30th week with probability of getting 56.7 per cent , 300 mm in the 33rd week with probability 53 per cent and 100 mm in the 38th week with probability 45.3 per cent. These data are represented in the form of a graph (Fig.1).

It is inferred from the graphical representation which shows that at the 73% probability level it takes five weeks to accumulate rainfall from 75 mm to 200 mm. Also, it takes five weeks at the end of rainy season to drop from an expected 300 mm to 100 mm. The analysis revealed that the monsoon starts effectively from 24th week at Navsari and remains active upto 39h week .One can expect therefore good monsoon shower for about 15 weeks in the region. Thus a short duration of rice of about 100 days can be taken in the region with good assurance of rainfall. Thus it can be concluded that the frequencies for the various spell of rainfall can be estimated by this type of study. Having worked out the probability of occurrence of dry spells of various duration the crops and crop varieties of suitable duration can be advised.

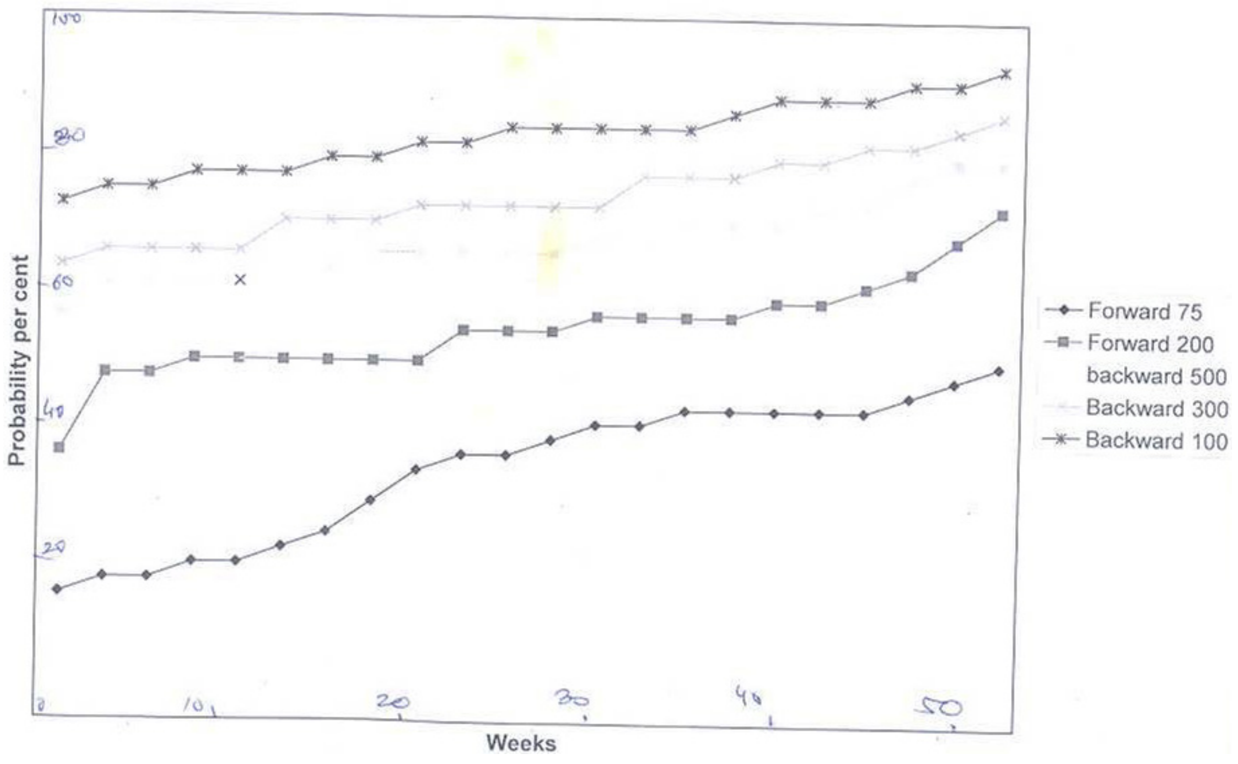

Fig. 1. Forward and backward accumulation of rainfall

ACKNOWLEGEMENTS

The authors are grateful to the Project Director, PDFSR, Modipuram, Meerut for providing necessary facilities and guidance in carrying out the present study.

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J. Farming Systems Research & Development **17** (1&2) : 44-51 (2011)

DIVERSIFICATION OF RICE *(ORYZA SATIVA)*- BASED CROPPING SYSTEMS FOR SUSTAINABLE PRODUCTIVITY AND PROFITABILITY IN IRRIGATED ECOSYSTEM OF BIHAR

R.D. SINGH[1] AND SHIVANI[2]

ICAR Research Complex for Eastern Region, ICAR Parisar, P.O. BV College, Patna – 800 014 (Bihar)

ABSTRACT

An experiment was conducted at Patna during 2004-05 to 2007-08 to develop diversified cropping system for irrigated ecosystem in Bihar by introducing pulse/oilseed/vegetables as second or third crop in ten rice based cropping systems. Four crop cycles for all the cropping systems have been completed. During all the year of experimentations, there were significant variations among cropping systems. Maximum paddy yield equivalent was recorded in rice-tomato-bottle guard (40.20 t/ha) followed by rice-potato-onion (30.89 t/ha), rice-coriander-ladies finger (27.12 t/ha), rice-carrot-cowpea (25.33 t/ha) and rice-mustard-tomato (24.29 t/ha), respectively. Higher value of diversification index (DI) represents higher level of crop diversification. It is evident from the results that DI varies from 0.299 on medium farm to 0.903 on small farm with an average DI of 0.643 among all categories of farmers. Survey revealed that average DI of small farmers was found to be the highest (0.741) as compared to those of medium (0.591) and large (0.626) categories of farmers and the differences were negligible. This seems to have reinforced the view that smaller the farm size; higher is the level of crop diversification.

Key words: Crop diversification, cropping system, diversification index, paddy-equivalent yield, vegetable, legume, oilseed, sustainable productivity.

Cropping system in India has attained great significance in terms of area, production and productivity. The cropping intensity of eastern region is as low as 140%, which needs to be increased in order to meet the growing food demand of the ever-increasing population. In Bihar, farmers of areas having medium and low land mostly grow rice-wheat cropping system. Both crops of the system are fertility exhaustive resulting unfavourable effect on sustainability of soil productivity. To meet the food grain requirement of the growing population and sustainability at reasonably higher productivity level is the need of the hour. Hence, there is an urgent need to diversify into new areas like vegetables, fruits, oilseeds, pulses and allied field. Crop diversification essentially means moving away from growing a single crop to a number of crops. Such a move towards crop diversification helps in (a) full and better use of available land, labour, water and other resources, (b) reducing risks arising out of crop failures, yield losses and market failures, and (c) realizing quicker or regular returns by the farmer. Thus, not only the number of crops but the type of crops included in the cropping sequence is also important. For this, heavy reliance on cereal crops needs to be shifted to other food crops like potato, vegetables, pulses and oilseeds. Inclusion of potato in rice-based crop sequences in West Bengal has become attractive because of high yield and remunerative price of potato. Samui *et. al.* (2004) reported that inclusion of

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[1] Principal Scientist (Agronomy) & Head, [2] Sr. Scientist (Agronomy).

legume increases soil fertility status. Gangwar and Ram (2005) reported that inclusion of legumes and other crops using intensification and interruptive approaches as per resource availability with considerable improvement in productivity and profitability on one hand with improvement in soil fertility on other. Hence, it was felt necessary to work out location-specific cropping system for central Bihar, which can utilize resources judiciously to maximize return and protect the environment and meet daily requirement of human and animals.

MATERIAL AND METHODS

A field experiment was conducted in randomized block design replicated thrice at Sabajpura farm during 2004-05 to 2007-08, to develop a suitable cropping system by introducing pulse/oilseed/ vegetables as second or third crop in rice based cropping system. Ten rice- based cropping systems namely rice-wheat-black gram (C_1), rice-capsicum - cucumber (C_2), rice- carrot- cowpea (C_3), rice- mustard- tomato (C_4), rice-potato-onion (C_5), rice- cabbage- french bean (C_6), rice-coriander- ladies finger (C_7), rice- tomato- bottle gourd (C_8), rice- pea-green chilli (C_9) and rice- lentil- sponge gourd (C_{10}) were undertaken. All the recommended management practices were followed. Soil samples were collected from the experimental plots and analyzed for physical and chemical properties. The texture of the soil was silt clay loam with mean value of pH 7.3, electrical conductivity 0.2 ds/m in 1:2 soils: water solution, organic carbon 0.54 %, available nitrogen 253.0 kg N/ha, available phosphorus 24.4 kg P/ha and available potash 394.0 kg K/ha respectively. To calculate the diversification index twenty-eight farmers of different categories – small (< 2 ha), medium (2-4 ha) and large (> 4 ha) – were randomly selected from Patna district. They were interviewed through a structured questionnaire to get information on their cropping pattern in different crop seasons (kharif, rabi and zaid) including area sown under different crops.

The productivity of different cropping systems was computed by converting the yield of all crops into rice equivalent yield based on prevailing market/ minimum support price and dividing by number of days, crops occupied the land in a year in a particular system. The returns were calculated by using prevailing market price of different commodities in the different years of experimentation. The relative economic efficiency (REE) was calculated by using the formula: (A-B)*100/B where A, net return of diversified system; B, net return in existing system and expressed in percentage.

Based on the data obtained from the selected farmers, their crop diversification indices were calculated to understand the level of crop diversification under different categories of farms. The crop diversification index (DI) was computed with the help of under mentioned formula:

$$DI = \sum_{i=1}^{n} pi \log 1/pi$$

Where, pi = proportion of area sown under crop i

i = 1, 2, 3, . . . n

n = number of crops sown

RESULTS AND DISCUSSION

Chemical properties of soil

Soil studies indicated that there was decreasing trend of average nutrient status such as EC, organic carbon, available nitrogen and available potash except available phosphorus after completion of fourth crop cycles and found significantly superior over each other (Table 1). Most of the soil parameters are significantly superior over each other after completion of first and fourth crop cycles but all the soil parameters after completion of third crop cycle was non-significant. It has been observed that there was buildup of organic carbon, available nitrogen and available phosphorus except available potash in most of the cropping systems after completion of fourth crop cycle because of added nitrogen, phosphorus, litter falls and addition of organic matter through underground portion of rice and other crops in the systems. It has been observed that 10-15 percent of top portion of dry matter per sq. meter is added to the soil every season. Apart from this, we are adding recommended dose of nitrogen to all the crops but only 40- 50 % is made available to the crop and remaining nitrogen fixed in the soil. This may be the reason for building up of organic carbon and available nitrogen in the soil. Available phosphorus and potash have decreased from initial status of soil in almost all the cropping systems because of vegetable dominating cropping system; whose phosphorus and potash requirement is more than cereals and pulses dominated crops in the system.

System productivity

Four crop cycles for all the cropping systems have been completed (Table 2). Pooled analysis of paddy yield equivalence revealed that during all the year of experimentations, there were significant variations among cropping systems. Maximum yield equivalence was recorded in rice-tomato-bottle gourd (40.20 t/ha) followed by rice-potato-onion (30.89 t/ha), rice-coriander-ladies finger (27.12 t/ha), rice-carrot-cowpea (25.33 t/ha) and rice-mustard-tomato (24.29 t/ha), respectively (Table 3). Higher system productivity (122.54 kg/ha/ day) was also recorded through intensified (rice-tomato-bottle gourd) system closely followed through interruptive approach of rice-potato-onion (94.27 kg/ha/ day), rice-mustard-tomato (77.59 kg/ha/day), rice-carrot-cowpea (77.57 kg/ha/day) and rice-coriander-ladies finger (76.32 kg/ha/ day), respectively. Intensification and inclusion of vegetables crops during rabi and summer season may be attributed to higher system productivity Similar results are reported by Gangwar and Ram (2005) and Katyal et.al. (2002).

Diversification index

The value of DI varies from zero to one (Table 3). Higher value of DI represents higher level of crop diversification. It is evident from the results that DI varies from 0.299 on a medium farm to 0.903 on a small farm with an average DI of 0.643 among all categories of farmers. Survey revealed that average DI of small farmers was found to be the highest (0.741) as compared to those of medium (0.591) and large (0.626) categories of farmers and the differences were negligible. This seems to have reinforced the view that smaller the farm size; higher is the level of crop diversification. A perusal of crop diversification pattern of farmers further revealed that majority of farmers was high crop diversifiers (46.4 per cent), followed by medium (35.7 per cent) and low (17.8 per cent) level of crop diversification. Similar trends were observed in case of small and large categories of farmers across their level of crop diversification except that in medium categories of farmers, wherein it was observed that farmers were distributed among low, medium and high

Table 1. (a). Chemical properties of soil after completion of crop cycles in diversified cropping system (2004-05 to 2007-08)

Treatments	Chemical properties											
	pH				EC (ds/m)				Organic carbon (%)			
	2004-05	2005-06	2006-07	2007-08	2004-05	2005-06	2006-07	2007-08	2004-05	2005-06	2006-07	2007-08
Initial Status of Soil	7.30	7.60	7.50	7.94	0.20	0.10	0.20	0.09	0.54	0.70	0.80	0.49
Rice-Wheat-Black Gram	7.73	7.60	7.86	7.27	0.10	0.16	0.07	0.10	0.70	0.51	0.10	0.69
Rice-Capsicum-Cucumber	7.63	7.36	7.90	7.41	0.12	0.21	0.11	0.09	0.56	0.83	0.53	0.66
Rice-Carrot-Cowpea	7.63	7.57	7.87	7.39	0.11	0.29	0.10	0.12	0.54	1.16	0.57	0.70
Rice-Mustard-Tomato	7.62	7.51	7.92	7.55	0.13	0.18	0.10	0.09	0.59	0.82	0.64	0.71
Rice-Potato-Onion	7.55	7.35	7.95	7.43	0.16	0.19	0.09	0.09	0.85	0.68	0.36	0.69
Rice-Cabbage-Bitter Gourd	7.56	7.59	8.03	7.45	0.15	0.12	0.10	0.11	0.86	1.01	0.83	0.70
Rice-Coriander-Ladies Finger	7.66	7.51	8.06	7.43	0.16	0.14	0.11	0.11	0.73	0.69	0.46	0.86
Rice-Tomato-Bottle Gourd	7.81	7.74	7.97	7.42	0.13	0.19	0.08	0.11	0.74	0.63	0.49	0.95
Rice-Pea-Green Chilli	7.66	7.69	7.89	7.36	0.13	0.13	0.09	0.70	0.63	0.54	0.62	0.74
Rice-Lentil-Sponge Gourd	7.46	7.47	7.99	7.39	0.20	0.19	0.09	01.10	0.86	0.85	0.31	0.95
SE (m) ±	0.14	0.11	0.07	0.05	0.02	0.039	0.01	0.01	0.08	0.28	0.24	0.13
C.D. at 5%	0.42	N.S.	NS	0.16	0.05	NS	NS	0.03	NS	0.83	NS	0.37

Table 1. (b). Chemical properties of soil after completion of crop cycles in diversified cropping system (2004-05 to 2007-08)

Treatments	**Chemical properties**											
	Available N (kg/ha)				Available P (kg/ha)				Available K (kg/ha)			
	2004-05	**2005-06**	**2006-07**	**2007-08**	**2004-05**	**2005-06**	**2006-07**	**2007-08**	**2004-05**	**2005-06**	**2006-07**	**2007-08**
Initial Status of Soil	253.0	232.3	319.5	295.3	24.4	22.2	21.2	26.7	394.0	207.1	228.6	137.5
Rice-Wheat-Black Gram	261.3	324.0	292.7	239.5	19.9	24.5	26.8	21.3	215.6	224.0	138.0	177.8
Rice-Capsicum-Cucumber	219.5	300.9	287.5	218.7	20.7	27.0	25.2	16.1	204.4	240.8	138.0	170.8
Rice-Carrot-Cowpea	211.0	271.8	313.6	218.7	23.3	21.7	27.8	29.9	260.4	241.7	133.6	177.8
Rice-Mustard-Tomato	240.7	294.7	292.7	239.5	24.2	22.8	30.0	15.2	198.8	223.1	135.1	186.7
Rice-Potato-Onion	240.4	313.6	308.3	197.9	21.1	26.3	26.9	14.8	191.3	250.1	140.9	190.4
Rice-Cabbage-Bitter Gourd	230.2	482.2	271.8	218.7	24.1	24.0	25.3	17.5	201.5	220.3	142.4	178.3
Rice-Coriander-Ladies Finger	219.5	261.3	334.5	208.3	20.6	23.5	26.4	18.4	205.3	221.2	135.1	177.3
Rice-Tomato-Bottle Gourd	209.1	324.1	271.8	229.1	20.8	23.0	28.2	15.1	210.0	205.0	142.1	183.9
Rice-Pea-Green Chilli	240.4	303.2	313.6	218.7	25.5	21.0	26.1	14.9	201.6	236.1	133.6	195.9
Rice-Lentil-Sponge Gourd	250.9	318.8	266.6	229.1	21.8	20.6	24.3	15.5	182.0	223.1	136.5	175.5
SE (m) ±	27.03	62.31	29.78	14.1	1.71	2.78	2.98	4.76	17.42	10.37	5.93	9.0
C.D. at 5%	80.33	185.15	NS	41.9	5.08	NS	NS	14.4	51.75	NS	NS	26.8

Table 2. Paddy equivalent yield (PEY-t/ha) of different cropping system (2004-05 to 2007-08)

Cropping systems	Paddy yield equivalent (t/ha)				
	2004-05	2005-06	2006-07	2007-08	Mean
Rice-Wheat-Black Gram	16.74	14.25	12.12	13.26	14.09
Rice-Capsicum-Cucumber	16..93	13.36	12.84	21.11	16.06
Rice-Carrot-Cowpea	21.70	31.38	22.68	22.61	24.59
Rice-Mustard-Tomato	27.39	24.16	21.81	24.39	24.44
Rice-Potato-Onion	27.44	35.20	32.12	19.14	28.47
Rice-Cabbage-Bitter Gourd	19.56	15.80	17.41	31.22	21.00
Rice-Coriander-Ladies Finger	27.14	28.30	25.90	25.84	26.79
Rice-Tomato-Bottle Gourd	51.07	28.07	41.72	40.90	40.44
Rice-Pea-Green Chilli	12.15	11.23	11.57	17.96	13.23
Rice-Lentil-Sponge Gourd	20.96	20.86	13.19	22.46	19.37
SE(m) ±	0.82	0.54	0.65	1.14	2.58
C.D. at 5%	2.44	1.61	1.93	3.37	7.66

Note: Price of paddy Rs. 6000/tonne taken for converting yield of different crops to the paddy yield equivalent.

Table 3. Farm size category and diversification index (DI)

Farm category	DI	Number of farmers with levels of diversification			Total number of farmers
		Low	Medium	High	
Small	0.741	1(12.5)	3(37.5)	4(50.5)	8
Medium	0.591	4(33.3)	4(33.3)	4(33.3)	12
Large	0.626	-	3(37.5)	5(62.5)	8
Overall	0.643	5(17.8)	10(35.7)	13(46.4)	28

Note: Figures in the parenthesis indicate percentage.

levels of crop diversification evenly to the tune of 33.3 per cent each. The results are in agreement with that of Singh and Sharma (2001).

System profitability

Maximum net profit (Table 4) was recorded in rice-tomato-bottle gourd (Rs. 1,39,124=00) followed by rice-coriander-lady's finger (Rs. 89,459=00) and rice-potato-onion (Rs. 82,365=00) respectively. Similar trend was observed in case of benefit cost ratio (Rs. 2.65, 2.44 and 2.36). The maximum

Tabe 4. Economics of diversified cropping systems

Treatments	Paddy yield equivalent (t/ha)	Productivity (kg/ha/ day)	Gross income (Rs./ ha)	Cost of cultivation (Rs./ ha)	Net return (Rs./ha)	Profitability (Rs./ha/ day)	B :C Ratio	Relative Economic Efficiency (REE)
Rice-Wheat-Black Gram	14.09	40.26	84540	57445	27095	77.41	1.47	-
Rice-Capsicum-Cucumber	16.06	49.72	96360	61608	34752	107.59	1.56	28.26
Rice-Carrot-Cowpea	24.59	77.57	147540	62401	85049	268.29	2.36	213.91
Rice-Mustard-Tomato	24.44	77.59	146640	57664	88976	288.46	2.54	328.39
Rice-Potato-Onion	28.47	94.27	170820	89982	80838	267.67	1.90	198.35
Rice-Cabbage-Bitter Gourd	21.00	72.66	126000	73504	52496	181.65	1.71	93.74
Rice-Coriander-Ladies Finger	26.79	76.32	160740	62057	98683	281.15	2.59	264.21
Rice-Tomato-Bottle Gourd	40.44	122.54	244440	84536	159904	484.56	2.89	490.16
Rice-Pea-Green Chilli	13.23	38.91	79380	54823	24557	72.22	1.45	(-) 9.38
Rice-Lentil-Sponge Gourd	19.37	61.49	116220	52605	63615	201.95	2.21	134.79
SE(m) ±	2.58	-	-	-	-	-	-	-
C.D. at 5%	7.66	-	-	-	-	-	-	-

profitability (Rs. 484.6/ha/day) and relative economic efficiency (490.2 %) was recorded in rice-tomato-bottle gourd followed by rice-mustard-tomato (Rs. 288.5/ha/day and 328.4 %), rice-coriander-ladies finger (Rs. 281.2/ha/day and 264.2%), while lowest in rice-pea-green chillies (Rs. 72.2/ha/day and (- 9.38 %), respectively. The results are in conformity with results of Gangwar and Ram (2005) and Katyal et.al. (2002) It is interesting to note that vegetable dominated cropping systems were more remunerative than cereal and pulse dominated cropping systems.

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J. Farming Systems Research & Development **17** (1&2) : 52-59 (2011)

RESOURCE USE EFFICIENCY AND WEED DYNAMICS OF DIFFERENT CROPPING SYSTEMS UNDER FIRB AND CONVENTIONAL PLANTING METHODS

VIPIN KUMAR, SANDEEP KUMAR[1], PREM SINGH AND R.K. NARESH[2]

Project Directorate for Farming Systems Research, Modipuram Meerut-250 110 (U.P.)

ABSTRACT

A Field experiment was conducted during 2005–2007 at Project Directorate for Cropping System Research, Modipuram Meerut to study the diversification opportunities of rice-wheat cropping systems through inclusion of potato, vegetable pea, mustard, green gram and chickpea through furrow irrigated raised bed planting technology to increase the production, economics and resource use efficiencies. Inclusion of potato, vegetable pea, mustard, green gram in the systems increased the production, economics and land use efficiency. Legumes and oilseed crops planted on raised bed proved significantly higher yield than that of conventional planting technology. Maize, vegetable pea (as a green pod), mustard, chick pea, green gram recorded up to 16.0, 33.0, 19.4, 12.9 and 12.4 percent higher yield as compared to conventional flat planting. Significantly higher rice equivalent yield (REY 26.5 t ha^{-1}), net return (Rs. 1,13,586 ha^{-1} $year^{-1}$) and energy ($56.06x10^6$ kcal ha^{-1}) was in maize-potato-wheat cropping system followed by rice-wheat-green gram REY (15.2 t ha^{-1}), net return (Rs. 68517 ha^{-1} $year^{-1}$) and energy ($41.95x10^6$ kcal ha^{-1}) as against traditional rice-wheat system REY (11.2 t ha^{-1}), net return and energy (Rs. 51546 ha^{-1} $year^{-1}$ and 35.69 $x10^6$ kcal ha^{-1}). Land use efficiency (LUE) of rice-mustard-green gram was the highest (90.4%) under conventional system, closely followed by that of rice-wheat-green gram and maize-potato-wheat (87.7 and 84.9 percent, respectively). Highest water use efficiency was recorded in maize–vegetable pea–green gram cropping system (230.8 kg REY/ha-cm), while the highest production efficiency, economic efficiency and lowest weed population were observed under maize-potato-wheat cropping system. FIRB planting system witnessed higher water use efficiency, production efficiency, economic efficiency, net return being (29, 13, 19, and 10 percent higher, respectively) and 48% lower weed population over conventional flat bed planting method.

Key words: Cropping system, Economics, Resource use efficiency, Raised bed, Weed dynamics

Resource efficient alternative cropping system to rice-wheat involving, potato, maize, green gram mustard and chickpea etc. are the eminent and of IGP in India, which led to induce the scope of increasing per unit productivity and sustainability. To improve the sustainability of rice-wheat system over the years, growing of legumes as break crop showed a marked influence on weed flora over the years and a reduction of 45 to 61% weed count was noted in

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[1] Associate Professor & Head, Dept. of Agronomy, CCR (PG) College, Muzaffarnagar, Ch.Charan Singh University, Meerut (U.P.) e mail: sandeepkail@yahoo.com

[2] Sardar Vallabhbhai Patel University of Agricultuere & Technology, Meerut (U.P.), India.

succeeding rice-wheat crop cycle. Continuous practice of one cropping system could not sustain the productivity of the crops. Further, new problems have started in the system posing a serious threat to its sustainability. It is necessary to accommodate a suitable crop in the cropping system to get higher return without depletion of soil fertility.

The crop yields increased perceptibly due to enhanced input-use efficiency. The combination of reduced cost and higher production results in better returns to the farmers. Irrigated rice-based cropping systems are among the major water users in Asia and account for around half of all diverted freshwater in Asia. Recent research has focused on water-saving technologies, especially in rice cultivation. A range of new irrigation and cultivation methods have been developed, which basically consist of growing rice under more aerobic conditions, *i.e.* no continuous flooding during the growing season. The alternation of aerobic and anaerobic field conditions in rice system affects the sustainability of rice production, environmental impact, and N dynamics. Resource conservation technology and nutrient management strategies would help maintain the crop productivity and soil fertility. This emphasizes the need to explore possibility to increase the farm income which can only be achieved through intensification and diversification of the existing system. In system mode it is necessary to express the response of cropping system in term of equivalent of a major crop prevailing in the concerned area. Keeping these in views, the present study was conducted to assess the production potential and efficiencies of different cropping systems under different crop establishment methods.

MATERIALS AND METHODS

The experiment was undertaken during 2005-06 and 2006-07 at the research farm of Project Directorate for Farming Systems Research (PDFSR), Modipuram, District Meerut (U.P.) at 29^0 4' N latitude and 77^0 46' E longitud*es* and at an elevation of 237 meters above mean sea level. It falls under the north western plain agro-climatic zone. The climate of Modipuram is broadly classified as semi-arid sub-tropical characterized by very hot summers and cold winters. The hottest months are May-June, when maximum temperature may sometimes shoot up as high as 45-46 ^{0}C, whereas Dec-Jan is the coldest months. The average annual rainfall is 862.7 mm, distributed July to September and a few scattered showers during winter. The experimental soil was sandy loam in texture (*Typic Ustochrept*) with a bulk density of 1.39 Mg m^{-3}, pH 8.0, available N 163.1 kg ha^{-1}, available P 18.7 kg ha^{-1}, available K 140.1 kg ha^{-1} and organic carbon 0.44%. The treatments consisted of two crop establishment practices (i) conventional flat bed method and (ii) furrow irrigated raised bed (FIRB) of seeding as sub plot and six crop sequences as main plot viz., (i) Rice-wheat (ii) Rice-Wheat-Greengram**,** (iii) Rice-Chickpea, (iv) Rice-

Mustard-Greengram, (v) Maize-Vegetable pea-Greengram and (vi) Maize-potato-wheat were laid out in factorial randomized block design. Each of the treatments was replicated thrice. Rice (Saket-4), Wheat (PBW-343), Maize (HQPM-1), Green gram (Pusa vishal), Chickpea (Awarodhi), Mustard (Pusa bold) Vegetable pea (Arkel) and potato (Khufri bahar) were grown as per crop establishment methods. At the time of establishment of the experiment, field was prepared well. Raised beds were prepared by using raised bed planter. Fresh beds were prepared each year after the crop harvest. The seeds were sown (dribbled) in rows under both beds and flat conventional methods. Three rows of rice and wheat, two rows of vegetable pea, green gram chickpea and mustard, and one row of maize were grown on top of 37.5 cm wide raised bed and irrigation was given in 30 cm wide furrow. The recommended dose of fertilizer was applied uniformly to both the establishment method treatments. The recommended package of practices was followed for each of the crops. The quantity of water applied each irrigation to the crops was measured using parshall flume. The economics were computed using the prevailing markets prices for inputs and outputs. Total field duration of a cropping system expressed in percentage of 365 days was taken as the land use efficiency (LUE) of the system. Water use efficiency (WUE) of different cropping systems was computed by dividing REY in term of system productivity with total water used by different crops in the cropping systems and was expressed as kg REY/ha-cm of water uses. Production efficiency was expressed as the ratio of system productivity in kg REY/ha to total duration of the system in days (Tomar and Tiwari 1990) and production efficiency in economic term (economic use efficiency) were calculated by taking net return instead of REY. The energies of different crops and cropping systems were calculated as described by Gopalan *et al.* (1978).

Results and Discussion

Yield and economics

Results revealed that grain yield of rice and wheat was positively reduced on raised bed (FIRB) 5.96 and 4.40 % respectively, owing to higher plant population in conventional system as compared to FIRB planting system while, On the contrary maize, legumes and oilseed crops planted on raised bed generated significantly higher yield than that of conventional planting technology. Maize, vegetable pea (as a green pod), mustard, chick pea, green gram recorded up to 16.0, 33.0, 19.4, 12.9 and 12.4 percent higher yield as compared to conventional flat planting (Fig 1). These findings corroborated the observations of Tripathi and Singh (2008).

There is sufficient scope to replace rice-wheat cropping system with other cropping systems without any decline in economic yield rather it improved substantially. Among the cropping systems, maize-potato-wheat registered significantly higher rice equivalent yield (REY 26.5 t ha^{-1}), net return (‘1,13,586 ha^{-1} year^{-1}) and energy (56.06x10^{6} kcal ha^{-1}) followed by rice-wheat-green gram REY (15.2 t ha^{-1}), net return (‘ 68517 ha^{-1} year^{-1}) and energy (41.95x10^{6} kcal ha^{-1}). It is closely followed by maize-vegetable pea-green gram sequence, which produced significantly higher REY (14.3 t ha^{-1}), net return of (‘ 61422 ha^{-1} year^{-1}) and energy (29.91 x10^{6} kcal ha^{-1}). Rice-chick pea cropping system produced lowest REY, net return and energy of 10.3 t ha^{-1}, ‘ 41768 ha^{-1} year^{-1} and 25.65

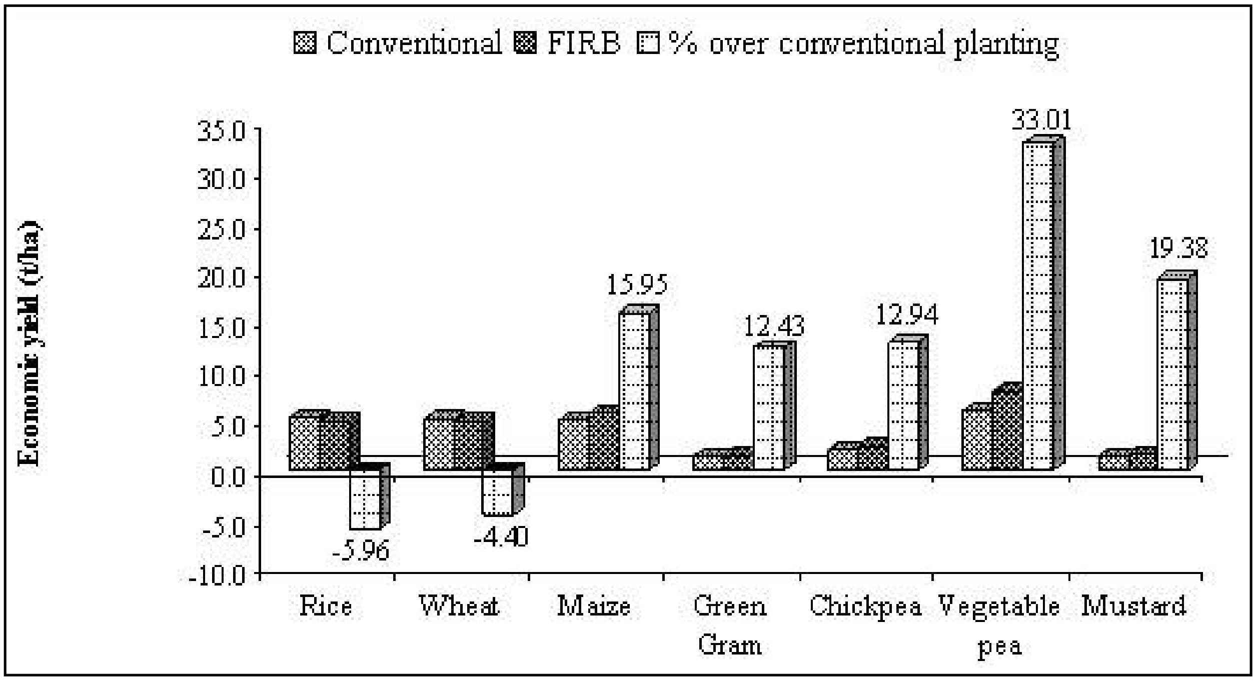

Fig. 1. Economic yield of different crops under conventional and raised bed (FIRB) planting technology and yield % increase or decrease over conventional planting

x10^6 kcal ha^{-1}, respectively. Under planting methods, furrow irrigated raised bed (FIRB) produced about 5.0 per cent higher REY and 10.0 percent more net return over conventional flat bed system (Table 1). Significantly higher benefit: cost ratio (return per rupee invested) was recorded in maize-vegetable pea-green gram sequence (1.76) being at par with maize-potato-wheat (1.65) than rest of all the sequences. Rice-mustard-green gram produced lowest B: C ratio (1.35). FIRB method gave significantly higher benefit cost ratios (1.68) as compared to flat bed planting methods (1.47). Singh *et al.* (2008) also reported similar results.

Resources-use efficiencies

Resources use efficiency gives an indication to the ability of the crop to convert utilizable resources to economic product. In the present study, different resources had been positively influenced by various cropping systems under conventional and raised bed (FIRB) planting system (Table 2). Land use efficiency (LUE) of rice-mustard-green gram was the highest (90.4%) under conventional system, closely followed by that of rice-wheat-green gram and maize-potato-wheat 87.7 and 84.9 percent, respectively. Other crop sequences showed LUE in the range of 68.5 to 74.0%. The existing rice-wheat system was most inferior in respect of land use as the land remained fallow for more than two months in a year. The variation in land use efficiency was primarily due to the duration of winter and summer crops in the cropping system. The results confirmed the findings of Tomar and Tiwari (1990). Under bed planting system the land use efficiency were recorded low as compared to conventional because of beds were dried more rapidly than flat system resulting lesser duration.

Tables 1: REY, economics and total energy output of different cropping systems as influenced by planting methods

Cropping systems	Rice equivalent yield (t ha^{-1})			Net return (Rs. ha^{-1})			B:C Ratio			Total calories output (x10^6 k cal)		
	Conventional	**FIRB**	**Mean**	**Conventional**	**FIRB**	**Mean**	**Conventional**	**FIRB**	**Mean**	**Conventional**	**FIRB**	**Mean**
Rice-Wheat	11.4	10.9	11.2	52491	50601	51546	1.57	1.60	1.59	36.51	34.88	35.69
Rice-Wheat-Green gram	15.2	15.1	15.2	68197	68838	68517	1.57	1.66	1.62	42.51	41.39	41.95
Rice-Chick pea	10.1	10.5	10.3	39350	44186	41768	1.35	1.60	1.47	25.64	25.67	25.65
Rice-Mustard-Green gram	12.3	13.2	12.7	47193	54694	50943	1.23	1.47	1.35	30.00	31.06	30.53
Maize-Vegetable Pea-Green gram	12.9	15.7	14.3	51875	70970	61422	1.47	2.06	1.76	27.32	32.51	29.91
Maize-Potato-Wheat	26.1	26.9	26.5	110470	116702	113586	1.59	1.71	1.65	54.83	57.29	56.06
Mean	14.7	15.4		61596	67665		1.47	1.68		36.13	37.13	
CD (*P=0.05*) Crop sequence			0.9			6255			0.18			2.02
Planting method			0.1			1046			0.03			0.33

Table 2. Indices of resource use efficiencies of different cropping systems as influenced by planting methods

Cropping systems	Land use efficiency (%)			Water use efficiency (kg REY/ha-cm)			Production efficiency (kg /ha/day)			Economic efficiency (Rs./ha/day)		
	Conventional	**FIRB**	**Mean**	**Conventional**	**FIRB**	**Mean**	**Conventional**	**FIRB**	**Mean**	**Conventional**	**FIRB**	**Mean**
Rice-Wheat	68.5	65.8	67.2	51.4	59.6	55.5	43.8	43.6	43.7	202	202	202
Rice-Wheat-Green gram	87.7	82.2	85.0	64.2	77.6	70.9	46.1	48.7	47.4	207	222	214
Rice-Chick pea	74.0	69.9	72.0	51.8	64.7	58.2	36.1	39.6	37.8	141	167	154
Rice-Mustard-Green gram	90.4	82.2	86.3	58.9	76.8	67.8	36.2	42.6	39.4	139	176	158
Maize-Vegetable Pea-Green gram	73.9	68.5	71.2	181.4	280.2	230.8	47.8	65.4	56.6	192	296	244
Maize-Potato-Wheat	84.9	82.1	83.5	209.4	239.7	224.5	81.6	89.7	85.6	345	389	367
Mean	79.9	75.1		102.8	133.1		48.6	54.9		204	242	

Different cropping systems consumed varied quantities of irrigation water. It is evident from the data that the highest water use efficiency was recorded in maize–vegetable pea–green gram (224.5 kg REY/ha-cm) followed by maize-potato-wheat because of high production with less water use. The other cropping systems rice wheat, rice-wheat-green gram, rice-chickpea and rice-mustard-green gram recorded lower water use efficiency ranging from 55.5–70.9 kg REY/ha-cm. The lowest water use efficiency was recorded with existing rice-wheat cropping system (55.5 kg REY/ha-cm). An examination of data clearly indicated that water use efficiency increased efficiently on FIRB by 29% as compared to conventional bed. The results obtained in close accordance with those of Maurya and Singh (2008). The cropping systems with maize as a component crop expressed higher economic efficiency (244 to 367 ‘ ha^{-1} day^{-1}), production efficiency (56.6 to 85.6 kg ha^{-1} day^{-1}), followed by rice-wheat green gram and rice-wheat sequence. Rice-mustard-green gram and rice-chickpea systems showed the minimum production and economic efficiency because of their lower REY and net return (Table 2).

Weed dynamics

Results revealed that total weeds population and dry weight was recorded significantly lower in maize-potato-wheat sequence followed by maize-vegetable pea-green gram. However, sequence rice-wheat and rice-wheat-green gram was statistically at par but, weed population and dry weight were found highest under both the sequences than the other sequences. Bed planting proved advantageous as it maintained lower population as well as dry matter of weeds than conventional flat planting. Raised bed reduced the weed population by 48.0 percent and dry weight of weeds 45 percent over conventional flat sowing (Table 3). Aggarwal and Goswami (2003) also observed significantly lesser population of weeds under bed planting compared to flat planting.

Based on findings of this experiment it can be concluded that under the conditions of north-western plains of India, maize-potato-wheat cropping

Table 3: Effect of crop establishment methods on weed count and dry matter of weeds of various cropping systems

Cropping systems	Total weed nos. m^{-2}			Dry matter weight (g m^{-2})		
	Conventional	FIRB	Mean	Conventional	FIRB	Mean
Rice-Wheat	275.4	134.5	205.0	56.0	30.5	43.3
Rice-Wheat-Green gram	288.7	162.5	225.6	63.7	35.6	49.7
Rice-Chick pea	199.2	102.5	150.9	47.1	26.8	36.9
Rice-Mustard-Green gram	222.5	106.5	164.6	51.9	24.5	38.2
Maize-Vegetable Pea-Green gram	113.8	69.5	91.7	34.9	22.7	28.8
Maize-Potato-Wheat	108.2	52.9	80.6	29.8	16.0	22.9
Mean	201.3	104.7		47.2	26.0	
CD (P=0.05) Crop sequence (A)			20.6			9.3
Planting method (B)			13.7			3.2

system is more productive, sustainable, resource-use efficient, remunerative and a yield replacement for traditional rice-wheat system. FIRB seem to work more effective comparison to conventional flat bed method sowing for diversification of cropping system.

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J. Farming Systems Research & Development **17** (1&2) : 60-72 (2011)

NUTRIENT CONTENT AND UPTAKE OF BARLEY AS AFFECTED BY FERTILIZER LEVELS AND PRECEDING CROPS GROWN WITHOUT AND WITH FYM

R.P.S. Shaktawat[1] and P.S. Shekhawat[2]

Krishi Vigyan Kendra, Mandsaur (Madhya Pradesh) 458001

Abstract

To study the effect of fertilizer levels and preceding crops grown with and without FYM on nutrient content, uptake of barley in IGNP command, an investigation was carried out during *kharif* and *rabi* seasons of 2003-04 and 2004-05 on sandy loam soils of Bikaner (Rajasthan). On the basis of two years study, it may be concluded that maximum nitrogen, phosphorus and potassium content and uptake at different growth stages in dry matter, grain and straw at harvest of barley were recorded when grown after clusterbean. Application of 10 t FYM ha^{-1} applied to kharif crops had significant effect on nitrogen, phosphorus and potassium content at 30, 60, 90 DAS in dry matter, grain and straw of barley at harvest. Similarly, N, P and K uptake by barley plant at different growth stages were significantly increased with FYM @ 10 t ha^{-1} applied to kharif crops and registered 64.79, 12.39 and 71.96 kg ha^{-1} higher uptake at harvest, respectively over control. Addition of fertilizer from control to 120 kg N + 60 kg P_2O_5 ha^{-1} significantly increased the nitrogen, phosphorus and potassium content and uptake estimated at different growth stages and in grain and straw. Application of 120 kg N + 60 kg P_2O_5 ha^{-1} registered the N, P and K content 1.747, 0.315 and 0.332 per cent in grain and 0.336, 0.087 and 1.747 per cent in straw of barley, respectively on pooled basis.

Key words: Fertilizer levels, preceding crops, FYM, Barley,

The problem of soil fertility depletion and decline in yields in western Rajasthan conditions may be due to the exhaustive nature of cereal – cereal cropping sequence. Inclusion of legume crops can help in sustaining the productivity of the system. FYM is rich source of organic matter and can be supplemented with the chemical fertilizers. A minimum nutrient loss due to slow release of nutrients from organic manures is an advantage. Therefore, the residual nutrients can be utilized by next crop in a crop rotation. Fertilizers, especially, nitrogen and phosphorus play a major role in early establishment of aerial portion capable of photosynthesis and increases root development to enable more efficient use of water and nutrients. Most of the workers have been confined to ascertain the response of nutrients in isolation (as N and P). Since, N and P have additive effect on grain yield, it is utmost important to assess their response in combination. Keeping all the facts in view, the present investigation was, therefore, undertaken.

Methods and Material

A field experiment was conducted during the *kharif* and *rabi* seasons of 2003-04 and 2004-05 at Agricultural Research Station, Rajasthan Agricultural University, Bikaner to study the effect of fertilizer levels and preceding crops grown with and without

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[1] Subject Matter Specialist (Agronomy).

[2] Assistant Professor (Agronomy), ARS, RAU, Bikaner

FYM on nutrient content and uptake by barley. The soil of the experimental plot was sandy loam in texture, saline in reaction (pH 8.30), low in organic carbon (0.08%), medium in available phosphorus (17.89 kg ha^{-1}) and high in available potassium (230.0 kg ha^{-1}). The 30 treatments were tested in split plot design as *kharif* crops and FYM in main plots and fertilizer levels in sub plots with three replications. The treatments consisting of 3 *kharif* crops (pearl millet, mothbean and clusterbean) with and without FYM (applied to kharif crops only) in main plots and 5 levels of fertilizer applied to barley only (control, 30 kg N + 15 kg P_2O_5 ha^{-1}, 60 kg N + 30 kg P_2O_5 ha^{-1}, 90 kg N + 45 kg P_2O_5 ha^{-1} and 120 kg N + 60 kg P_2O_5 ha^{-1}) in sub plots. The HHB-67, RMO-40 and RGC-986 varieties of pearl millet, mothbean and clusterbean were sown with full recommended dose of fertilizer i.e. 80 kg N + 40 kg P_2O_5 ha^{-1}, 20 kg N + 40 kg P_2O_5 ha^{-1} and 20 kg N + 40 kg P_2O_5 ha^{-1}, respectively. After harvesting of kharif crops, the RD –2508 variety of barley was sown in rows, 22.5 cm apart, on November 19, 2003 and November 21, 2004. The barley crop was fertilized (N + P_2O_5) as per treatment. The whole of phosphorus and half dose of nitrogen was applied as basal through DAP and urea, respectively and the remaining half dose of nitrogen fertilizer was applied through urea as top dressing at the time of first irrigation. The harvesting of the barley was done on March 23 and March 20, during 2004 and 2005, respectively. The total rainfall in *kharif* season was 222.0 and 102.8 mm and in *rabi* season was 7.5 and 65.4 mm during 2003-04 and 2004-05, respectively.

The plant samples collected at 30, 60, 90 DAS and grain and straw samples collected at harvest from each plots were dried and then ground to find powder for estimation of nitrogen, phosphorus and potassium content by standard methods. Estimation of nitrogen was done by colorimetric method using Nessler's reagent to develop colour (Snell and Snell, 1949). Phosphorus content was determined by "Vanadomolybdo phosphoric acid" yellow colour method. Digestion of sample was done by tri-acid mixture (Jackson, 1967). Potassium content in samples was determined in tri – acid digested material by using flame photometer (Jackson, 1967). The uptake of nitrogen, phosphorus and potassium by plant samples collected at 30, 60 and 90 DAS was computed from their content in plant samples using following relationship:

Nutrient uptake by plant (kg ha^{-1}) = Nutrient content in sample (%) X Dry matter production (q ha^{-1})

The uptake of nitrogen, phosphorus and potassium by grain and straw samples at harvest was computed from their content in grain and straw using following relationship and the total nutrient uptake by plant at harvest was worked out by adding the nutrient uptake by grain and straw:

Nutrient uptake by grain or straw (kg ha^{-1}) = Nutrient content in grain or straw (%) X Yield of grain or straw (q ha^{-1})

RESULTS AND DISCUSSION

Effect of kharif crops

The nitrogen content was estimated in plant dry matter at 30, 60, 90 DAS and in grain and straw at harvest of barley. It is revealed from the data (Table 1) that nitrogen content significantly affected due to residual effect of kharif crops during both the years of experimentation. At all the growth stages, the maximum nitrogen content of barley plant was recorded when barley was grown after clusterbean which was significantly

Table 1. Effect of kharif crops, FYM and fertilizer levels on nitrogen content (%) in barley

Treatments	Nitrogen content (%) in barley														
	At 30 DAS			At 60 DAS			At 90 DAS			Grain			Straw		
	2003-4	2004-5	Pooled	2003-4	2004-5	Pooled	2003-4	2004-5	Pooled	2003-4	2004-5	Pooled	2003-4	2004-5	Pooled
Kharif crops															
Pearl millet	3.409	3.288	3.348	2.196	2.188	2.192	0.985	0.979	0.982	1.703	1.690	1.697	0.301	0.294	0.298
Mothbean	3.450	3.443	3.446	2.224	2.219	2.222	0.997	0.988	0.992	1.714	1.712	1.713	0.306	0.304	0.305
Clusterbean	3.504	3.495	3.499	2.256	2.239	2.247	1.025	1.026	1.026	1.727	1.731	1.729	0.319	0.329	0.324
S. Em. ±	0.0174	0.0105	0.0101	0.0112	0.0073	0.0067	0.0049	0.0063	0.0040	0.0052	0.0039	0.0033	0.0021	0.0031	0.0018
CD 5%	0.0548	0.0331	0.0300	0.0355	0.0231	0.0198	0.0156	0.0201	0.0119	0.0166	0.0124	0.0097	0.0068	0.0097	0.0055
FYM (t ha^{-1})															
Control	3.425	3.361	3.393	2.205	2.197	2.201	0.985	0.981	0.983	1.696	1.692	1.694	0.301	0.302	0.301
10	3.483	3.456	3.469	2.245	2.234	2.239	1.020	1.014	1.017	1.734	1.730	1.732	0.317	0.315	0.316
S. Em. ±	0.0142	0.0085	0.0083	0.0092	0.0059	0.0054	0.0040	0.0052	0.0033	0.0043	0.0032	0.0026	0.0017	0.0025	0.0015
CD 5%	0.0448	0.0270	0.0245	0.0290	0.0188	0.0162	0.0128	0.0164	0.0097	0.0136	0.0101	0.0079	0.0056	0.0079	0.0045
Fertilizer levels (N + P_2O_5 ha^{-1})															
Control	3.246	3.218	3.232	2.125	2.132	2.128	0.957	0.953	0.955	1.673	1.666	1.669	0.283	0.286	0.284
30 + 15	3.376	3.317	3.346	2.172	2.172	2.172	0.981	0.979	0.980	1.700	1.696	1.698	0.297	0.292	0.295
60 + 30	3.423	3.380	3.401	2.230	2.214	2.222	1.010	1.002	1.006	1.718	1.718	1.718	0.309	0.306	0.308
90 + 45	3.551	3.517	3.534	2.283	2.262	2.272	1.024	1.019	1.022	1.733	1.731	1.732	0.321	0.317	0.319
120 + 60	3.676	3.611	3.643	2.316	2.297	2.307	1.039	1.035	1.037	1.749	1.744	1.747	0.333	0.329	0.336
S. Em. ±	0.0146	0.0123	0.0095	0.0067	0.0060	0.0045	0.0019	0.0024	0.0015	0.0019	0.0024	0.0015	0.0014	0.0024	0.0014
CD 5%	0.0417	0.0350	0.0268	0.0192	0.0173	0.0127	0.0054	0.0070	0.0044	0.0054	0.0069	0.0043	0.0042	0.0068	0.0039

higher over pearl millet, respectively during 2003-04, 2004-05 and pooled basis of analysis. During 2003-04, significant highest nitrogen content in grain (1.727%) of barley was recorded when grown after clusterbean as compared to pearl millet but it was statistically at par when grown after mothbean. Similarly the highest nitrogen content of grain of barley was estimated after clusterbean during 2004-05 and pooled mean, which was significantly higher than mothbean and pearl millet. The maximum nitrogen content of straw was recorded when barley was grown after clusterbean which was significantly higher by 5.98, 11.90 and 8.72 per cent over pearl millet, respectively during 2003-04, 2004-05 and pooled basis of analysis.

Experimental data given in Table 2 showed that phosphorus content estimated at 30, 60 and 90 DAS in plant dry matter and in the grain and straw at harvest were significantly affected due to residual effect of kharif crops during both the years of experimentation. At all the growth stages, phosphorus content of barley plant was significantly higher when grown after clusterbean as compared to mothbean and pearl millet. During 2003-04, significantly highest phosphorus content (0.304%) in grain of barley was recorded when grown after clusterbean as compared to pearl millet but it was statistically at par when grown after mothbean. Further data indicated that the highest phosphorus content of grain of barley was estimated after clusterbean, which was significantly higher than estimation after mothbean and pearl millet during 2004-05 and on the basis of pooled analysis. Similarly, maximum phosphorus content in straw was recorded when barley was grown after clusterbean which was significantly higher by 7.58, 13.85 and 10.61 per cent over pearl millet, respectively during 2003-04, 2004-05 and on pooled basis of analysis. Phosphorus content of straw at harvest of barley grown after mothbean was non-significantly higher than barley grown after pearl millet.

Data presented in Table 3 revealed that potassium content of plant dry matter of barley significantly influenced when grown after kharif crops. At 30 DAS, maximum potassium content (4.226%) in dry matter of plant was recorded when grown after clusterbean followed by mothbean (3.972%). Similarly, on the basis of pooled analysis, maximum potassium content (2.271%) of dry matter of plant sample taken at 60 DAS was recorded after clusterbean, which was significantly higher by 6.22 and 13.89 per cent over mothbean and pearl millet, respectively. Data further revealed that potassium content in dry matter of plant estimated at 90 DAS was maximum when barley was grown after clusterbean but it was statistically at par when barley grown after mothbean. Similarly potassium content of dry matter was significantly higher after mothbean as compared to pearl millet during 2004-05 and on the basis of pooled mean; both were statistically at par during 2003-04. A perusal of data makes it amply clear that clusterbean as a preceding crop significantly increased the potassium content in grain and straw at harvest. In grain, after clusterbean, there were 4.93 and 7.41 per cent improvement in potassium content over mothbean and pearl millet, respectively on the basis of pooled mean. During 2003-04, K content of straw was found significantly superior after clusterbean and mothbean whereas, variation between above mentioned kharif crops was non-significant. While during 2004-05 and

Table 2. Effect of kharif crops, FYM and fertilizer levels on phosphorus content (%) in barley

Treatments	Phosphorus content (%) in barley														
	At 30 DAS			At 60 DAS			At 90 DAS			Grain			Straw		
	2003-4	2004-5	Pooled	2003-4	2004-5	Pooled	2003-4	2004-5	Pooled	2003-4	2004-5	Pooled	2003-4	2004-5	Pooled
Kharif crops															
Pearl millet	0.379	0.372	0.376	0.271	0.243	0.257	0.135	0.141	0.138	0.292	0.280	0.286	0.066	0.065	0.066
Mothbean	0.396	0.391	0.394	0.294	0.290	0.292	0.143	0.145	0.144	0.299	0.295	0.297	0.067	0.067	0.067
Clusterbean	0.417	0.411	0.414	0.312	0.316	0.315	0.149	0.158	0.154	0.304	0.303	0.303	0.071	0.074	0.073
S. Em. ±	0.0028	0.0038	0.0023	0.0033	0.0019	0.0019	0.0026	0.0017	0.0015	0.0018	0.0021	0.0014	0.0011	0.0015	0.0009
CD 5%	0.0090	0.0120	0.0070	0.0104	0.0062	0.0056	0.0083	0.0056	0.0047	0.0057	0.0068	0.0042	0.0036	0.0050	0.0029
FYM (t ha^{-1})															
Control	0.391	0.383	0.387	0.284	0.269	0.277	0.132	0.138	0.135	0.288	0.284	0.286	0.059	0.060	0.060
10	0.404	0.399	0.402	0.302	0.297	0.299	0.152	0.158	0.155	0.307	0.300	0.304	0.077	0.078	0.078
S. Em. ±	0.0023	0.0031	0.0019	0.0026	0.0016	0.0015	0.0021	0.0014	0.0013	0.0015	0.0017	0.0011	0.0009	0.0013	0.0008
CD 5%	0.0073	0.0098	0.0057	0.0085	0.0051	0.0045	0.0067	0.0045	0.0038	0.0047	0.0056	0.0034	0.0030	0.0041	0.0023
Fertilizer levels (N + P_2O_5 ha^{-1})															
Control	0.363	0.357	0.360	0.259	0.239	0.249	0.114	0.124	0.119	0.278	0.270	0.274	0.049	0.049	0.049
30 + 15	0.387	0.380	0.383	0.279	0.266	0.272	0.131	0.136	0.133	0.288	0.282	0.285	0.061	0.062	0.061
60 + 30	0.398	0.395	0.396	0.294	0.284	0.289	0.143	0.149	0.146	0.300	0.294	0.297	0.067	0.067	0.067
90 + 45	0.414	0.409	0.411	0.308	0.302	0.305	0.154	0.160	0.157	0.307	0.304	0.306	0.079	0.078	0.079
120 + 60	0.425	0.416	0.421	0.324	0.323	0.323	0.169	0.172	0.170	0.317	0.313	0.315	0.086	0.088	0.087
S. Em. ±	0.0026	0.0028	0.0019	0.0017	0.0018	0.0012	0.0018	0.0012	0.0010	0.0010	0.0013	0.0008	0.0009	0.0011	0.0007
CD 5%	0.0076	0.0080	0.0054	0.0050	0.0051	0.0035	0.0051	0.0035	0.0030	0.0030	0.0039	0.0024	0.0026	0.0033	0.0021

Table 3. Effect of kharif crops, FYM and fertilizer levels on potassium content (%) in barley

Treatments	Potassium content (%) in barley														
	At 30 DAS			At 60 DAS			At 90 DAS			Grain			Straw		
	2003-4	2004-5	Pooled	2003-4	2004-5	Pooled	2003-4	2004-5	Pooled	2003-4	2004-5	Pooled	2003-4	2004-5	Pooled
Kharif crops															
Pearl millet	3.719	3.663	3.691	2.011	1.977	1.994	1.626	1.690	1.658	0.304	0.290	0.297	1.704	1.690	1.697
Mothbean	4.047	3.898	3.972	2.177	2.099	2.138	1.744	1.797	1.770	0.306	0.301	0.304	1.714	1.713	1.714
Clusterbean	4.263	4.190	4.226	2.287	2.254	2.271	1.883	1.828	1.855	0.319	0.319	0.319	1.729	1.733	1.731
S. Em. ±	0.072	0.028	0.038	0.036	0.014	0.019	0.057	0.031	0.032	0.0022	0.0029	0.0018	0.0051	0.0043	0.0033
CD 5%	0.227	0.088	0.114	0.113	0.045	0.057	0.180	0.100	0.096	0.0070	0.0091	0.0053	0.0163	0.0136	0.0099
FYM (t ha^{-1})															
Control	3.825	3.732	3.779	2.062	2.013	2.038	1.647	1.652	1.649	0.303	0.294	0.299	1.697	1.693	1.695
10	4.193	4.101	4.147	2.255	2.207	2.231	1.855	1.892	1.873	0.317	0.312	0.315	1.735	1.731	1.733
S. Em. ±	0.059	0.022	0.031	0.029	0.011	0.015	0.046	0.026	0.026	0.0018	0.0023	0.0014	0.0042	0.0035	0.0027
CD 5%	0.186	0.072	0.093	0.092	0.037	0.046	0.146	0.082	0.078	0.0057	0.0074	0.0044	0.0133	0.0111	0.0081
Fertilizer levels (N + P_2O_5 ha^{-1})															
Control	3.555	3.498	3.526	1.919	1.886	1.903	1.669	1.546	1.607	0.283	0.274	0.279	1.673	1.666	1.669
30 + 15	3.732	3.694	3.713	2.015	1.993	2.004	1.681	1.652	1.667	0.299	0.291	0.295	1.702	1.698	1.700
60 + 30	4.063	3.965	4.014	2.187	2.135	2.161	1.778	1.761	1.770	0.310	0.305	0.308	1.719	1.719	1.719
90 + 45	4.239	4.148	4.194	2.281	2.232	2.256	1.778	1.876	1.827	0.322	0.316	0.319	1.735	1.733	1.734
120 + 60	4.458	4.279	4.368	2.391	2.304	2.347	1.849	2.023	1.936	0.334	0.329	0.332	1.749	1.744	1.747
S. Em. ±	0.036	0.036	0.025	0.018	0.018	0.012	0.039	0.037	0.027	0.0013	0.0011	0.0008	0.0020	0.0024	0.0015
CD 5%	0.103	0.103	0.072	0.052	0.051	0.036	0.113	0.107	0.077	0.0039	0.0031	0.0024	0.0057	0.0070	0.0044

pooled mean data shows that after clusterbean significantly higher K content of straw was obtained when compared with mothbean and pearl millet.

It is evident from the data (Table 4) that nitrogen uptake by grain, straw and total uptake by barley plant at harvest was significantly affected by residual effect of kharif crops during both the years of experimentation as well as pooled mean. The magnitude of increase in nitrogen uptake estimated in barley after clusterbean was 11.09 and 20.78 per cent in grain, 15.14 and 29.03 per cent in straw and 11.80 and 22.20 per cent in total plant at harvest when compared with nitrogen uptake estimated after mothbean and pearl millet, respectively.

Data presented in Table 5 revealed that phosphorus uptake by grain, straw and total uptake by barley plant at harvest was significantly affected by residual effect of kharif crops during both the years of experimentation. The magnitude of increase in phosphorus uptake estimated in barley after clusterbean was 12.37 and 25.06 per cent in grain, 17.70 and 31.80 per cent in straw and 13.45 and 26.44 per cent in total plant at harvest when compared after mothbean and pearl millet, respectively on the basis of pooled means.

A perusal of data (Table 6) indicated that kharif crops significantly increased potassium uptake by grain, straw and total uptake by plant at harvest. The magnitude of increase was 15.57 and 26.65 per cent in grain, 9.49 and 21.27 per cent in straw and 10.29 and 21.98 per cent in total plant at harvest under the treatment barley grown after clusterbean when compared with potassium uptake estimated after mothbean and pearl millet, respectively on the basis of pooled means.

Different preceding crops had significant effect on nitrogen, phosphorus and potassium content and uptake in barley crop at different growth stages and in grain and straw at harvest. The pooled data (Table 4.27 to 4.29) indicated that nitrogen, phosphorus and potassium contents and uptake were higher when barley was grown after clusterbean than mothbean and pearl millet. Higher dry matter accumulation and more vegetative growth of barley under preceding kharif legumes might be due to higher extraction of nitrogen from the soil. Significant increase in nitrogen uptake by barley due to preceding kharif crops was probably due to cumulative effect of increased dry matter and nitrogen concentration on account of higher availability of nitrogen under legume than pearl millet. The preceding kharif legumes not only increased the nitrogen content in the grain but also improved the quality of grain by increasing protein content of barley grain. This increase in protein content of barley was due to enrichment of soil with nitrogen after harvest of clusterbean and its greater uptake by succeeding crop of barley as protein content of grain is the function of its N content (Sharma and Vyas, 2002). Padhi and Parida (2000) reported an increase in nitrogen content and uptake in wheat when grown in sequence with a kharif legume than cereal crop.

Phosphorus uptake by barley at different growth stages and in grain and straw at harvest due to preceding kharif crops was influenced significantly (Table 5). The kharif legume residue especially of clusterbean acted as soil renovator and increased the solubility and availability of phosphorus to succeeding barley due probably to the development of P – solubilizing organisms in the root zone of

Table 4. Effect of kharif crops, FYM and fertilizer levels on nitrogen uptake (Kg ha^{-1}) by barley

Treatments	Nitrogen uptake (Kg ha^{-1})																	
	At 30 DAS			At 60 DAS			At 90 DAS			Grain			Straw			Total		
	2003-04	2004-05	Pool	2003-04	2004-05	Pool	2003-04	2004-05	Pool	2003-04	2004-05	Pool	2003-04	2004-05	Pool	2003-04	2004-05	Pool
Kharif crops																		
Pearl millet	7.84	8.04	7.94	33.82	31.67	32.74	48.56	45.79	47.17	45.83	44.28	45.05	9.59	9.14	9.37	55.42	53.42	54.42
Mothbean	9.59	9.10	9.34	35.11	34.67	34.89	53.72	51.33	52.53	48.21	49.75	48.98	10.49	10.52	10.50	58.70	60.26	59.48
Clusterbean	10.98	10.26	10.62	38.35	39.43	38.89	62.15	60.63	61.39	52.83	55.98	54.41	11.58	12.61	12.09	64.41	68.59	66.50
S. Em. ±	0.326	0.183	0.187	0.870	0.758	0.577	0.682	1.561	0.852	0.985	0.648	0.589	0.130	0.172	0.108	1.077	0.765	0.660
CD 5%	1.029	0.578	0.552	2.742	2.389	1.702	2.151	4.919	2.513	3.104	2.043	1.739	0.404	0.545	0.319	3.395	2.412	1.949
FYM (t ha^{-1})																		
Control	8.72	7.84	8.28	31.95	31.72	31.84	48.72	48.66	48.69	44.64	46.68	45.66	9.62	10.01	9.82	54.27	56.69	55.48
10	10.21	10.43	10.32	39.57	38.79	39.18	60.90	56.50	58.70	53.27	53.33	53.30	11.49	11.50	11.49	64.75	64.82	64.79
S. Em. ±	0.266	0.150	0.153	0.710	0.619	0.471	0.557	1.274	0.695	0.804	0.529	0.481	0.106	0.141	0.088	0.879	0.625	0.539
CD 5%	0.840	0.472	0.451	2.239	1.951	1.390	1.756	4.017	2.052	2.535	1.668	1.420	0.335	0.445	0.260	2.772	1.970	1.591
Fertilizer levels (N + P_2O_5 ha^{-1})																		
Control	5.23	4.87	5.05	15.98	16.05	16.02	24.68	23.69	24.18	25.03	20.58	22.80	4.97	4.12	4.55	30.00	24.70	27.35
30 + 15	7.59	6.69	7.14	27.27	24.87	26.07	46.94	41.79	44.36	44.21	42.01	43.11	8.82	8.77	8.79	53.03	50.78	51.90
60 + 30	9.05	8.80	8.92	36.58	36.00	36.29	59.06	52.72	55.89	50.37	52.04	51.20	10.22	10.62	10.42	60.59	62.66	61.62
90 + 45	11.59	11.20	11.39	44.20	45.29	44.74	68.06	64.76	66.41	59.85	64.08	61.97	13.25	14.01	13.63	73.10	78.10	75.60
120 + 60	13.89	14.11	14.00	54.78	54.07	54.42	75.32	79.95	77.64	65.32	71.31	68.32	15.52	16.26	15.89	8.85	87.56	84.20
S. Em. ±	0.275	0.195	0.168	1.128	0.910	0.725	1.126	1.454	0.919	0.795	0.792	0.561	0.141	0.188	0.117	0.881	0.805	0.596
CD 5%	0.783	0.555	0.473	3.209	2.588	2.035	3.203	4.135	2.582	2.262	2.254	1.576	0.401	0.537	0.331	2.506	2.289	1.675

Table 5. Effect of kharif crops, FYM and fertilizer levels on phosphorus uptake (Kg ha^{-1}) by barley

Treatments	Phosphorus uptake (Kg ha^{-1})																	
	At 30 DAS			At 60 DAS			At 90 DAS			Grain			Straw			Total		
	2003-04	2004-05	Pool	2003-04	2004-05	Pool	2003-04	2004-05	Pool	2003-04	2004-05	Pool	2003-04	2004-05	Pool	2003-04	2004-05	Pool
Kharif crops																		
Pearl millet	0.88	0.92	0.90	4.26	3.67	3.97	7.91	7.01	7.46	7.94	7.46	7.70	2.20	2.15	2.17	10.14	9.61	9.87
Mothbean	1.10	1.04	1.07	4.73	4.63	4.68	9.09	7.93	8.51	8.48	8.66	8.57	2.42	2.44	2.43	10.89	11.10	11.00
Clusterbean	1.31	1.21	1.26	5.41	5.71	5.56	10.59	9.82	10.20	9.36	9.89	9.63	2.73	2.98	2.86	12.09	12.87	12.48
S. Em. ±	0.038	0.018	0.021	0.126	0.063	0.070	0.229	0.257	0.172	0.268	0.178	0.161	0.074	0.105	0.064	0.393	0.264	0.237
CD 5%	0.120	0.059	0.063	0.397	0.201	0.208	0.722	0.811	0.508	0.845	0.562	0.475	0.233	0.331	0.189	1.241	0.834	0.700
FYM (t ha^{-1})																		
Control	1.00	0.90	0.95	4.22	4.05	4.13	7.79	7.18	7.48	7.67	7.95	7.81	1.9	2.08	2.04	9.65	10.03	9.84
10	1.19	1.21	1.20	5.38	5.30	5.34	10.61	9.33	9.97	9.52	9.39	9.46	2.91	2.96	2.93	12.43	12.35	12.39
S. Em. ±	0.031	0.015	0.017	0.103	0.052	0.057	0.187	0.210	0.140	0.219	0.145	0.131	0.060	0.085	0.052	0.321	0.216	0.193
CD 5%	0.098	0.048	0.051	0.324	0.164	0.170	0.589	0.662	0.415	0.690	0.459	0.388	0.191	0.270	0.154	1.013	0.681	0.571
Fertilizer levels (N + P_2O_5 ha^{-1})																		
Control	0.59	0.54	0.57	1.96	1.83	1.89	3.01	3.13	3.07	4.18	3.34	3.76	0.87	0.71	0.79	5.04	4.05	4.55
30 + 15	0.87	0.77	0.82	3.54	3.09	3.32	6.48	6.06	6.27	7.50	7.00	7.25	1.83	1.85	1.84	9.33	8.85	9.09
60 + 30	1.06	1.03	1.04	4.84	4.69	4.77	8.98	8.03	8.51	8.81	8.92	8.86	2.22	2.35	2.29	11.03	11.28	11.15
90 + 45	1.35	1.30	1.33	5.98	6.09	6.03	11.82	10.44	11.13	10.63	11.28	10.96	3.29	3.47	3.38	13.92	14.76	14.34
120 + 60	1.62	1.63	1.62	7.69	7.66	7.67	15.68	13.61	14.64	11.86	12.80	12.33	4.03	4.23	4.13	15.89	17.03	16.46
S. Em. ±	0.035	0.024	0.021	0.143	0.094	0.085	0.219	0.163	0.136	0.236	0.315	0.196	0.072	0.116	0.068	0.313	0.385	0.248
CD 5%	0.102	0.069	0.061	0.408	0.268	0.241	0.622	0.465	0.383	0.671	0.896	0.552	0.205	0.331	0.192	0.892	1.096	0.697

Table 6. Effect of kharif crops, FYM and fertilizer levels on Potassium uptake (Kg ha^{-1}) by barley

Treatments	Potassium uptake (Kg ha^{-1})																	
	At 30 DAS			At 60 DAS			At 90 DAS			Grain			Straw			Total		
	2003-04	2004-05	Pool	2003-04	2004-05	Pool	2003-04	2004-05	Pool	2003-04	2004-05	Pool	2003-04	2004-05	Pool	2003-04	2004-05	Pool
Kharif crops																		
Pearl millet	8.69	9.12	8.91	31.59	29.30	31.45	45.45	48.07	46.76	8.81	7.75	8.03	53.38	51.86	52.62	61.69	59.62	60.65
Mothbean	11.35	10.46	10.91	35.36	33.51	34.44	53.31	55.50	54.41	8.72	8.88	8.80	58.01	58.55	58.28	66.73	67.43	67.08
Clusterbean	13.48	12.42	12.95	39.47	40.26	39.86	62.78	64.54	63.66	9.85	10.48	10.17	62.08	65.54	63.81	71.93	76.03	73.98
S. Em. ±	0.339	0.275	0.218	1.658	1.143	1.007	1.841	1.477	1.180	0.257	0.260	0.183	1.073	1.811	1.052	1.290	2.230	1.288
CD 5%	1.069	0.868	0.645	5.227	3.603	2.971	5.801	4.655	3.482	0.811	0.819	0.540	3.381	5.709	3.106	4.066	7.028	3.800
FYM (t ha^{-1})																		
Control	9.86	8.81	9.33	30.42	29.67	30.04	46.97	49.96	48.46	8.07	8.28	8.17	53.52	55.16	54.34	61.59	63.45	62.52
10	12.49	12.53	12.51	40.53	39.05	39.79	60.73	62.11	61.42	9.85	9.80	9.82	62.13	62.14	62.14	71.98	71.94	71.96
S. Em. ±	0.277	0.225	0.178	1.354	0.933	0.822	1.503	1.206	0.963	0.210	0.212	0.149	0.876	1.479	0.859	1.053	1.821	1.051
CD 5%	0.873	0.709	0.526	4.268	2.941	2.426	4.737	3.801	2.843	0.662	0.669	0.440	2.760	4.661	2.536	3.320	5.738	3.103
Fertilizer levels (N + P_2O_5 ha^{-1})																		
Control	5.78	5.34	5.56	14.56	14.30	14.43	22.12	23.24	22.68	4.26	3.40	3.83	29.29	23.98	26.64	33.55	27.37	30.46
30 + 15	8.46	7.51	7.99	25.42	23.02	24.22	42.05	44.05	43.05	7.78	7.25	7.51	50.39	50.51	50.45	58.17	57.77	57.97
60 + 30	10.85	10.39	10.62	36.14	35.08	35.61	55.70	56.88	56.29	9.12	9.30	9.21	56.65	59.24	57.95	65.77	68.54	67.16
90 + 45	13.91	13.32	13.61	44.29	44.92	44.61	68.67	72.06	70.37	11.16	11.76	11.46	71.42	76.33	73.88	82.58	88.10	85.34
120 + 60	16.88	16.79	16.84	56.95	54.46	55.71	80.69	83.94	82.32	12.49	13.49	12.99	81.37	83.19	82.28	93.86	96.68	95.26
S. Em. ±	0.348	0.282	0.224	1.666	1.466	1.109	1.866	1.747	1.278	0.235	0.377	0.222	0.904	1.703	0.964	0.984	2.046	1.135
CD 5%	0.989	0.802	0.629	4.737	4.170	3.115	5.307	4.967	3.588	0.670	1.073	0.624	2.570	4.844	2.706	2.800	5.820	3.188

legumes. Thus increased availability of P to the crop of barley grown after clusterbean than pearl millet led to similar variation in dry matter production and its P contents resulting finally in higher P uptake by barley grown after clusterbean than pearl millet. These results are in close conformity with the results obtained by Jain and Jain (1993).

Effect of FYM

Application of FYM @ 10 t ha^{-1} to kharif crops has significant effect on nitrogen content of barley plant dry matter at different growth stages, grain and straw at harvest. On the basis of pooled analysis, this treatment increased the nitrogen content estimated in grain and straw by 2.24 and 4.98 per cent as compared to control, respectively.

It is evident from the data (Table 2) that application of FYM @ 10 t ha^{-1} to kharif crops has significant effect on phosphorus content of barley plant dry matter at different growth stages, grain and straw. On the basis of pooled analysis, FYM @ 10 t ha^{-1} applied to kharif crops increased the phosphorus content estimated in dry matter of plant at 30, 60, 90 DAS, grain and straw by 3.88, 7.94, 14.82, 6.29 and 30.00 per cent as compared to control, respectively.

Irrespective of different growth stages, the higher potassium content was estimated under the application of FYM @ 10 t ha^{-1} to kharif crops which was significantly higher over control. On the basis of pooled analysis, application of FYM @ 10 t ha^{-1} significantly increased the potassium content by 9.74, 9.47, 13.58, 5.35 and 2.24 per cent over control estimated in dry matter of plant at 30, 60, 90 DAS, grain and straw at harvest, respectively.

It is apparent from data presented in Table 4 that application of FYM @ 10 t ha^{-1} to kharif crops significantly increased the nitrogen uptake by grain, straw and total plant of barley at harvest. The magnitude of increase over control was 16.73, 17.01 and 16.78 per cent in grain, straw and total plant at harvest, respectively on the basis of pooled analysis.

Application of FYM @ 10 t ha^{-1} to kharif crops significantly affected the phosphorus uptake by grain, straw and total plant at harvest. The magnitude of increase over control was 21.13, 43.63 and 25.91 per cent in grain, straw and total plant at harvest, respectively on the basis of pooled analysis.

Further examination of data (Table 6) revealed that application of FYM @ 10 t ha^{-1} to kharif crops significantly affected the potassium uptake by grain, straw and total plant at harvest. The magnitude of increase over control was 20.20, 14.35 and 15.10 per cent in grain, straw and total plant at harvest on the basis of pooled analysis, respectively.

The FYM application to kharif crops led to enrichment of the soil with N, P and K and consequently adequate and sustained availability to the succeeding crop of barley resulted in significant increases in N, P and K contents and uptake at different growth stages and in grain and straw of barley during both the years of experimentation. The increased uptake of N, P and K by the crop due to FYM application could also be due to improvement in nutritional environment of root zone, which encouraged the proliferation of roots thereby facilitating more withdrawal of water and nutrients from larger area and greater depth (Sharma and Bali, 2001). The higher nitrogen content is a result of availability of nitrogen from mineralization of native and added nutrient from FYM. The increased P content in plant, grain and straw of barley is possibly due to solubilization effect of FYM on native and applied P. The decomposition of FYM resulted into the formation of CO_2 which might have played an important role in the solubilization of native P and formation of phospho – humic complexes, which are more easily taken up and assimilated by the plants by the process of isomorphic replacement of phosphate ions by humate ions and coating of sesquioxide particles by humus to form a protective cover which reduces the phosphate fixing capacity of the soil. The increase in protein content in grain under the influence of FYM seems to be due to increased nitrogen content in grain which has a significant role in synthesis of protein in grain (Meena *et al.*, 2002).

Effect of Fertilizer level

It is apparent from the data (Table 1) that successive addition of fertilizer up to 120 kg N + 60 kg P_2O_5 ha^{-1} significantly increased the nitrogen content of barley plant dry matter estimated at 30, 60, 90 DAS, grain and straw at harvest. Addition of fertilizer levels from control to 30 kg N + 15 kg P_2O_5 ha^{-1}, 60 kg N + 30 kg P_2O_5 ha^{-1}, 90 kg N + 45 kg P_2O_5 ha^{-1} and 120 kg N + 60 kg P_2O_5 ha^{-1} increased the nitrogen content to the extent of 1.74, 2.94, 3.77 and 4.67 per cent in grain and 3.87, 8.45, 12.32 and 18.31 per cent in straw over preceding lower level of fertilizer, respectively on the basis of pooled analysis.

It is clear from the data (Table 2) that successive addition of fertilizer up to 120 kg N + 60 kg P_2O_5 ha^{-1} significantly increased phosphorus content of barley plant dry matter recorded at 30, 60 and 90 DAS, grain and straw at harvest. The maximum phosphorus content at all the stages was recorded when 120 kg N + 60 kg P_2O_5 ha^{-1} was applied to barley. On the basis of pooled analysis, addition of fertilizer levels from control to 30 kg N + 15 kg P_2O_5 ha^{-1}, 60 kg N + 30 kg P_2O_5 ha^{-1}, 90 kg N + 45 kg P_2O_5 ha^{-1} and 120 kg N + 60 kg P_2O_5 ha^{-1} increased the phosphorus content to the extent of 4.01, 4.21, 3.03 and 2.94 per cent in grain and 24.49, 9.84, 17.91 and 10.13 per cent in straw over preceding lower level of fertilizer, respectively.

Successive increase in fertilizer levels up to 120 kg N + 60 kg P_2O_5 ha^{-1} significantly increased potassium content of plant dry matter recorded at 30, 60 and 90 DAS, grain and straw at harvest during both the years of experimentation. On the basis of pooled means, the magnitude of increase with 120 kg N + 60 kg P_2O_5 ha^{-1} in potassium content was to the extent of 4.08, 7.79, 12.54 and 19.00 per cent in grain and 0.75, 1.63, 2.76 and 4.67 per cent in straw over 90 kg N + 45 kg P_2O_5 ha^{-1}, 60 kg N + 30 kg P_2O_5 ha^{-1}, 30 kg N + 15 kg P_2O_5 ha^{-1} and control, respectively.

Increase in fertilizer application up to 120 kg N + 60 kg P_2O_5 ha^{-1} significantly increased nitrogen uptake by grain and straw of barley. The data further indicates that crop fertilized with 120 kg N + 60 kg P_2O_5 ha^{-1} increased the nitrogen uptake by 45.52 and 11.34 kg N ha^{-1} in grain and straw over control on the basis of pooled mean, respectively. Similarly, each increase in fertilizer levels up to 120 kg N + 60 kg P_2O_5 ha^{-1} significantly increased the nitrogen uptake by plant at harvest. The magnitude of increase over respective lower level was 89.76, 18.73, 22.69 and 11.38 per cent, on the basis of pooled mean.

Successive increase in fertilizer up to 120 kg N + 60 kg P_2O_5 ha^{-1} significantly increased phosphorus uptake by grain and straw of barley. Crop fertilized with 120 kg N + 60 kg P_2O_5 ha^{-1} increased phosphorus uptake by 8.57 and 3.34 kg P ha^{-1} in grain and straw over control on the basis of pooled mean, respectively. Similarly, application of 120 kg N + 60 kg P_2O_5 ha^{-1} significantly increased the phosphorus uptake by plant at harvest over control, 30 kg N + 15 kg P_2O_5 ha^{-1}, 60 kg N + 30 kg P_2O_5 ha^{-1} and 90 kg N + 45 kg P_2O_5 ha^{-1} treatments. The magnitude of increase over respective lower level was 99.78, 22.66, 28.61 and 14.78 per cent, on the basis of pooled mean.

Fertilizer application significantly increased potassium uptake by grain and straw of barley. Crop fertilized with 120 kg N + 60 kg P_2O_5 ha^{-1} increased potassium uptake by 9.16, 55.64 and 64.80 kg ha^{-1} in grain, straw and total plant at harvest over control on the basis of pooled mean, respectively. The magnitude of increase in potassium uptake by plant at harvest up to 120 kg N + 60 kg P_2O_5 ha^{-1} over respective lower level was 90.32, 15.85, 27.05 and 11.62 per cent, on the basis of pooled mean.

Successive increases in fertilizer application up to 120 kg N + 60 kg P_2O_5 ha^{-1} significantly increased the N, P and K contents of barley at different growth stages, grain and straw at harvest as well as N, P and K uptake by the crop. The significant increases in nutrient contents might be due to greater availability of nutrients in soil supplied through applied fertilizer. Uptake of nutrients as a function of biomass production and nutrient content of that biomass increased with fertilizer application. These results are in close conformity with the findings of Ramavtar (1995), Gupta *et al.* (2001) and Meena *et al.* (2002).

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J. Farming Systems Research & Development **17** (1&2) : 73-79 (2011)

EVALUATION OF SPENT MUSHROOM (*PLEUROTUS SAJOR CAJU*) SUBSTRATES (SMS) FOR THEIR UTILIZATION IN RADISH (*RAPHANUS SATIVUS* LINN.) CULTIVATION AND SOIL IMPROVEMENT

K.P. Tripathi, R.B. Tewari and Prem Singh

Project Directorate for Farming Systems Research, Modipuram, Meerut-250 110 (U.P.)

Abstract

Spent mushroom (*Pleurotus sajor caju* strain no. 1140) substrates (SMS), a left over residue of mushroom cultivation, were evaluated for their use in vegetable production and soil improvement. Experiment was conducted with SMS residues of wheat straw, sorghum stover, mung bean husk, cowpea husk, FYM and control (without any residue). Residues were finely grounded prior to their application in the soil. Radish(*Raphanus sativus* Linn. Cv Pusha Deshi) was grown in soil, while maintaining 70% water holding capacity throughout experimental period. Higher biomass production under SMS residues of mung bean and cowpea husks could be ascribed to their narrower C:N ratios and better decomposition and microbial activities. Higher CO2 released from soil surface during radish cultivation under mung bean and cowpea SMS residues could assigned another reason for more root and shoot production under these residues. The per cent organic carbon contributed by microbial biomass carbon was highest with SMS residue of mung bean husk (12.71%0 as against 10.32, 9.89,9.70, 8.53 and 8.49%, respectively under SMS residues of cowpea husk, control, wheat straw, FYM and sorghum stover, respectively. Thus, SMS residues were a viable organic materials for radish cultivation.

Key words: Spent mushroom substrate (SMS), Radish,Organic carbon,Soil microbial biomass carbon.

Mushroom cultivation is a viable recycling process for farm wastes through eco-friendly technology. The fungal mycelia present in different edible mushroom species are able to degrade lignocelluloses in the residues by producing certain enzymes. After degradation, carbon and mineral nutrients released from complex structures in the residues are further utilized for cultivation of mushroom. In the process of mushroom cultivation, therefore, agronomic value of leftover residues which are also called as spent mushroom substrate (SMS) increases because of degradation of complex materials of lignins and celluloses had taken place. These SMS residues have traditionally been discarded as wastes, creating an environmental nuisance. In recent years, mushroom growers are facing pressures from environmental activists related to disposal of SMS. Recycling of SMS could be used successfully to solve agronomic or environmental problems, while generating more income to mushroom growers (Levanon and Danai, 1995). SMS could also be used for rehabilitation of unproductive soils (Rupert, 1995). By looking into the compost value of the SMS, mushroom growers sell it as the compost (Riggle, 1997).

Nowadays in the country, farmers are being encouraged by government agencies to grow mushroom as small scale industries by utilizing their farm wastes. After mushroom cultivation, by product SMS residues need to be evaluated for its further utilization in crop and vegetable production and also for animal feed. Soil application of SMS and their impact on yield (Selvi and Augustine Selvaseelan, 1997a), nutrients uptake (Singhania & Singh 1986; Singh et al. 1987), soil availability of nutrients (Maskina and Randhawa (1983) and soil physical properties (Selvi and Augustine Selvaseelan, 1997b) have been reported. However, there is a little attempt to evaluate SMS generated from different crop residues spent mushroom substrates for their use in crop cultivation in the arid sandy soils as a substitutes for organic manures, which is the objective of this study.

Materials and Methods

Experiment was conducted at Central Arid Zone Research Institute, Jodhpur with spent mushroom substrates (SMS) generated from residues of wheat straw, sorghum stover, mung bean husk and cowpea husk after cultivation of mushroom species namely, *Pleurotus sajor caju* strain no.1140. Residue balance of the mushroom cultivation together with span run days is presented in Table1. SMS residues collected after mushroom production were grinded and passed through 2 mm sieve prior to application into the soil. SMS residues were applied in micro-plots of the size 1m x 1m @ 10 t ha^{-1} or 100 gm^{-2} in triplicate plots. FYM applied with the same rate together with control plot (without any residue) were also kept as treatments for the comparison. Soil used for study belonged to the Typic camborthids with sand content >85%, organic carbon 0.24%, available P 14.3 kg ha^{-1}, available K 217 kg ha^{-1}, EC 3.7 dS m^{-1}, pH 8.2, total N 0.065% and dehydrogenase 2.1 p kat g^{-1} soil.

Radish (*Raphanus sativus* Linn.), a popular vegetable for both tropical and temperate regions, was shown in the spot irrigated soils at about 70% of water holding capacity. This moisture content in the soil was maintained throughout the experimental period. Plant shoot and root weight were recorded at the harvest after 61 days after sowing. Nutrients uptake was recorded by uprooting, washing with water and 0.01 N HCl, drying in the oven at 70 ^{0}C for 24 hr. N content was determined by digestion of plant samples in H_2SO_4, whereas P and Ca contents were analyzed after di-acid digestion (AOAC,1990). Soil organic carbon and microbial biomass carbon were determined by procedures outlined by Black (1965) and Jacinthe et. al. (2002), respectively. Soil respiration was assayed by trapping CO_2 generated from soil surface in the KOH solution. Data were analyzed by the statistical procedures suggested by Panse and Sukhatme (1995).

Results and Discussions

Out of 4 crop residues (Table 1) of wheat straw, sorghum stover, mung bean husk and cowpea husk used for mushroom production, *Pleurotus sajor caju*, the spent mushroom substrate (SMS) production was lowest with cowpea husk (3.17 g g^{-1} fruit) followed by mung bean husk, wheat straw and sorghum stover. Loss of residue as CO_2 during mushroom cultivation was highest with wheat straw followed by sorghum stover, mung bean husk and cowpea husk as 6.83, 4.31, 4.29, and 4.08 g g^{-1} dry frit, respectively. On the other hand the mushroom production was highest with mung bean husk (94.5 g kg^{-1}) followed by cowpea husk (83.5 g kg^{-1}), wheat straw (63.8 g kg^{-1}) and sorghum stover (61.2 g kg^{-1}). These results could be summarized that mushroom cultivation, SMS by product generation and residue loss as CO_2 are dependent on the quality and type of residues used as a base materials for

Table 1: Residues balance in the mushroom production of species *Pleurotus sajor-caju*

Crop residues	Dry weight taken (g)	Span run days	Mushroom produced (g dry weight)	CO_2-C during mushroom cultivation (g g^{-1} dry fruit)	SMS (g g^{-1} dry fruit)
Wheat straw	1000	26	63.8	6.83	3.91
Sorghum stover	1000	28	61.2	4.31	5.63
Mung bean husk	1000	23	94.5	4.29	3.70
Cowpea husk	1000	24	83.5	4.08	3.19

mushroom cultivation. For all these parameters, performance of leguminous SMS residues of mung bean and cowpea husks were better than the non-leguminous residues of wheat and sorghum. Lower mushroom production efficiency and higher decomposition loss of wheat and sorghum residues led to more SMS production than the mung bean husk and cowpea husk.

There was significant reduction in the C: N ratio of crop residues after mushroom cultivation upon them (Table 2). The highest reduction (54.1%) in C: N ratio was observed with sorghum stover (from 124.3 to 67.14). However, reduction in C: N ratio of wheat straw, mung bean husk and cowpea husk was almost similar as 47.50, 48.18 and 47.29%, respectively. The decrease in the C: N ratio under all SMS residue, were even lower than FYM (C: N ratio 61.53). This observation clearly indicated that mushroom cultivation improved the agronomical quality of the SMS residues. Substantial increase in N content and narrowing of C: N ratio in SMS to cultivation of *Pleurotus sp.* has also been reported by Nallathambi and Marimuthu (1993).

The highest shoot and root weight of radish (Table 3) was recorded with the SMS of mung bean husk as 124.5 and 27.632 g plant^{-1}, respectively which was followed by SMS of cowpea husk as 116.35 and 142.30 g plant^{-1}, respectively. The shoot and root weight under SMS residues of wheat straw and sorghum stover were statistically at par (LSD 0.05), however these were significantly lower than the shoot and root weight with mung bean husk and cowpea husk.

Table 2: C:N ratio of crop residues before and after mushroom production (*Pleurotus sajor-caju*)

Treatment	C:N ratio of unused residue (2)	C:N ratio of SMS (3)	% reduction in C:N in column 3 over column 2
Wheat straw	166.2	78.96	47.50
Sorghum stover	124.3	67.14	54.01
Mung bean husk	88.3	42.55	48.18
Cowea husk	97.2	45.97	47.29
FYM	—	61.53	—

Table 3: Effect of different SMS on growth and yield of radish (mean of 5 plants)

Treatment	Shoot weight (g plant^{-1})	Root weight (g plant^{-1})	Total yield (g plant^{-1})	Shoot:root ratio	Root:total fresh weight ratio
Control	55.2	61.3	116.5	0.90	0.53
Wheat straw	73.7	121.2	194.9	0.60	0.62
Sorghum stover	81.0	110.1	191.1	0.73	0.58
Mung bean husk	124.5	276.3	400.8	0.45	0.69
Cowpea husk	116.3	142.3	258.6	0.51	0.55
FYM	72.3	86.6	158.9	0.83	0.54
LSD(0.05)	11.7	22.4	—	—	—

Similarily, shoot weight under mung bean and cowpea husk were statistically at par (LSD 0.05), but significant difference in their root weight was observed. These results indicated that leguminous SMS residues (mung bean husk and cowpea husk) were more efficient than the non-leguminous residues (wheat straw and sorghum stover). Shoot and root weight of radish was recorded significantly lower under FYM treated soil as compared to all SMS residues. FYM application could only produce significantly more biomass than the control treatment. The shoot and root ratio was lowest with SMS of mung bean husk (0.45) and was further followed by cowpea husk (0.51), wheat straw (0.60), sorghum stover (0.73), FYM (0.83) and control (0.90). Root biomass as per cent of total biomass was highest (68.93) under SMS residue of mung bean, which indicated that this treatment not only produced highest radish biomass (root+shoot) but also converted maximum biomass into roots. The root conversion was more in leguminous SMS residue than non-leguminous residues, which was further followed by FYM. In case of control, only 52.6% (lowest of all) biomass was occupied by roots. Higher biomass production under SMS residues of mung bean and cowpea husks could be ascribed to their narrower C:N ratio (Table 2) and better decomposition and microbial activities (Table 5). Higher CO_2 released from soil surface during radish cultivation under mung bean and cowpea SMS residues could be assigned another reason for more root and shoot production under these residues (Sandhu,1993).

Nutrient content of root and shoot parts of the plant (Table 4) indicated that the N, P and ca under SMS of mung bean husk and cowpea husk were statistically at par (0.05), except P content in shoot (81.7 mg 100g^{-1} fresh weight) was significantly higher under SMS residue of mung bean husk than the cowpea husk (77.1 mg 100g^{-1} fresh weight). Similarly N, P and Ca content in shoot and root of SMS residues of wheat straw and sorghum stover were statistically at par (p=0.05), except P content under sorghum stover (29.9 mg 100g^{-1}fresh weight) than the wheat straw (25.1 mg 100g^{-1}). However, overall nutrients content in leguminous SMS residues of mung bean and cowpea husks were significantly higher than the non-leguminous SMS residues of wheat

Table 4: Nutrients content of root and shoot of radish grown under different SMS

Treatment	N (mg 100 g $^{-1}$ fresh weight)		P (mg 100 g $^{-1}$ fresh weight)		Ca (mg 100 g $^{-1}$ fresh weight)	
	Root	Shoot	Root	Shoot	Root	Shoot
Control	87.4	317.1	24.1	71.0	47.0	270.1
Wheat straw	97.1	329.4	25.1	65.5	51.5	286.5
Sorghum stover	93.3	304.5	29.9	69.5	52.4	275.8
Mung bean husk	111.9	409.8	31.5	81.7	56.3	310.5
Cowpea husk	114.3	387.2	32.1	77.1	59.8	305.2
FYM	105.8	373.9	29.2	78.1	59.1	308.4
LSD(0.05)	6.8	28.4	3.7	4.1	3.8	17.4

straw and sorghum stover. FYM treatment significantly indicated more concentration of N, P and Ca in root and shoot than the non-leguminous SMS residues and control but lower than the leguminous SMS residues. Sherry Hsiao-Lei Wand et. al. (1984) and Stewart et. al. (2003) evaluating the growth response of vegetable crop to the SMS inferred that concentrations of nutrients in the seedlings of tissues of vegetable crops like snap bean, cucumber, radish, spinach and tomato increased. Swarup (1987) reported higher P uptake with the mushroom compost. Singh et. al. (1987) reported better N and Ca uptake under mushroom spent compost than the FYM. SMS with its higher Ca content (5.1%) has a slight edge over the other manures.

Organic carbon content of control plots (without any residue application) was almost unchanged (2400 µg g^{-1}). Application of FYM led to 50% increase in organic carbon over control. SMS from wheat straw and sorghum stover each resulted in 33.3% increase in soil organic carbon over control. Highest increase in SOC was observed with SMS residue of cowpea husk (87.5%).

Table 5: Effect of different quality SMS on soil properties after radish cultivation

Treatment	Microbial biomass carbon (µg g^{-1} soil)	Organic carbon (µg g^{-1} soil)	% of OC in MBC	Soil respiration* (mg CO$_2$ m^{-2} d^{-1})
Control	237.5	2400	9.89	31.55
Wheat straw	310.6	3200	9.70	57.51
Sorghum stover	271.9	3200	8.49	48.48
Mung bean husk	432.3	3400	12.71	65.40
Cowpea husk	464.6	4500	10.32	66.29
FYM	307.3	3600	8.53	57.21
LSD (0.05)	51.2	500	—	7.3

* period of observation 20 days.

However, SMS residue of mung bean husk (3400 µg g^{-1}) was less effective in soil organic carbon as compared to cowpea husk (4500 µg g^{-1}) and FYM (3600µg g^{-1}). SMS residues release high molecular weight dissolved organic matter which are further adsorbed by the sol (Guo and Chorover, 2003) and may contribute to the soil organic carbon pool.

Microbial biomass carbon was highest with SMS residue of cowpea husk (464.6 µg g^{-1}), but was significantly at par (0.05) with SMS residue of mung bean (432.3 µg g^{-1}). However, these two treatments reflected significantly higher microbial biomass carbon than SMS residues of wheat straw (310.6 µg g^{-1}), sorghum stover (271.9 µg g^{-1}), FYM (307.3 µg g^{-1}), and control (237.5 µg g^{-1}). The per cent organic carbon contributed by microbial biomass carbon was however, highest under SMS residue of mung bean husk (12.71%) as against 10.32, 9.89, 9.70, 8.53 and 8.49%, respectively under SMS residues of cowpea husk, control, wheat straw, FYM and sorghum stover, respectively. Upadhyaya and Arunachalam (2003) also found that the contribution of microbial C to soil organic C was found variable when the nature of residues are changed. Soil respiration, an indicator of biological activities in the soil during crop growth, was highest under SMS residue of mung bean husk (65.40 mg CO_2 m^{-2} d^{-1}). CO_2 evolution was recorded higher under wheat straw and FYM than sorghum stover. Overall, it could be concluded that the SMS is a good organic manure substitute with its higher reserve of plant nutrients and favourable soil properties (Stewart et. al.1998).

Thus, application of SMS residues in the soil led to important in soil organic carbon, microbial biomass carbon, shoot and root yield of radish and N, P and Ca nutrients Uptake. SMS from mung bean husk was found superior to other residues and FYM. Leguminous SMS residues were observed more beneficial to the crop and soil than the non-leguminous SMS residues.

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J. Farming Systems Research & Development **17** (1&2) : 80-83 (2011)

PRODUCTION POTENTIAL OF ORGANIC CROPPING SYSTEMS

P. Devasenapathy, Prema. S, Parimala Devi. R and Senthil Kumar. G

Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore-3

Abstract

Field experiments were conducted during 2004 - 2007 at Tamil Nadu Agricultural University, Coimbatore to evaluate a suitable cropping system based on productivity and profitability under organic farming. Pooled analysis of three years showed that Cotton- Maize- Green manure sequence produced higher cotton equivalent yield than other cropping systems. Higher system productivity and production efficiency were recorded in cotton based cropping system. Higher net return, economic efficiency were also registered in this cropping system.

Key words: System Productivity, Economic Efficiency, Net return, Organic cropping system

Crop sequence is the largest agricultural production system, which occupies 13.5 millian ha, including 10.3 million ha in India, extending from Indo-Gangetic plains to Himalayan foot-hills (Timsina and Connor, 2001). The choice of efficient crops and cropping systems depends on several factors. In most of the field crops, only a part of the total dry matter produced is taken as the crop yield. The need for sustainability and stability of any cropping system of the cropping system is that crop engaged in rotation should complete its life cycle or the period of economic viability in the available time frame. In the era of shrinking resource base of land, water and energy, resource use efficiency is an important aspect for considering the suitability of cropping system (Yadav, 2002). Hence, choice of the component crops needs to be suitably manoeuvered to harvest the synergism towards efficient utilization of resource base and to increase overall productivity (Anderson, 2005). Organic farming encourages the development of technologies and farming practices that not only increase productivity, but also arrest degradation as well as reclaim, rehabilitate, restore and enhance biological diversity and monitor adverse effects on sustainable agricultural diversity. Organic farming plays in both above and below-ground biodiversity, reduction of agricultural pollutants and the preservation and restoration of on-farm biodiversity. Careful selection of crops for the organic cropping system is an important prerequisite in organic farming. Keeping this in view present investigation was carried out to select productive, resource use efficient and remunerative cropping system for irrigated ecosystem.

Material and methods

Field experiments were conducted during 2004-2007 at Tamil Nadu Agricultural University, Coimbatore to evaluate a suitable cropping system based on productivity and profitability under organic farming. The soil was sandy clay loam with a pH of 8.66. The nutrient status indicated 0.52 % of organic carbon and 207.0, 16.0 and 625.2 kg ha^{-1} of available N, P and K. The experiment was laid out in Strip plot design with nine treatments. The main plots were three different cropping systems (CS$_1$- Cotton- Maize- Green manure, CS$_2$- Chillies - Onion - Green manure, CS$_3$- Turmeric + Onion – Green manure) and subplot were three different methods of practices (MP$_1$- Organic, MP$_2$-

Inorganic and MP_3- Integrated nutrient management) replicated thrice. After the second crop harvested in the cropping sequence green manure (Sun hemp) was sown and incorporated 45 days after sowing. For organic treatment, manures were applied on N equivalent basis of the individual crop. The difference in P requirement if any was met through application of Rock Phosphate. The organic manures like Vermicompost, Neem cake and Farm yard manure were applied at the time of last ploughing. For integrated management treatment half dose of calculated organic manures and half dose of inorganic fertilizers were applied. Recommended full dose of inorganic manures were applied in inorganic treatment. The treatments were separated by a hedge row of daincha for one meter width. The need based plant protection measures like neem oil spray was given when the pest infestation was severe. Panchagavya spray was given from 30th day after planting at 15 days interval thrice in both organic as well as integrated nutrient management.

Different crop sequence were compared by converting the yield of all the crops in a sequence in to base crop equivalent yield on price basis and then averaged. System Productivity was calculated by adding the base equivalent yield of the crop sequence. Production efficiency was calculated as equivalent base crop yield in a crop sequence divided by duration of crop sequence. (Tomar and Tiwari, 1990). Economic efficiency was calculated as per the procedure ascribed by Patil *et al.* (1995). Pooled data for three years was taken for comparison.

Table 1. Produce yield and equivalent yield of crops in the cropping sequence (Pooled data of two years)

Treatment	**Crop sequence**			**Yield (kg/ha)**			**Equivalent yield (kg/ha)**		
	Kharif	***Rabi***	***Summer***	***Kharif***	***Rabi***	***Summer***	***Kharif***	***Rabi***	***Summer***
CS_1MP_1	Cotton	Maize	GM	1322	3806	6066	1322	1642	6066
CS_1MP_2	Cotton	Maize	GM	931	3216	6066	931	1411	6066
CS_1MP_3	Cotton	Maize	GM	944	3483	6066	944	1529	6066
CS_2MP_1	Chillies	Onion	GM	922	3901	6066	922	1560	6066
CS_2MP_2	Chillies	Onion	GM	809	3798	6066	809	1518	6066
CS_2MP_3	Chillies	Onion	GM	895	3752	6066	895	1500	6066
CS_3MP_1	Turmeric + Onion		GM	4906		6066	1635		6066
CS_3MP_2	Turmeric + Onion		GM	3257		6066	1085		6066
CS_3MP_3	Turmeric + Onion		GM	3629		6066	1209		6066

	CS	MP	CSxMP	MPxCS
SEd	20.83	25.93	42.17	44.91
CD	57.83	56.49	98.04	97.85

GM- Green manure

RESULTS AND DISCUSSION

Cotton equivalent yield

System productivity and profitability played a vital role in determining the most useful and profitable crop sequence. The pooled analysis of the data of three years revealed that system productivity in terms of cotton equivalent yield of Cotton – Maize - Green manure crop sequence produced higher equivalent yield. Higher cotton equivalent yield in cotton based cropping sequence was due to intensification.

Among the different management techniques, organic method of cultivation registered the highest system productivity in terms of equivalent yield. This was followed by inorganic method of cultivation. Cotton based cropping system with organic management recorded higher system productivity which was on par with cotton based cropping system with integrated method of crop management. The least system productivity was obtained from turmeric based cropping system with inorganic method of cultivation.

Production efficiency and economic efficiency

Cotton – Maize - Green manure cropping system registered the highest production efficiency of 16.94 kg/ ha/ day. Among the management practices, organic method of cultivation registered higher production. Cotton based cropping system with organic cultivation registered higher efficiency. The cropping system with Chilli expressed higher economic efficiency of 136.57 Rs/ha/day because of the cost of chilli as vegetable.

It is concluded that, Cotton - Maize - Green manure cropping system recorded higher net return and economic efficiency and hence recommended in place of any other cropping system.

Table 2. System Productivity, production efficiency and economic efficiency of the cropping sequence (Pooled data of two years)

	System Productivity (kg/ha)			Production efficiency (kg/ha/day)			Economic efficiency (Rs/ha/day)		
Treatments	MP1	MP2	MP3	MP1	MP2	MP3	MP1	MP2	MP3
CS1	5675	5053	5185	16.94	15.08	15.47	112.19	115.07	101.73
CS2	4914	5039	5106	14.67	15.04	15.24	98.52	136.57	117.28
CS3	4906	3257	3629	14.64	9.72	10.83	-7.55	9.68	-13.74
		SEd	CD (P=0.05)		SEd	CD (P=0.05)		SEd	CD (P=0.05)
CS		260.18	722.39		0.78	1.70		31.75	88.16
MP		160.65	350.03		0.48	1.05		6.60	14.38
CS x MP		345.42	869.73		1.03	2.60		33.10	90.32
MP x CS		278.26	606.27		0.83	1.81		1.43	4.90

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J. Farming Systems Research & Development **17** (1&2) : 84-90 (2011)

PERFORMANCE OF POTATO BASED CROPPING SYSTEM UNDER ORGANIC MODE DURING INITIAL YEARS OF CONVERSION IN RELATION TO NUTRIENT MANAGEMENT PRACTICES

MANOJ RAGHAV, NARENDRA KUMAR* AND SHASHI KAMAL

Department of Vegetable Science, Department of Soil Science, College of Agriculture, G. B. Pant University of Agriculture & Technology, Pantnagar-263 145, U.S.Nagar, Uttarakhand*
E-mail:skkvkdhakrani@gmail.com

ABSTRACT

The study compares the performance of potato, cowpea and okra crops during initial three years of conversion (2003-04 to 2005-06) from conventional cultivation to organic cultivation. The experiment was conducted at Organic Farming Centre, G.B. Pant University of Agriculture and Technology, Pantnagar for three consecutive years revealed that the crop yield as well as available nitrogen, phosphorus and potassium content of soil improved with organic management and time after the harvesting of each crop. The effect of different organic manures and their doses showed significant influence on yield and chemical properties of soil. The highest yield during last year in each crop was obtained by the application of FYM@ 40 t/ha. While the continuous use of inorganic fertilizers showed no increase in yield and this was almost same in all the years. The soil health was also improved in terms of organic carbon, available nitrogen, phosphorous and potassium content with treatment having FYM @ 40t/ha.

Key words: Potato, cowpea, okra, organic mode, nutrient management

Organic farming is an alternative agriculture system, which has been proposed as a solution to the problem of soil health, sustainable yield and pollution associated with inputs of fertilizers and pesticides. A crop like cowpea has greater prospects of growing organically due to its low nutritional requirement, probable cultural practices to control weeds and Integrated Pest Management module to control diseases and pest to great extent. Crop rotation is a central tool that integrates the maintenance and development of soil health with different aspects of crop under organic system heavily reliant on organic sources. Nutrients supply to crops under organic systems mainly depends on organic sources such as manures, legumes and biofertilizers. The development and implementation of well designed crop rotation is the basis of success of organic production system (Chhabra and Chhabra, 2003). The present study has been conducted on okra-potato-cowpea cropping system to evaluate their potential yields from first year to third year of conversion of land from conventional to organic mode. The study also involved evaluation of soil health in terms of organic matter, available N, P and K after harvest the crop.

MATERIALS AND METHODS

The field experiment was conducted at the Organic Farming Centre, G.B. Pant University of Agriculture and Technology, Pantnagar. It lies in the narrow belt of foot hills of Shivalik range of Himalayas known as *tarai*. Soil of the experiment site had 6.9 pH, high in organic carbon, medium in total and available N and P and high in total and available K. The *kharif* crop okra was sown in the month of June. After harvest of okra, potato has been planted in the month of October then cowpea was sown in March after harvest of potato every year. The experiment was laid out in Randomized Block Design with three replications. Treatments consisted of nine combinations *i.e.* T_1- FYM @ 20t/ha, T_2-FYM @ 25t/ha, T_3- FYM @ 30t/ha, T_4- FYM @ 35t/ha, T_5- FYM @ 40t/ha, T_6-Poultry Manure (PM) @ 5t/ha, T_7- PM @7.5t/ha, T_8- FYM @ 20t/ha+ Biofertilisers (Azotobacter + Phosphorus Solubilising Bacteria) and T_9- Recommended Dose of Fertilizers (RDF). Recommended dose of fertilizers were applied for okra, potato and cowpea (80:60:40, 160:100:120 and 30:60:50 kg N, P_2O_5 and K_2O per hectare, respectively). The sources of chemical fertilizers were urea, single super phosphate and muraite of potash for N, P_2O_5 and K_2O, respectively. According to the need of crop, regular cultural operations were done to raise a healthy crop. To control weeds hand weeding was done according to the need. Neem formulated insecticides and bio-control agents have been used to control insects and disease. The yield was recorded on plot basis and the same was converted into quintal per hectare. The soil samples were analyzed using standard procedure for nitrogen (Subbiah and Asija, 1956), phosphorus (Olsen *et al.*, 1954) and potassium (Hanway and Heidel, 1952).

RESULTS AND DISCUSSION

During initial years of conversion from conventional to organic mode of cultivation yield and available nutrients showed an increasing trend from first year onward in all the crops *viz.* okra, potato and cowpea.

Impact on Crop Yield

Okra- The data pertaining to yield (Table-1) from 2003-04 to 2005-06 showed increasing trend in all the treatments having organic sources of nutrition except T_9 *i.e.* recommended dose of fertilizers. During first year highest yield (67.6 q/ha) was obtained in treatment T_5- FYM@40t/ha and same

Table 1. Effect of organic manure on crop yield

Treatment	Okra (q/ha)			Potato (q/ha)			Cowpea (q/ha)		
	2003-04	04-05	05-06	2003-04	04-05	05-06	2003-04	04-05	05-06
T1	56.1	62.7	67.3	172.6	197.6	218.3	35.6	39.9	44.7
T2	58.5	64.8	70.2	186.5	202.5	227.1	37.7	41.2	46.7
T3	60.3	67.3	74.8	194.0	216.8	230.9	40.8	45.6	51.8
T4	62.1	69.9	77.3	212.0	236.3	251.8	44.8	50.4	56.8
T5	67.6	77.2	86.9	225.0	243.8	268.1	50.6	56.7	62.9
T6	62.6	65.1	69.2	177.0	193.0	208.9	39.7	42.7	44.1
T7	65.7	69.7	74.7	188.0	205.7	211.7	43.2	47.8	49.2
T8	70.1	73.2	77.3	201.3	214.2	231.8	43.1	47.6	50.8
T9	80.7	81.2	80.3	230.8	228.3	225.9	55.2	54.1	55.6
CD at 5%	6.2	5.3	6.1	8.6	7.9	7.4	2.8	2.9	2.3

trend was found during next two years 77.2 q and 86.9 q, respectively. In all there was about 22.21% increase in the yield of okra crop. Contrary to this the treatment T_9 (recommended dose of fertilizers) have not shown any increase in yield during experimental period. The increase in yield was in line with the findings of Somkumar *et al.* (1997).

Potato- Organic manures *i.e.* FYM and poultry manure applied to the crop influenced tuber yield during all the three years (Table-1). Tuber yields of potato were recorded significantly higher in treatment T_5 (FYM@40t/ha) during all the three consecutive years (225.0 q/ha, 243.8q/ha and 268.1q/ha, respectively). Rainys and Rudokas (2005) also reported that application of FYM @ 40 t/ha gave better yield than the application of lower dose of FYM and recommended dose of chemical fertilizers.

Cowpea- Like okra and potato, pod yield in cowpea also increased due to organic treatments applied in the crop from initial year to third year of the experiment but in case of the inorganic fertilizers (T_9), the yield was stable from first to third year. The highest yield (55.2q/ha) was observed in treatment T_9. In organic treated plots lowest yield (44.7 q) has been recorded in treatment T_1 (200q FYM/ha) in third year. The levels of FYM and poultry manure had significant effect on yield in all three years. A similar result of higher pod yield in cowpea by application of FYM was reported by Sharma *et al.*, (2002).

Such increase in yields of okra, potato and cowpea due to FYM has been reported to be associated with the release of macro and micronutrients during the course of microbial decomposition. Organic matter also functions as source of energy for soil micro flora which brings about the transformation of inorganic nutrients held in soil, manure or applied through fertilizers in a form that is readily utilized by growing plants. The beneficial effects of FYM application are also related to improvement in soil physical properties and availability of sufficient amount of plant nutrients throughout the growth period and especially at critical growth periods of crops resulting superior yield (Sharma *et al.*, 2002).

Impact on Soil Health

The results presented in Table-2, 3 and 4 showed that the application of farm yard manure, poultry manure and biofertilizers *viz.*, *Azotobacter* and phosphorus solublising bacteria were useful in maintaining the soil fertility. During the initial year of organic farming, the fertility level of soil *i.e.* organic carbon, available nitrogen, phosphosphorus and potassium content was 0.69-0.72%, 228.0-232.07, 13.0-15.2 and 120.61-123.27 kg per hectare but after three years of experiment, the fertility level in all the organic treatments was improved. But in case of inorganic fertilizers (T_9) *i.e.* recommended dose of fertilizers; there was no increase in fertility level. The highest increase in fertility level *i.e.* organic carbon, available nitrogen, phosphosphorus and potassium content have been recorded in treatment T_5 (FYM@ 40t/ha) from initial 0.69%, 228 kg/ha, 13.0 kg/ha and 123.02kg/ha, respectively to last year 0.76%, 241.07 kg/ha, 18.03 kg/ha and 128.43 kg/ha, respectively of experiment. The added organic manure *i.e.* FYM has resulted in a substantial increase in organic carbon in post harvest soil, which was clear from the soil analysis (Table-4). **S**imilar increase in organic carbon content due to application of organic manure was reported by Chellamuthu *et al.*, (1988). Organic matter added through FYM, poultry

Table 2. Status of nutrients in soil before sowing of okra crop

Treat-	2003-04				2004-05				2005-06			
ment	O.C% N(kg/ha)	Available P_2O_5 (kg/ha)	Available K_2O (kg/ha)	Available	O.C% N(kg/ha)	Available P_2O_5 (kg/ha)	Available K_2O (kg/ha)	Available	O.C% N(kg/ha)	Available P_2O_5 (kg/ha)	Available K_2O (kg/ha)	Available
T1	0.72	230.12	14.50	121.81	0.76	243.70	17.38	126.99	0.77	250.79	22.87	132.61
T2	0.70	232.07	15.20	123.27	0.75	245.06	18.49	128.82	0.77	250.18	22.21	134.19
T3	0.71	228.17	14.00	120.61	0.76	243.00	18.56	128.93	0.77	255.67	22.88	135.61
T4	0.69	229.01	13.50	122.32	0.75	245.07	18.73	129.62	0.79	256.17	23.01	136.32
T5	0.69	228.00	13.00	123.02	0.78	247.09	19.78	130.87	0.83	260.08	24.91	139.81
T6	0.70	231.06	14.62	122.47	0.73	242.52	19.56	128.21	0.74	249.98	20.96	132.96
T7	0.71	232.00	14.92	120.97	0.74	243.89	17.93	128.79	0.75	251.20	21.68	133.83
T8	0.72	228.16	14.00	122.81	0.75	242.53	17.47	128.61	0.77	249.07	21.38	132.41
T9	0.71	229.07	15.00	121.92	0.69	246.70	17.96	126.01	0.70	257.02	20.19	130.09
CD at 5%	0.002	1.217	0.986	0.087	0.101	1.672	0.896	0.732	0.001	1.312	1.001	1.123

Table 3. Status of nutrients in soil before sowing of potato

Treatment	2003-04				2004-05				2005-06			
	O.C% N(kg/ha)	Available P_2O_5 (kg/ha)	Available K_2O (kg/ha)	Available	O.C% N(kg/ha)	Available P_2O_5 (kg/ha)	Available K_2O (kg/ha)	Available	O.C% N(kg/ha)	Available P_2O_5 (kg/ha)	Available K_2O (kg/ha)	Available
T1	0.73	235.16	15.25	123.21	0.76	245.16	18.43	128.43	0.77	252.67	22.13	134.18
T2	0.72	237.06	16.29	125.34	0.76	248.16	19.37	130.11	0.77	256.70	23.61	136.82
T3	0.73	232.07	15.92	123.81	0.76	247.07	19.92	130.51	0.78	258.19	24.57	138.61
T4	0.72	234.16	15.96	124.63	0.76	248.07	20.03	131.22	0.80	260.00	24.87	139.72
T5	0.73	233.07	16.07	125.97	0.80	252.96	21.71	133.19	0.83	262.47	26.73	143.17
T6	0.71	236.10	15.92	124.13	0.73	244.17	18.77	129.98	0.74	252.21	22.27	134.17
T7	0.72	237.06	15.98	123.81	0.74	246.86	19.03	130.34	0.75	253.61	23.44	135.62
T8	0.73	235.00	15.15	124.20	0.76	244.16	18.59	129.17	0.78	252.18	23.37	134.29
T9	0.71	236.16	16.00	123.18	0.69	250.01	18.90	127.41	0.70	259.81	21.87	132.00
CD at 5%	0.003	1.341	1.624	1.112	0.003	2.816	1.776	2.176	0.003	1.861	1.712	2.543

Table 4. Status of nutrients in soil before sowing of cowpea

Treat- ment	2003-04				2004-05				2005-06			
	O.C% N(kg/ha)	Available P_2O_5 (kg/ha)	Available K_2O (kg/ha)	Available	O.C% N(kg/ha)	Available P_2O_5 (kg/ha)	Available K_2O (kg/ha)	Available	O.C% N(kg/ha)	Available P_2O_5 (kg/ha)	Available K_2O (kg/ha)	Available
T1	0.74	240.10	16.07	125.69	0.76	247.62	19.67	130.14	0.77	255.11	23.81	135.96
T2	0.73	242.07	17.09	127.13	0.76	250.72	20.92	131.77	0.77	259.37	24.89	138.27
T3	0.75	238.00	16.83	127.18	0.76	251.00	21.13	132.43	0.79	262.12	26.08	140.21
T4	0.73	240.01	16.92	127.34	0.77	251.72	21.67	133.01	0.81	263.14	26.89	142.46
T5	0.76	241.07	18.03	128.43	0.81	255.16	23.16	136.01	0.85	266.81	28.57	146.53
T6	0.72	239.20	16.40	126.18	0.73	246.14	19.81	131.23	0.74	255.44	23.61	136.53
T7	0.73	240.00	16.67	126.83	0.74	247.16	20.33	132.17	0.75	256.91	23.98	138.03
T8	0.74	239.10	16.12	127.18	0.76	246.19	20.01	130.62	0.78	254.81	24.81	136.08
T9	0.70	241.00	17.28	124.81	0.69	254.17	19.68	129.30	0.69	261.34	23.86	133.63
CD at 5%	0.002	1.214	1.516	0.896	0.003	1.752	1.300	1.789	0.003	1.081	1.001	2.610

manure and crop residue incorporation improves soil physical, chemical and biological properties for better growth and yield of the crop (Pasricha, 1988). Availability of N, P and K in soil increased substantially when FYM was added in soil. FYM is a good source of nutrients such as NPK and nutrient availability is increased with FYM application which is thought to be due to the action of organic acids released from the organic matter complex. Some of which in addition to influencing pH, form stable complexes or chelated compounds with cations responsible for phosphate fixation (Staford and Pierre, 1953). The use of organic manures increased soil organic carbon by 5.33 to 18.82 per cent, available nitrogen by 9.69 to 14.55 per cent, phosphorus 37.78 to 54.54 per cent and potassium 9.75 to 16.04 per cent. In case of yield, 11.19 to 20.93 per cent, 9.31 to 22.21 per cent and 9.98-21.23 per cent higher yields were recorded under organic mode in potato, okra and cowpea, respectively. From the experimental results it could be concluded that shifting okra-potato-cowpea cultivation from conventional mode to organic mode can increase yield potential by third year. But growing of legume crops in the cropping sequence would be beneficial for accumulating nitrogen and improving the quality of soil.

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J. Farming Systems Research & Development **17** (1&2) : 91-99 (2011)

EFFECT OF NUTRIENT MANAGEMENT, PUDDLING AND IRRIGATION LEVELS ON PRODUCTIVITY AND ECONOMICS OF RICE (*ORYZA SATIVA*) – WHEAT (*TRITICUM AESTIVUM*) SYSTEM

SUBHASH CHANDRA, GURVINDER SINGH AND M.S. YADAV

G B Pant University of Agriculture & Technology, Pantnagar, U S Nagar (Uttarakhand)

ABSTRACT

A field study was carried out for 7 consecutive years (1997- 98 to 2003-04) on a Silty Clay Loam soil at Crop Research Center of G B Pant University of Agriculture & Technology, Pantnagar to study the long term effect of puddling, moisture regimes and nutrient management in rice – wheat system under shallow water table conditions. The rice grain yield was the maximum with recommended NPK+ green manure during all the years (mean 6.57 t/ha). This treatment also resulted the maximum residual effect on succeeding wheat crop (mean 4.35 t/ha). Under conventional puddling, the rice grain yield was higher than the reduced puddling, while the grain yield of following wheat exhibited the reverse trend. To rice, when irrigation was scheduled at 3 days after disappearance of ponded water, proved significantly superior over irrigation scheduled at 5 & 7 days after disappearance of ponded water. The grain yield pattern of rice over the years indicated that the yield differences between integrated nutrient management and recommended NPK alone widened as the study progressed. Variation in the grain yield of wheat grown on residual fertility also exhibited the similar trend over the years. The system economics was higher with reduced puddling, irrigation to rice at 3 DADPW and supplementation of NPK with organics.

Key words: Rice – wheat system, nutrient management, puddling, irrigation levels, economics

Rice – wheat is the most popular crop rotation practiced in about 12.0 m ha area in the Indo-gangatic plains of India. In the long run the system has been known to adversely affect productivity of the crops and soil properties. Puddling in transplanted rice has been the main cause for reduction in yield and deterioration in the soil conditions by way of making hard pan and deteriorating the soil structure. The main aim of the puddling has been to check the downward entry of water. Kukal (2002) reported that puddling caused considerable reduction in the percolation rate of the soil. This is a very exhaustive system and removes approximately 350-550 kg N P K ha$^{-1,}$ of which nitrogen accounts for 150-250 kg ha^{-1} (Paikaray et al 2002). Nutrients supply through inorganic sources alone in imbalanced form has resulted in reduction in soil fertility in long run. Integrated supply of nutrients through organic and inorganic sources have not only provided higher yields but also sustained the soil fertility (Parihar, 2004**)**. The time gap between wheat harvesting and rice transplanting can be utilized effectively by growing green manure crop. Two months sunhemp (*Crotolara juncea*) could accumulate 170 kg N, 20 kg P and 130 kg K ha^{-1} (Patro, 2002).

On an average, rice – wheat system requires 1350 – 3150 mm water for successful completion of the rotation. A common practice of water management with farmers' is maintaining submergence in the rice fields. Considering the huge water requirement of the system, there is need look into the water saving irrigation schedules for higher efficiency. The results of different studies have shown that transplanted rice does not require continuous submergence. Parihar, 2004 reported that irrigation at 5 DADPW brought significant reduction in the grain yield of rice as compared to irrigation at 1 & 3 DADPW. Rice – wheat is the predominant crop rotation of the tarai region of Uttarakhand, hence the present study was under taken to find out the effect of integrated nutrient management, puddling and irrigation levels on rice – wheat system under tarai conditions.

MATERIALS AND METHODS

Field study was carried for 7 consecutive years on rice – wheat cropping system at Crop Research Center of G B Pant University of Agriculture & Technology, Pantnagar from 1997-98 through 2003-04 on a Silty Clay Loam soil. The soil of the experimental site was neutral in reaction (pH 7.6), high in organic carbon (0.76%), low in available nitrogen (205 kg/ha), and medium in available phosphorus (10.5 kg P/ha) and potash (110 kg K/ha). The available water content of the experimental soil was 21 cm /m. The water table fluctuated between 45 cm to 85 cm during the course of study. Total 18 treatments were tested in Split - split plot design, replicated 3 times. The combination of 3 levels of nutrient management (Rec. NPK, Rec. NPK + Green manure, Rec. NPK + 10 t FYM) and 2 levels of puddling (conventional puddling, reduced puddling) were kept in main plots and 3 levels of irrigation (7 cm irrigation at 3, 5 & 7 days after disappearance of ponded water, DADPW) in sub plots. The size of main plot was 17 x 3 m and that of sub plot 5 x 3 m. In green manure plots, 50 days old Dhaincha was incorporated before rice transplanting. Conventional puddling consisted of 2 cross passes of puddler, while reduced puddling one cross pass of cultivator. In case of rice (variety Narendra 359), 25 days old seedlings were transplanted at a spacing of 20x10 cm using 2 seedlings per hill. For rice, the recommended dose of NPK was 120:60:40. Half N along with total P & K were applied as basal and remaining N in 2 equal splits at tillering and panicle initiation stages, respectively. As a next crop in the rotation, wheat was taken using a common NPK dose applied @ 120:60:40. Wheat (variety UP 2338) was raised with recommended package of practices as a sequential crop for studying the residual effect of treatments applied to rice. The number of irrigation applied to rice during different years has been given below:

Number of irrigation applied to rice during different years

Treatments	1997	1998	1999	2000	2001	2002	2003
Irrig. 3 DADPW	7	7	Nil	2	7	6	1
Irrig. 5 DADPW	4	5	Nil	1	3	4	1
Irrig. 7 DADPW	4	3	Nil	1	3	3	1
Rainfall (mm)	78.0	94.2	215.8	207.2	87.2	92.5	123.2

DADPW: Days after disappearance of ponded water

RESULTS AND DISCUSSION

Effect of nutrient management

Rice yield

The grain yield of rice was affected significantly during all the years and the highest grain yield was recorded from rec. NPK + green manure, mean being (6.57 t/ha) followed by rec. NPK + FYM and rec. NPK (Table 1). Parihar (2004) also reported the similar results. The yield levels with rec. NPK + FYM remained lower than the rec. NPK + green manure. The grain yield of rice over the years varied in the similar fashion (Fig. 1). However, in the first year the difference in the yield levels under three nutrients management systems was narrow, which widen further as the study progressed till 7th year (Table 1). This indicates the accumulation of the residual effect of the applied organic manure in the soil in the long run which supports the soil fertility and physical conditions.

Wheat yield

When wheat was grown after rice in the plots consisting nutrient management treatments to study the residual effect, the grain yield varied significantly during all the years. The grain yield was significantly higher after rec. NPK + green manure and rec. NPK + FYM than the rec. NPK alone during first as well as 7th year (Table 1). Higher residual effect of GM+NPK and FYM+NPK over NPK alone has been in line with Parihar (2004). The direct effect of NPK + green manure /FYM on rice yield against rec. NPK did not vary much in the first and last year of the study. However, the residual effect of rec. NPK+ GM/FYM over NPK alone on wheat yield increased as the study progressed. In the first year the wheat yield after rec. NPK + green manure was 9.7% more than rec. NPK, which increased to 17.7% in the 7th year. Similarly, the residual effect of NPK + FYM over rec. NPK increased to 15% in the last year as compared to only 5%

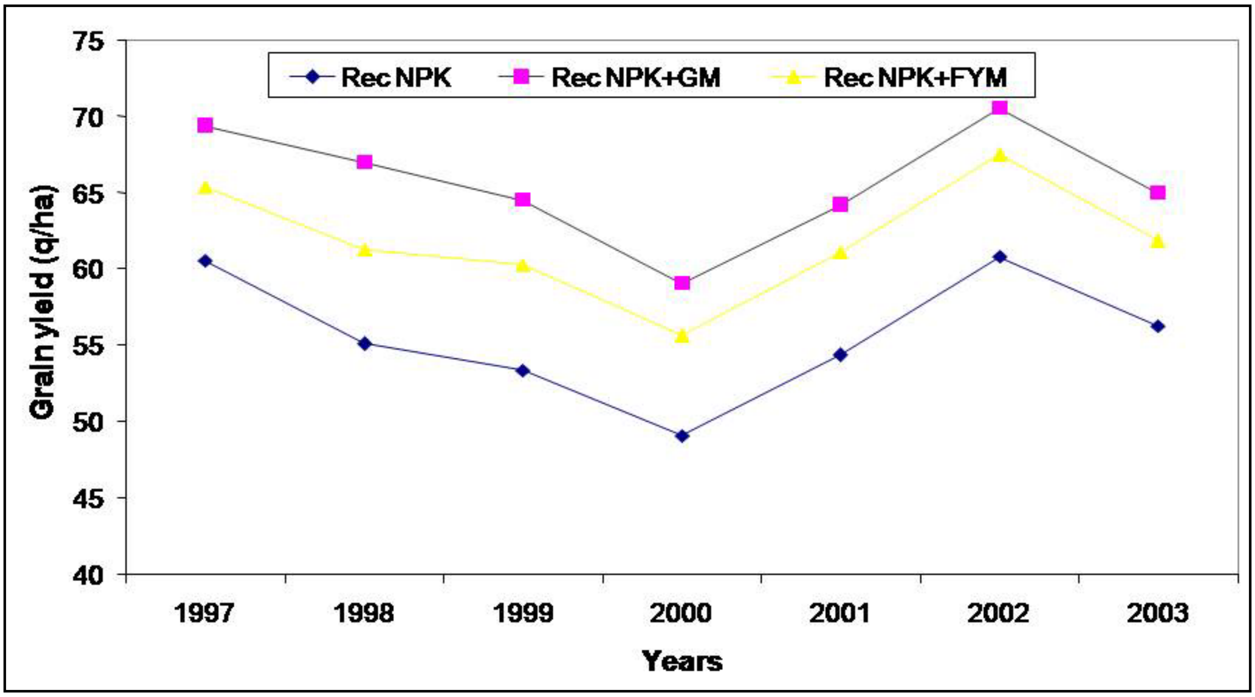

Fig. 1. Grain yield of rice under nutrient management levels

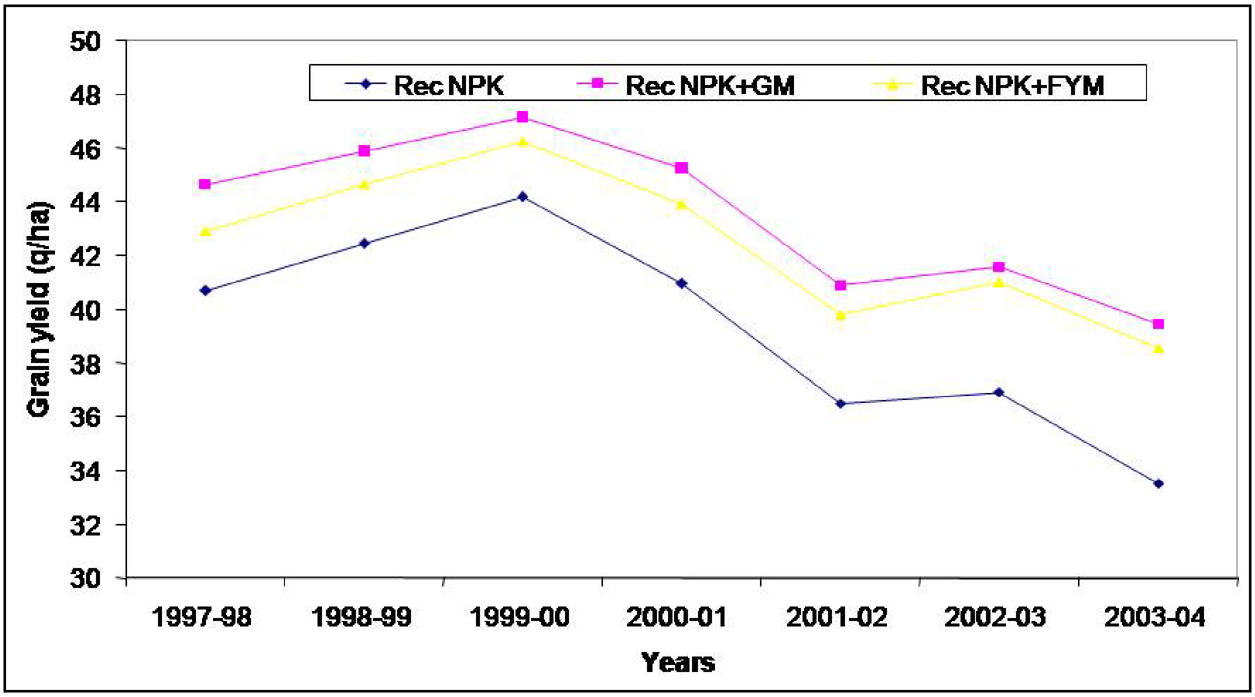

Fig. 2. Grain yield of wheat as affected by nutrients applied to rice

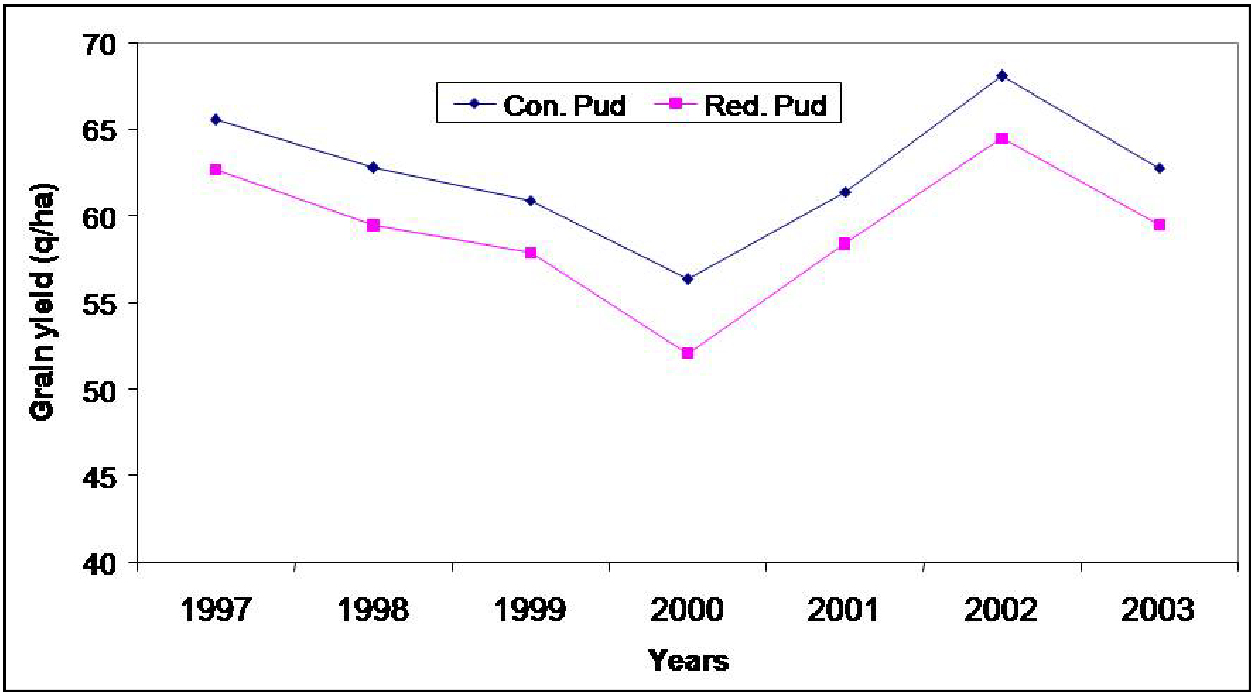

Fig. 3. Rice grain yield under two pudlling levels

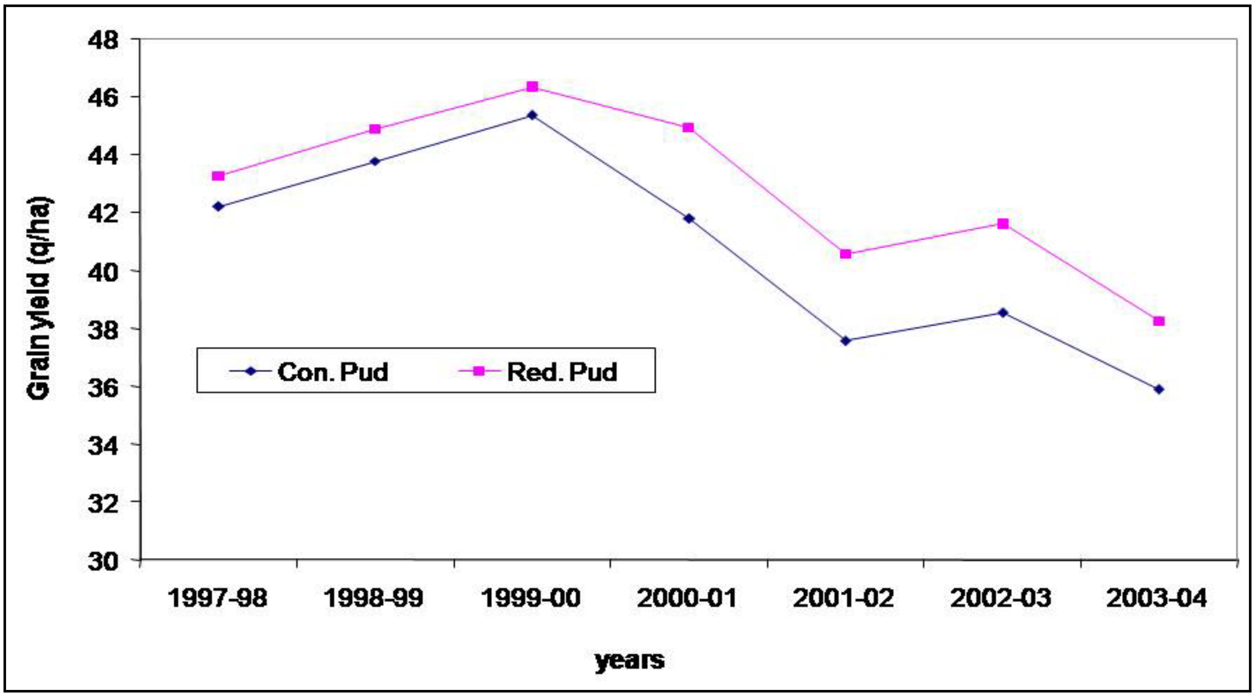

Fig. 4. Residual effect of puddling on wheat yield

in the first year (Table 1). The mean increase in rice grain yield was 18.2% with NPK + GM and 11.3% with NPK + FYM over the rec. NPK alone.

Effect of Puddling

Rice yield

The rice grain yield was affected significantly due to puddling intensity during all the years. Conventional puddling recorded significantly higher grain yield than reduced puddling (Table 1). Increase in rice grain yield with increasing pudlling intensity has also been reported by Singh and Jat (2005). The difference in grain yield due to puddling intensities over the years did not vary much. When wheat was grown in the plots subjected to reduced puddling, exhibited reverse trend than that of rice. In the first year, the wheat grain yield did not differ significantly due to residual effect of puddling, however, in the last year wheat yield was significantly more following reduced puddling than the conventional puddling. This indicates the accumulation of deteriorating effect of conventional puddling on soil productivity when practiced over a long period.

Effect of irrigation scheduling

Irrigation to rice at 3 days after disappearance of ponded water produced significantly higher grain yield than the irrigation applied at 5 and 7 days after disappearance of ponded water. Parihar 2004 also reported significant reduction in rice grain yield when irrigation was differed from 3 to 5 DADPW. The number of irrigation ranged from nil to 7 in case of irrigation scheduled at 3 DADPW and from nil to 4 in case of 5 & 7 DADPW. The residual effect of variable irrigations imposed to previous rice crop did not affect the yield of succeeding wheat crop. This can be attributed to the long gap between rice harvesting and wheat

Table 1. Grain yield of rice and wheat as affected by nutrient management, puddling and irrigation levels

Treatments	Rice grain yield (t/ha)		Mean	Wheat grain yield (t/ha)		Mean
	I year	VII year		I year	VII year	
Nutrient management						
Rec. NPK	6.05	5.63	5.56	4.07	3.35	3.93
Rec. NPK+FYM	6.54(8.1)	6.19(10.0)	6.19(11.3)	4.29(5.4)	3.86(15.2)	4.24(7.9)
Rec. NPK+GM	6.94(14.7)	6.50(15.5)	6.57(18.2)	4.46(9.6)	3.94(17.6)	4.35(10.7)
CD (P=0.05)	0.21	0.19	0.16	0.08		
Puddling						
Red. puddling	6.26	5.95	5.92	4.33	3.82	4.28
Conv.puddling	6.56(4.8)	6.28(5.6)	6.25(5.6)	4.22(-2.5)	3.59(-6.0)	4.07(-4.9)
CD (P=0.05)	0.17	0.16	NS	0.23		
Irrigation levels						
Irrig. 7 DADPW	6.21	6.04	5.87	4.17	3.65	4.12
Irrig. 5 DADPW	6.42(3.4)	6.10 (1.0)	6.00(1.5)	4.26 (2.2)	3.67 (0.6)	4.17(1.2)
Irrig. 3 DADPW	6.90(11.1)	6.19(2.5)	6.40(9.0)	4.39(3.1)	3.83(4.9)	4.24(2.9)
CD (P=0.05)	0.14	NS	NS	NS		

( ) indicates the percent increase/decrease over control

Table 2. System productivity (t/ha) under different treatments

Treatments	Rice	Wheat	System Productivity
Nutrient management			
Rec. NPK	5.56	3.93	9.49
Rec. NPK+FYM	6.19	4.24	10.43
Rec. NPK+GM	6.57	4.35	10.92
Puddling			
Reduced puddling	5.92	4.28	10.20
Con. puddling	6.25	4.07	10.33
Irrigation levels			
Irrig. 7 DADPW	5.87	4.12	9.99
Irrig. 5 DADPW	5.96	4.17	10.13
Irrig. 3 DADPW	6.40	4.24	10.65

sowing (mid Oct to mid Nov) which has caused depletion of soil moisture left at harvest of rice through evaporation process.

Effect on system productivity

The productivity of the system (rice + wheat grain yield) varied with the treatments imposed to rice crop (**Table 2).** The system productivity increased from 9.92 t/ha with rec. NPK to 10.92 t/ha with rec. NPK + GM. This suggests the higher direct and residual effect of rec. NPK + GM over the rec. NPK. Parihar (2004) also recorded higher system productivity of rice – wheat rotation with NPK + organic manure than inorganic alone. Due to puddling there was variable response by two crops, rice yield was favoured by more intensive puddling, while that of wheat affected adversely. As a net outcome the system productivity was higher by 0.13 t/ha under conventional puddling than reduced puddling. Although there was no marked residual effect of the variable irrigation schedules followed in rice, but the system productivity was favoured by the frequent irrigations applied to rice. The system productivity decreased from 10.65 t/ha with 3 DADPW to 9.99 t/ha with irrigation applied at 7 DADPW.

Economics

Rice

The gross and net returns of rice were affected significantly due to puddling, nutrient management and irrigation levels (Table 3). Conventional puddling recorded significantly higher gross as well as net return than reduced puddling, the increase being 5.1 per cent. However, the B:C ratio did not differ significantly. It suggests that additional cost incurred on conventional puddling did not bring the corresponding output in terms of crop productivity. Nutrient management NPK +GM recorded significantly higher gross and net returns than NPK alone and NPK+FYM. The NPK+GM treatment also recorded the highest B:C ratio, however, the difference was not significant. The increased yield of rice with green manuring may be credited to higher returns. Among irrigation levels, irrigation at 3 DADPW recorded significantly highest return and return decreased significantly with delayed irrigation from 3 DADPW to 5 and 7 DADPW. The former criterion also recorded numerically higher B: C ratio.

Wheat

Conventional puddling adversely affected the economics of wheat crop, which decreased significantly as compared to reduced puddling. The reduced puddling also caused significant increase in B: C ratio of wheat, over conventional puddling. This may be justified with reduced yield of wheat after conventional puddling. The residual effect of FYM and green manure to rice was also reflected on economics of subsequent wheat (Table 3.). The gross, net returns & B:C ratio of wheat did not differ following FYM and green manure however, both recorded significantly higher values than NPK dose (gross return Rs. 48570/ha & net return Rs. 29127/ha). The increased yield of wheat due to residual effect of FYM and GM, caused enhanced returns over NPK. Residual effect of irrigation levels maintained in rice did not cause significant variation in the economics of wheat. However, better moisture regimes to rice, exhibited better effect on following wheat.

Rice-wheat system

The gross and net returns did not vary due to variable puddling levels (Table 3), with net return being higher in reduced puddling. Reduced puddling over

Table 3. Economics of rice wheat system under different treatments

Treatment	Rice			Wheat			Total		
	Gross return (Rs/ha)	**Net return (Rs./ha)**	**B:C ratio**	**Gross return (Rs/ha)**	**Net return (Rs./ha)**	**B:C ratio**	**Gross return (Rs/ha)**	**Net return (Rs./ha)**	**B:C ratio**
Puddling									
Red. puddling	62693	38098	2.55	50596	31153	2.60	113292	69251	2.57
Conv. puddling	59515	36192	2.56	53142	33699	2.73	112733	69869	2.63
C D 5%	1882	1882	NS	1543	1543	0.08	NS	NS	0.044
Nutrient management									
Rec. NPK	55264	33517	2.55	48570	29127	2.50	103845	62644	2.52
Rec. NPK+FYM	62184	37470	2.52	54174	34731	2.79	116469	72168	2.64
Rec. NPK+GM	65863	40449	2.59	52862	33419	2.72	118723	73868	2.48
C D 5%	2305	2305	NS	1889	1889	0.097	2342	2420	0.053
Irrigation levels									
Irrigation 7 DADPW	59931	36428	2.55	51142	31699	2.63	111069	68093	2.58
Irrigation 5 DADPW	59701	35936	2.52	51732	32289	2.66	111444	68225	2.58
Irrigation 3DADPW	63680	39072	2.59	52732	33289	2.71	116523	72361	2.64
C D 5%	1996	1996	NS	NS	NS	NS	2687	2681	NS

a period of 7 years brought significant increase in the B:C ratio of rice – wheat system.

Nutrient management effected the B:C ratio, gross as well as net return significantly. Both the nutrient management practices including organics recorded significantly higher gross, net return & B:C ratio than NPK alone. However, both the former treatments remained statistically at par. The higher returns with organic may be attributed to enhanced crop productivity due to beneficial accumulative effect on soil health. The variable irrigation schedule to rice did not affect the B:C ratio of the system significantly . Irrigation at 3 DADPW to rice recorded the highest gross & net return and B:C ratio, which may be justified due to higher yield of rice under this level of irrigation.

The results of the present study suggest that green manuring along with recommended NPK was superior to NPK alone. Reduced puddling was better from system sustainability point of view. Rice needs to be irrigated at 3 DADPW to achieve higher yields. The system economics was higher with reduced puddling, irrigation to rice at 3 DADPW and supplementation of NPK with organics.

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J. Farming Systems Research & Development **17** (1&2) : 100-104 (2011)

NON CHEMICAL WEED MANAGEMENT PRACTICES ON SOIL MICROBIAL POPULATION AND NUTRIENT UPTAKE IN SORGHUM BASED ORGANIC CROPPING SYSTEM

P. DEVASENAPATHY, PARIMALA DEVI. R, PREMA. S AND SENTHIL KUMAR. G

Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore -3.

ABSTRACT

Field experiments were conducted during 2006-07 and 2007-08 to evaluate the non chemical weed management practices on soil microbial population *viz.*, bacteria, fungi and actinomycetes and nutrient uptake in sorghum based cropping system. Microbial population was found to be maximum with treatment T_2 (mulching + hand weeding once) in Black gram, Sorghum and Sesame at the stage of harvest. Intercropping with smothering crops combined with one hand weeding recorded the next higher level of microbial population in all the three crops. In case of nutrient uptake, the treatment T_3 which received hand weeding twice recorded the maximum N, P and K uptake followed by the treatment T_5 (Mechanical weeder + hand weeding once).

Key words: Non chemical weed management, Microbial population, Nutrient uptake, Crop yield.

INTRODUCTION

Due to continuous cropping, ever increasing use of chemicals like herbicides, pesticide, etc. without adequate organic recycling deteriorated soil productivity and created environmental pollution. Considering its importance, the application of organic manures, organic weed and pest management practices, etc. are popular as a part of organic farming.

A concern about the potential increase in weed population due to non use of herbicides is rated as serious problem in organic farming (Bond and Gundy, 2001). Weed management in organic farming mostly emphases the cultural control measures and the use of plastic and degradable mulches. Unlike those plastic mulches, organic mulches can easily be tilled back in to the soil after the growing season and can easily be implemented in most production operations without the use of specialized equipments. Many of the potential weed problems can be averted through management activities and agronomic practices that diversify the cropping system and the weed environment (Sunil, 2007). Common weed management practices followed in organic system include stale seed bed techniques, crop rotation, use of green manure and cover crops, forages, mulches, intercropping, use of highly competitive crops, crop cultivars and use of the allelopathic crop etc. The present study was taken up to develop eco-friendly and economically viable non chemical weed management practice for the organically grown Black gram – Sorghum – Sesame cropping system.

MATERIAL AND METHODS

Field experiments were conducted during 2006 - 2008 at Tamil Nadu Agricultural University, Coimbatore to evaluate the effect of non chemical weed management practices on soil microbial population, nutrient management and yield of organically maintained Black gram- Sorghum-Sesame cropping system. The soil was sandy clay loam with a pH of 8.68. The nutrient status indicated 0.71 % organic carbon and 252.2, 18.5 and 689.5 kg ha^{-1} of available N, P and K. The experiment was laid out in Randomized Block Design with six treatments (T_1 - Stale seedbed + HW once, T_2 - Mulching + HW once, T_3 - Hand weeding twice, T_4 - Intercropping with smothering crops (Daincha) and incorporation + HW once, T_5 - Mechanical Weeder + HW once and T_6 – Control) replicated thrice. The data was pooled and analysed.

RESULTS

The organic package of practices was adopted from planting to crop harvest for all the crops in the system. The microbial population *viz.*, bacteria, fungi and actinomycetes was recorded at the end of the cropping system. Nutrient uptake was worked out as per the standard procedure. The data pertaining to microbial population, crop yield and nutrient uptake of crops are presented in the fore-going pages.

Mulching along with one hand weeding (T_2) recorded significantly higher number of microbial population, followed by mechanical weeder combined with one hand weeding (T_5) (Fig.1-3). The results of the present study showed that, the uptake of nutrients was positively influenced by the different treatments. Among the treatments hand weeding twice showed its superiority and expressed higher values of crop uptake and recorded the lowest values of nutrient removal by weeds (Table 1 & 2). Among the treatments hand weeding twice recorded significantly higher crop yield and it was followed by mechanical weeder and intercropping with smothering crops (Table 3).

DISCUSSION

Soil microbial population increase by mulching coupled with one hand weeding might be due to the reason that the organic matter added to the soil through mulching would have increased the microbial activity and population in the soil. This might be attributed to the addition of the biomass/organic matter to the soil and the process of decomposition. Similar findings were

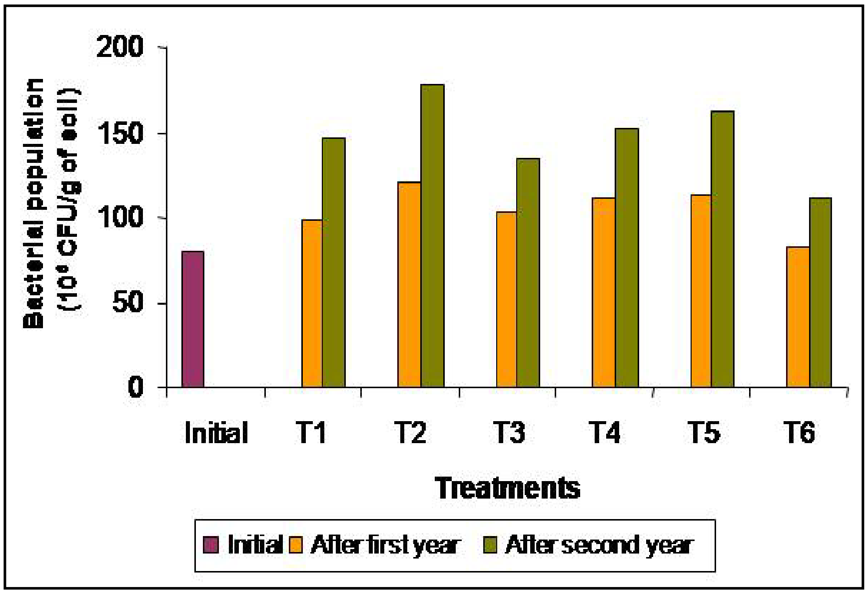

Fig. 1. Effect on non chemical weed management pratices on soil bacterial population

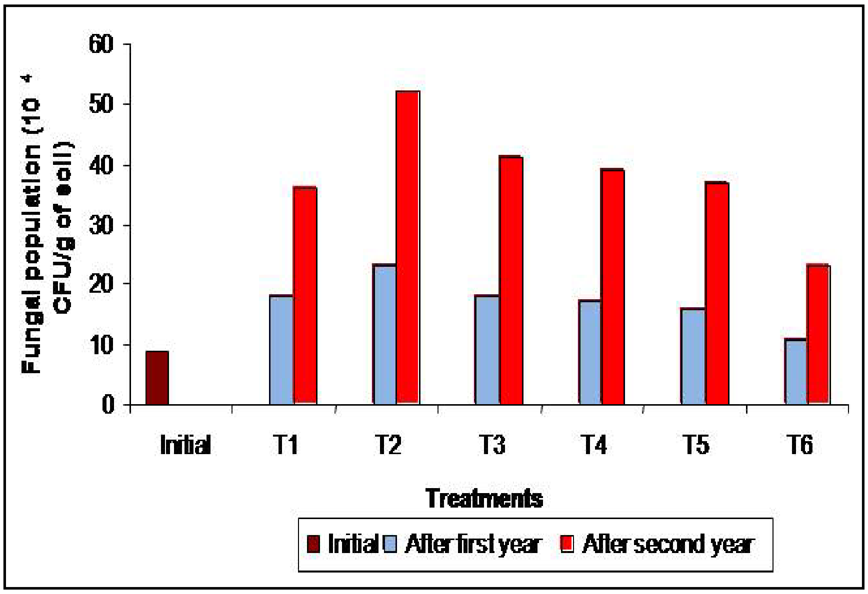

Fig. 2. Effect on non chemical weed management practices on soil fungal population

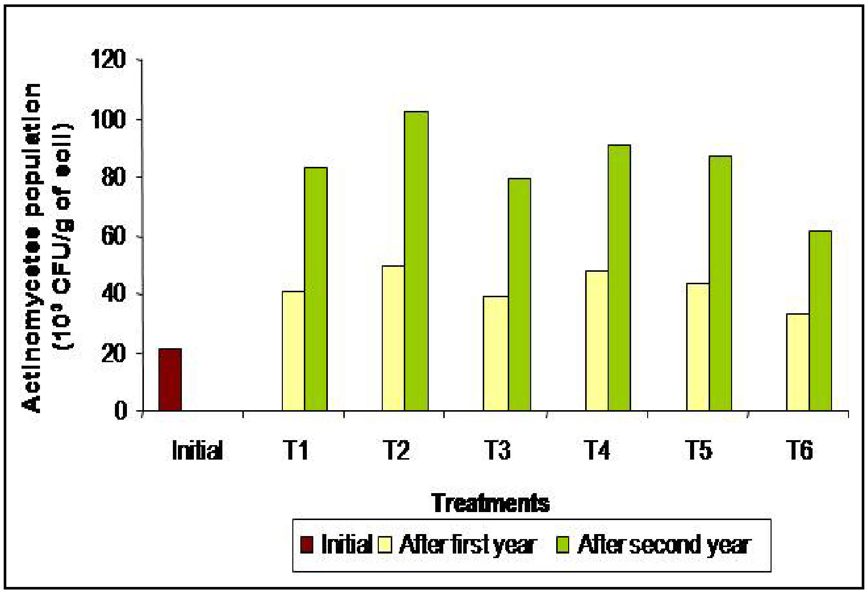

Fig. 3. Effect on non chemical weed management on soil actinomycetes population

observed in the research work of Gayathry (2002) and De Roy *et al.* (2006) where in promotion of soil micro flora observed due to addition of biomass to soil.

Under different weed management practices tested, hand weeding twice (T_3) effectively controlled the weed population, exhibited less nutrient removal, higher crop uptake and contributed to higher yield in all the crops under Black gram - Sorghum - Sesame cropping system. Nutrient depletion from the soil is a function of dry weight and nutrient content in the weed plants. Weeds usually grow faster than crop plants and

Table 1. Non chemical weed management Practices on Nutrient uptake (kg/ha) (Pooled data of two years)

Treatments	Nutrient uptake (kg/ha)								
	Black gram			Sorghum			Sesame		
	N	P	K	N	P	K	N	P	K
T_1	21.25	10.70	19.96	127.20	71.25	14.44	36.85	23.90	9.55
T_2	22.90	11.60	20.60	133.15	74.70	14.90	38.35	25.25	10.95
T_3	26.85	12.85	22.40	147.50	83.15	16.85	54.75	33.60	12.55
T_4	22.05	11.00	20.30	130.20	73.10	14.71	37.65	24.70	10.35
T_5	24.10	11.95	21.40	137.70	77.80	16.35	50.40	31.25	11.85
T_6	16.20	9.50	18.55	106.15	60.00	10.65	26.55	18.15	7.00
SEd	0.40	0.13	0.15	1.56	0.88	0.25	1.15	0.63	0.23
CD (P=0.05)	0.89	0.29	0.33	3.46	1.95	0.55	2.56	1.41	0.50

Table 2. Non chemical weed management practices on nutrient removal by weeds (kg/ha) (Pooled data of two years)

Treatments	Nutrient removal by weeds (kg/ha)								
	Black gram			Sorghum			Sesame		
	N	P	K	N	P	K	N	P	K
T_1	12.70	8.00	3.40	14.10	9.10	4.15	16.95	10.70	4.25
T_2	11.15	6.65	2.35	12.30	7.55	3.08	14.15	8.75	2.75
T_3	9.75	5.55	1.40	11.28	6.48	2.15	10.08	6.08	2.19
T_4	12.05	7.45	2.75	13.35	8.55	3.34	16.45	10.15	3.80
T_5	10.15	5.85	1.75	12.15	7.45	2.80	11.25	6.85	3.00
T_6	27.15	15.6	4.35	27.15	16.35	6.00	26.30	15.90	5.35
SEd	0.75	0.43	0.13	0.68	0.41	0.16	0.66	0.40	0.13
CD (P=0.05)	1.66	0.95	0.29	1.51	0.92	0.34	1.46	0.88	0.29

thus absorb the available nutrients quickly resulting inadequate supply of the nutrients to the crop (Mukhopadhyay, 1974). The final estimate of the nutrient depletion at harvest showed that hand weeding twice reduced the nutrient removal by the weeds. This phenomenal reduction of nutrient uptake by the weeds was resultant of lower weed population and dry weight of weeds due to the effective control.

Table 3. Non chemical weed management practices on yield of crops in sorghum based organic cropping system (Pooled data of two years)

Treatments	Crop yield (kg/ha)		
	Black gram	Sorghum	Sesame
T_1	459	3529	1483
T_2	485	3581	1590
T_3	574	3710	1688
T_4	511	3607	1521
T_5	556	3651	1622
T_6	258	3261	767
SEd	12.88	165.37	56.00
CD (P=0.05)	28.69	375.40	122.00

The increased yield may be attributed to the better weed control with congenial environment for the crop growth. The research findings of Wanjari *et al.* (2001) are in concomitant with the present study observations, where in unweeded control accounted for the lower crop yield.

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J. Farming Systems Research & Development **17** (1&2) : 105-108 (2011)

OPTIONS FOR DIVERSIFICATIONS OF RICE BASED CROPPING SYSTEMS ON PRODUCTION, WATER, LAND USE EFFICIENCIES AND ECONOMICS IN THE NAGARJUNA SAGAR LEFT CANAL COMMAND AREA

V. Rajendra Prasad, M. Goverdhan and Shaik Mohammad

AICRP on Cropping Systems Research, Acharya N.G. Ranga Agricultural University, Rajendranagar, Hyderabad – 30

Abstract

Experiments were conducted in the farmers field from 2005-06 to 2007-08 year in Nalgonda and Khammam districts of Andhra Pradesh under left canal command area of Nagarjunasagar. Five cropping systems are evaluated in 24 farmer's fields during each year. The major constraint is the receding flow of water for rice during the crucial flowering and grain filling stage during *Rabi* in middle and lower reaches. The experimental evidence identified that rice-maize is the best option to realize as high as 12196 kg/ha than the total productivity of 8576 kg/ha from the existing rice–rice cropping system. The production use efficiency recorded high rice equivalent yield of 46.71 kg/ha/day and Rs.338 ha/day with high water use efficiency of 6.68 kg rice equivalent yield ha/cm water and better land utilization with 68.5 per cent of the days in a year occupied by the crops. The respective values of rice-rice cropping system were 28.58 kg/ha/day, Rs. 200 ha/day, 3.57 kg rice equivalent yield ha/cm and land use efficiency of 82.2 per cent. It was also the most profitable cropping system fetching more than two times net profit of Rs.49442/ha and Rs.1.41 per rupee investment than on rice-rice. The Rice-cluster bean was also highly efficient cropping system but it needed a high expenditure of Rs. 45000/ha compared to Rs. 35000/ha for rice-maize cropping system. Yet it was most efficient in terms of water use efficiency producing 8.99 kg rice equivalent yield ha/cm. Rice-Sesame cropping system is an option for poor farmers with low investment capacity and yet utilize the land and water more efficiently and still earn more profit of Rs. 26322/ha and 0.87 per rupee investment.

Key words : Crop diversification, Rice based cropping systems, Economics

Water is the most precious natural input. It should be utilized most efficiently to produce more food grains per drop of water, land and investments on the cost of cultivation. The Nagarjuna Sagar commands an area of 10 lakh hectares in the left canal covering the districts of Nalgonda, Khammam and West Godavari. Farmers in the middle reach of the command often run the risk of uncertainty in the flow of water to support the water guzzling rice crop to its full maturity for potential yield realization. This is more serious in the lower reaches. Therefore there is a need to identify ideal crops in lieu of rice in *Rabi* which increase the rice equivalent yield, production, water and land use efficiency vis-à-vis high profits per unit land and per rupee investment.

Materials and Methods

Experiments on cultivator's fields were conducted from 2005-06 to 2007-08 in different mandals of Nalgonda and Khamman districts. The soils are sandy loam in texture. The pH ranged from 5.15 to 8.06. They were non saline having an EC of 0.271 to 1.743 dS/m. They also ranged from low organic content of only 0.32 to very rich status of 1.58 per cent. The available P ranged from 26.88 to 50.22. The available K is from 56.24 to 1076.32 kg/ha respectively. Every year the experiment was conducted on 24 farmer's fields with five rice based cropping systems. The plot size ranged from 100-200 m^2 depending on the availability. All the recommended package of practices was followed for each crop. Rice was fertilized with 160-60-40 kg/ha in Kharif, 180-60-40 in *Rabi*, Maize was fertilized with 120-6050 kg/ha, cluster bean 30-68-68 kg/ha, sesamum 40-40-60 kg/ha and black gram 20-50-0 kg/ha NPK. The production efficiency of the cropping systems was assessed by converting the yield of *Rabi* crops into rice equivalent yield as suggested by Verma and Modgal (1983). The production, water use and land use efficiency were worked out as suggested by Bastia et al., (2008). The economic evaluation was made from the production and existing cost of produce for net returns per hectare and per rupee investment.

RESULTS AND DISCUSSION

The data on mean performance of three years investigation of different rice based cropping systems is furnished in Table 1. The total productivity of rice - rice cropping system was 8576 kg/ha. Its production use efficiency was 28.58 kg/ha and Rs. 200/ha/day. The diversification of rice in the *Rabi* season with maize or cluster bean raised the rice equivalent yield to 12196 and 12320 kg/ha respectively. Therefore these two systems were more efficient than rice by 42 and 44 Per cent. The production use efficiency was also much higher with rice equivalent yield of 46.71 kg/ha/day and Rs. 338/ha/day from rice-maize cropping system. The water use efficiency was 6.68 kg rice equivalent yield/ha/cm. This is the most important input use efficiency to conserve the moisture more efficiently. This system also surpassed the rice-rice cropping system in land use efficiency by occupying the field only for 68.5 Per cent of the days in a year compared to 82.2 Per cent in the conventional rice-rice cropping system. In the present day context of acute labour shortage, occupation of the land for less time also appeal the farmer to switch over to this cropping system. The rice-maize cropping system was also most economical. It fetched Rs. 49442/ha and Rs. 1.41/Re investment compared to less than half of the this income i.e., Rs. 23832/ha and Rs. 0.65/Re/rupee investment in rice-rice cropping system. The rice-cluster bean cropping system was also more beneficial than rice- rice cropping system. Its production use efficiency was 43.32 kg/ha/day and Rs. 375/ha/day. This was 61 and 87 Per cent more efficient than rice-rice cropping system. Its water utilization was most outstanding.

The rice equivalent yield was 8.99 kg ha/cm of water. This is more than two times the production than from rice-rice cropping system per unit of water used. The land use efficiency was also much less even than rice-maize cropping system occupying the land only for 63 Per cent of the days in a year. However, this system needed maximum expenditure of Rs. 45,000/ha/year and yet it was highly profitable with a net gain of Rs. 41241/ha and Rs. 0.91/Re investment. Rice-sesame fetched low rice equivalent but utilize the water more efficiently to produce 5.75 kg rice equivalent yield ha/cm and occupied the land 63 Per cent of the days in a year. It was also less expensive to cultivate and yet fetched higher profit of Rs. 26322/ha and Rs. 0.87/Re investment. This cropping system option could be fairly adopted by the farmers with less investment capacity and gets more profit as well as better water use efficiency than rice-rice cropping system. Rice-black gram was not a relatively efficient cropping system than rice-rice mainly because of high

Table 1. nfluence of cropping systems on rice equivalent yield, production, water and land use efficiencies and economics.

Treatments	Rice equivalent yield (kg/ha)	Yield (kg/ha)		Production use efficiency		Water use efficiency kg Rice equivalent yield /ha-cm	Land use efficiency (%)	Cost of culti-vation (Rs./ha)	Net returns (Rs./ha)	Net returns /Re invest-ment
		Kharif	*Rabi*	kg/ha/ day	Rs/ha/ day					
Rice – rice	8576	3745	4830	28.58	200	3.57	82.2	36200	23832	0.65
Rice – maize	12196	4284	7394	46.71	337	6.68	68.5	35000	49442	1.41
Rice – sesame	8046	4326	8968	22.58	244	5.75	63.0	30000	26322	0.87
Rice – black gram	6389	4610	692	23.56	198	4.73	61.6	31250	13476	0.43
Rice – cluster bean	12320	4463	5500	43.32	374	8.99	63.0	45000	41241	0.91

Sale price (Rs/Quintal) rice = 700, maize = 750, sesame = 3000, black gram = 1800, cluster bean = 1000 susceptibility of black gram to yellow vein mosaic virus recurrent every year leading to severe yield loses.

The study established that the farmers of middle and lower reach in the left canal command area have a fair option to diversify the existing rice-rice cropping system with rice-maize, for maximum production of rice equivalent yield, production, water use and land use efficiency as well as high profit with relatively low expenditure. Rice-cluster bean is the best option for best water and land use efficiency with high rice equivalent yield and net profits but for farmers who can afford to spend more on cultivation expenses.

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J. Farming Systems Research & Development **17** (1&2) : 109-113 (2011)

STUDIES ON ENERGY BUDGETING IN PEARLMILLET-WHEAT CROPPING SYSTEM UNDER SEMI-ARID CONDITION OF AGRA REGION OF WESTERN U.P. (AESR 4.1)

RAJVIR SINGH*, O.P. RAJPUT AND BRAJ RAJ SINGH

Cropping System Research Project (ICAR) Department of Agronomy, R.B.S. College,
Bichpuri, Agra-283105 (U.P.)

ABSTRACT

A field experiment was conducted during 1998-99 to 2005-06 (8 years) at the R.B.S. College, Agril. Research Farm in Cropping Systems Research Project (ICAR), Bichpuri, Agra (U.P.) in a continuous cropping of 'pearlmillet-wheat' system. The results indicated that the maximum energy input was utilized by T_8 [50% N though waste residue of crops (WRC), integrated with 50% NPK through fertilizers (40-20-20) in pearlmillet, followed by 100% NPK, i.e. 120-60-40 kg ha^{-1} through fertilizers in wheat crop)]. The minimum energy input was used in T_1 (Control i.e. No fertilizers and No organics, say $N_0P_0K_0$), whereas, energy output was noticed maximum with T_5 (100% NPK through fertilizers) in both pearlmillet and wheat. The energy ratio of the 'pearlmillet-wheat' sequence – as a whole was computed maximum (10.57) with T_6 (50% NPK through fertilizers, integrated with 50% N through FYM) in pearlmillet, followed by 100% NPK (120-60-40 kg ha^{-1}) through fertilizers in wheat crop grown in the system.

Key words **:** Energy-input, Energy-output and Energy ratio.

An increase in agricultural production is possible mainly through intensive cropping systems, where seed, fertilizer, weeding, irrigation, chemicals (pesticides) and efficient management of power machinery affect the energy budgeting. The efficient management of overall farm resources may increase the farmer's income by way of intensive cropping system, being adopted by them. Research efforts in energy budgeting in cropping system gathered momentum from 19's seventies due to global fossil fuel crises and rapidly increasing demand for food. Energy relationship in cropping system may vary and constitute a dependent function of the crops knitted in sequence, yield level, nature of power use, soil type, energy input and agro-climate. Keeping in view these facts, the present investigation was carried-out to assess the energy-input, energy-output and their ratio for energy budgeting in various fertility treatments adopted in 'pearlmillet-wheat' system.

MATERIALS AND METHODS

A field experiment was conducted at the Agricultural Research Farm of Raja Balwant Singh College, Bichpuri, Agra in Cropping Systems Research Project (ICAR) during 1998-99 to 2005-06. The experiment was laid in 'Randomized Block Design', having 12 treatments (Table 1), as given below and 4 replications in 'pearlmillet-wheat' system.

The pearlmillet and wheat crops were sown between 20-25 July and between 15-20 November, respectively in eight years of experimentation. As per the fertility treatments, quantities of FYM, waste-residue of crops (WRC), green manure (*dhaincha – Sesbania aculeate*) having 0.5% N in FYM, 0.6-0.62% N in

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* Present address- Asstt. Professor Janta P. G. College, Bakewar (Etawah)

Table 1. Treatments details for varying integrated nutrient management option used under pearlmillet-wheat system

Treatments	***Kharif*** **(Pearlmillet)**	***Rabi*** **(Wheat)**
T_1	Control (No fertilizers, no organics)	Control (No fertilizers, No organics)
T_2	50% recommended NPK through fertilizers	50% recommended NPK through fertilizers
T_3	50% recommended NPK through fertilizers	100% recommended NPK through fertilizers
T_4	75% recommended NPK through fertilizers	75% recommended NPK through fertilizers
T_5	100% recommended NPK through fertilizers (80-40-40 kg/ha)	100% recommended NPK through fertilizers (120-60-40 kg/ha)
T_6	50% recommended NPK through fertilizers + 50% N through FYM @ 8 t/ha	100% recommended NPK dose through fertilizers
T_7	75% recommended NPK through fertilizers + 25% N through FYM @ 4 t/ha	75% recommended NPK dose through fertilizers
T_8	50% recommended NPK through fertilizers + 50% N through waste residue of crops (WRC) @ 6.6 t/ha	100% recommended NPK dose through fertilizers
T_9	75% recommended NPK through fertilizers + 25% N through waste residue of crops (WRC) @ 3.3 t/ha	75% recommended NPK dose through fertilizers
T_{10}	50% recommended NPK through fertilizers + 50% N through green manure (*dhaincha*) @ 5.50 t/ha	100% recommended NPK dose through fertilizer
T_{11}	75% recommended NPK dose through fertilizers + 25% N through green manure (*dhaincha*) @ 2.75 t/ha	75% recommended NPK dose through fertilizers
T_{12}	Farmer's practice (40-0-0 kg NPK/ha) only	Farmer's practice (40-0-0 kg NPK/ha) only

WRC and 1.0-0.75% N in green manure during 1998-99 and 2005-06 were applied before sowing of pearlmillet crop and required quantity of nitrogen (half at sowing and rest half at knee-high stage in pearlmillet and at the time of first irrigation in wheat crop) as top dressing was applied through urea (46% N). All the practices including basal doses of P and K were applied in both the crops.

In the present investigation, the direct energy refers to both operational and non-operational energy. Operational energy constitutes manual (labourers), ploughing (fuel, machinery) etc.; whereas, non-operational energy encompasses seed, fertilizers, insecticides etc. No statistical analysis was done and average data (mean) for different treatments considered for total production, energy-input, energy-output and energy input/output ratio for different fertility treatments.

RESULTS AND DISCUSSION

Effect on energy requirement pearlmillet: The maximum energy input was noted with T_8 (50% N substitution through WRC), followed by T_9 (25% N substitution through WRC), T_{10} (50% N substitution through green manure) and T_{11} (25%N substitution through green manure *dhaincha*). These treatments (T_8 to T_{11}) showed higher energy-input, compared to treatments of FYM substitution (T_6 and T_7) and T_5 (100% NPK through fertilizers). The farmer's practice also showed lower energy-input and the lowest with control ($N_0P_0K_0$). These results clearly indicated that substitution of organics increased the energy-input, compared to other treatments.

Wheat : As the level of NPK reduced from 100% recommended to 75% or to 50% NPK, there was reduction in energy-input utilization. Farmer's practice and control indicated lower energy-input.

Energy budgeting of 'pearlmillet-wheat' sequence : The higher energy input in pearlmillet in T_8 treatment, fertilized with 50% N through WRC was mainly due to its residual effect on the crop, being grown in a long term experiment for last 8 years (i.e. w.e.f. 1990-91). Contrary to this, pearlmillet yield in control required less energy in agricultural operations, particularly for no fertilization, showed the minimum energy inputs employed in this treatment. The results were quite obvious, because of low cost of cultivation under poor supply of nutrients.

Increased modernization, in general, involves lesser input of energy in crop production. Earlier studies in rice cultivation indicated that traditional production practices involved minimum input of energy, as experienced in T_1 (Control) and farmer's practice in this investigation. Baishya and Sharma (1990), Padhi (1993) and Jaipal *et al.* (1993) have also reported maximum energy input with rice based cropping system than other systems. Obviously, rice crop utilized more energy for chemical-source than maize. Further results indicated that higher energy-input in terms of fertilizers under recommended fertilizer treatments from T_5 to T_{11}, than inadequate, poor supply or no supply of nutrient (control). These results are in close conformity with the findings of Billore *et al.* (1994), they found higher energy-input with recommended fertilizer than reduced level of fertility.

The energy-output from the crops grown in 'pearlmillet-wheat' sequence varied from treatment to treatment under different levels of fertilization. The 100% recommended NPK through fertilizers (T_5) as well as 50% N substitution through FYM/WRC or green manure treatments enhanced the energy output due to their higher yield and this was reduced with reduction in level of NPK and farmer's practice as well as control (no fertilization). In general, wheat crop showed higher energy output than pearlmillet, because of higher grain and straw yields of wheat, therefore, the energy output of total main products (TMP) and total harvested bio-mass (THB) was obtained higher with 100% NPK through fertilizer and treatments integrated with organics.

Higher energy ratio in T_6 and T_7, wherein 25% to 50% N was substituted by FYM, was the resultant of higher grain and straw yields obtained, which had direct relationship with energy output/input ratio, along with low cost

Table 1. Energy-input (MJ ha^{-1}), energy-output (MJ ha^{-1}) and energy output/energy input ratio as affected by various fertility treatments in 'pearlmillet-wheat' system (pooled over eight years i.e. 1998-99 to 2005-06)

Treatments	Energy-input (MJ ha^{-1})			Energy-output (MJ ha^{-1})			Energy output/input ratio		
	Pearlmillet	Wheat	Total of Sequence	Pearlmillet	Wheat	Total of Sequence	Pearlmillet	Wheat	Total of Sequence
T_1	3294.70	89.54.29	12248.99	48331.70	55546.20	103878.90	14.60	6.20	8.48
T_2	6050.17	13021.29	19071.46	71855.80	126075.90	197931.70	11.87	9.68	10.37
T_3	6050.17	17088.29	23138.46	74688.50	162371.70	237060.20	12.34	9.50	10.24
T_4	7428.17	15043.79	22482.96	68403.70	140006.80	208410.50	9.20	9.29	9.26
T_5	8806.17	17088.29	25894.46	91367.50	168440.20	259808.00	10.37	9.85	10.03
T_6	6770.17	17088.29	23858.46	89320.40	162868.80	252189.20	13.19	9.53	10.57
T_7	7788.17	15054.79	22842.96	90584.80	149776.60	240361.40	11.63	9.94	10.52
T_8	30800.00	17088.29	47888.46	91156.60	158855.10	250011.70	2.95	9.29	5.22
T_9	19803.17	15054.79	34857.96	90704.00	144221.30	244925.30	4.58	10.24	7.20
T_{10}	18050.17	17088.29	35138.46	89933.40	160968.20	250902.60	4.98	9.41	7.14
T_{11}	13428.17	15054.79	28482.96	8856.30	14698.50	234424.80	6.59	9.76	8.26
T_{12}	5694.17	11354.29	17048.46	63752.40	101984.51	165736.90	11.19	8.96	9.72

of cultivation. Padhi (1993) was of the opinion that the sequences, which achieved highest energy output would give the maximum energy output ratio.

CONCLUSION

Forgoing results reveals that substitution of organics increased the energy output (MJ ha^{-1}) as well as energy-input and was decreased with reduced fertility levels. The increasing cost of input and energy crises, the substitution of 50% N through FYM @ 4 t ha^{-1} with 50% NPK (40-20-20 kg ha^{-1}) – fertilizers in pearlmillet, followed by 100% recommended NPK (120-60-40 kg ha^{-1}) – to wheat in the system recorded maximum (10.57) energy-output/input ratio.

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J. Farming Systems Research & Development **17** (1&2) : 114-120 (2011)

STUDIES ON PEARL MILLET BASED CROPPING SYSTEMS WITH ZERO TILLAGE IN MEDIUM BLACK SOILS OF NORTHERN DRY ZONE OF KARNATAKA

A.K. GUGGARI[1] AND S.B. PATIL[2]

AICRP on Pearl Millet
Regional Agricultural Research Station, Bijapur-586 101, Karnataka, India
E-mail : *akguggari@gmail.com*

ABSTRACT

A field experiment was conducted for three rainy seasons (2004-06) at Regional Agricultural Research Station, Bijapur, Karnataka. There were sixteen treatments consisting of nine sequence cropping systems after *kharif* pearl millet which was planted in three planting patterns *viz.*, at 45 cm, 135 cm rows and in paired row system of 45/225 cm followed by three *rabi* crops viz., sunhemp (seed), sunflower and chick pea. Mean results of three years indicated that, grain yield of pearl millet differed significantly due to the methods of planting. Planting of pearl millet at normal row spacing of 45 cm recorded significantly higher grain yield (2108 to 2243 kg/ha) compared to wider row spacing of 135 cm (1485 to 1644 kg/ha) and wider paired row system of planting (1555 to 1806 kg/ha). Among the various cropping systems, the intercropping system of Pearl millet + pigeon pea (2:1) recorded significantly higher pearl millet equivalent yield (5124 kg/ha), net returns (Rs.13,051/ha) and benefit cost ratio (2.07) over other cropping sequences and sole crops which were grown with zero tillage. However, it was on par with planting of pearl millet sown at normal row spacing of 45 cm during *kharif* followed by chick pea during *rabi* with zero tillage (4807 kg/ha, 11,802/ha and 1.96, respectively). Sunhemp either in sequence cropping with pearl millet or in sole cropping recorded lowest pearl millet equivalent yield and economic returns among all the cropping systems.

Key words : Zero tillage, pearl millet, sequence cropping, equivalent yield.

Pearl millet is one of the important and predominant coarse cereals grown in arid and semi-arid regions of the country. Its cultivation is mostly confined to poor and impoverished soils and cultivated by resource poor farmers. In Karnataka, Pearl millet is an important food crop of *kharif* season, grown in shallow to medium black soils. It is the most assured crop amongst the other *kharif* crops even under low rainfall situations. Pearl millet area is mainly concentrated in Northern Karnataka where the crop is normally grown as a sole or mixed crop with pigeonpea, horse gram, moth bean in shallow soils. In medium black soil areas and where protective irrigation facilities exist, farmers take second crop after harvest of pearl millet. In northern Karnataka, sunflower, safflower, chickpea and sorghum are important *rabi* crops grown in medium to deep black soils. In these soil types including deep black soils, large section of the farmers leave the land fallow during *kharif* and go for only *rabi* cropping due to uncertainty of *kharif* rains. In medium black soil areas where sole cropping is in vogue (practice is there), under good rainfall situations there is a possibility to take up second crop after harvest of pearl millet. But after the harvest of pearl millet, if one goes for land preparation and other

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[1]Senior Scientist (Agronomy), [2]Research Associate

tillage operations before sowing up of *rabi* crops, there is a possibility to loose all the stored soil moisture and it may not be possible to take up the second crop successfully. Therefore, keeping all these points in view an attempt was made to study the possibility of taking up of a second crop after harvest of pearl millet with zero tillage practice in order to take advantage of *rabi* rains and stored soil moisture and to increase the cropping intensity and productivity.

MATERIALS AND METHODS

A field experiment was conducted for three rainy seasons (2004-05, 2005-06 and 2006-07) at Regional Agricultural Research Station, Bijapur, Karnataka. There were sixteen treatments consisting of nine sequence cropping systems after *kharif* pearl millet which was planted in three different planting patterns *viz.*, at 45 cm, 135 cm rows and in paired row system of 45/225cm followed by three *rabi* crops viz., sunhemp (seed), sunflower and chick pea. These cropping sequences were compared with their sole crops of sunhemp, sunflower, chickpea and pearl millet and an intercropping system of pearl millet + pigeon pea (2:1) is recommended for the region, was grown with normal recommended cultivation practices. The sequence crops of sunhemp, sunflower and chickpea were grown after harvest of pearl millet with zero tillage without any land preparation. These three *rabi* crops were also grown with normal cultivation practices as sole single crops by keeping the land fallow during *kharif*. The experiment was laid out in randomized block design with three replications. The gross and net plot sizes were 5.0 m x 7.2 m and 4.4 m x 6.3 m, respectively. The soil of the experimental site was medium black soil with low in available nitrogen (160 kg/ha) and P_2O_5 (16 kg/ha), medium in available K_2O (308 kg/ha) with 0.24 per cent organic carbon and having alkaline pH (8.1).

The crops included in cropping system were raised by following recommended package practices (Table 1). Pearl millet was fertilized with 50 kg N and 25 kg P_2O_5/ha at the time of sowing. Other sequence crops were fertilized with their recommended dose of fertilizers. Sequence crops were sown immediately after harvest of pearl millet without any land preparation and afterwards all the cultural operations and plant protection measures were adopted as and when needed. A total rainfall of 655.1, 591.9 and 802.2 mm was received in 50, 40 and 48 rainy days from January to December during 2004, 2005 and 2006, respectively as against the normal rainfall of 594.3 mm (average of 100 years) received in 38 rainy days (Table 2). The performance of various cropping systems was judged on the basis of pooled results in terms of pearl millet equivalent yield and economic returns. The economics was calculated on basis of prevailing market price for sale of produce and cost of inputs.

RESULTS AND DISCUSSION

Effect on pearl millet yield

Grain yields of pearl millet were higher during 2005-06 compared to 2004-05 and 2006-07 even though the rainfall received during the cropping period (June-September) was lower. This may be attributed to uniform distribution of rainfall. During 2004-05 though rainfall received was higher, the crop suffered due to moisture stress at the time of flowering since the rainfall received was very low during August. During 2006-07, the rainfall was lower

Table 1. Details of the variety, spacing and fertilizer dose adopted for different crops in the experiment

Sl. No.	Crops	Variety	Spacing (cm)	Fertilizer dose (N:P:K, kg/ha)
1.	Pearl millet	ICMV-221	45 x 15	50:25:0
2.	Chick pea	A-1	45 x 10	10:25:0
3.	Sunflower	KBSH-1	60 x 20	35:50:35
4.	Sunhemp	Local	45 x 10	25:50:25
5.	Pigeopea	Maruti	90 x 20	25:50:0

Table 2. Mean monthly rainfall of Regional Agricultural Research station, Bijapur recorded during the years of experimentation

Month	Rainfall (mm)				Rainy days			
	2004	2005	2006	Normal*	2004	2005	2006	Normal*
Jan	4.0	0	0	4.4	1	0	0	0
Feb	0.0	0	0	2.3	0	0	0	0
March	0.0	0	1.9	6.0	0	0	0	0
April	0.5	76.1	4.0	21.2	0	5	1	2
May	108.9	66.4	152.5	38.4	9	3	7	3
June	144.7	24.9	212.1	86.0	9	3	10	6
July	153.2	135.6	32.4	72.2	10	10	5	5
Aug	23.0	96.2	37.0	78.1	3	5	7	5
Sept.	120.0	80.4	237.3	151.6	12	6	11	8
Oct.	100.8	112.3	81.8	96.2	6	8	4	6
Nov.	0.0	0	0	30.6	0	0	3	2
Dec.	0.0	0	0	7.3	0	0	0	1
Total	655.1	591.9	759.0	594.3	50	40	48	38

* Average of 100 years (1901 to 2000)

during July and August months and there was a long dry spell resulting in lower grain yields.

Mean results of three years (2004-06) indicated that, grain yield of pearl millet differed significantly due to different planting patterns (Table 2). Planting of pearl millet at normal row spacing of 45 cm recorded significantly higher grain yield (2108 to 2243 kg/ha) compared to wider row spacing of 135 cm (from 1485 to 1644 kg/ha) and paired row system of

45/225 cm planting (1555 to 1806 kg/ha). Higher grain yield in pearl millet at 45 cm row spacing could be attributed to its higher plant population over 135 cm and paired row planting system of 45/225cm.

Sequence/Inter crops yield

The yields on sequence/inter crops were presented in Table 3. Sunflower and sunhemp yields were low during 2005-06 and 2004-05 as compared to 2006-07. While, there was not much variation in chickpea yields during all the three seasons. Pigeon pea grain yield was higher in 2004-05 (1336 kg/ha) compared to 2005-06 (866 kg/ha) and 2006-07 (812 kg/ha) due to higher rainfall and rainy days in initial stage of crop growth.

Pearl millet equivalent yield

A significant variation in pearl millet equivalent yield was observed among the various cropping systems (Table 3). The pooled mean yield of different cropping systems and their production in terms of pearl millet equivalent yield were significantly highest (5124 kg/ha) under pearl millet + pegionpea (2:1) intercropping system over other cropping sequences with zero tillage practice and sole crops of pearl millet, chick pea, sunflower and sunhemp. However, it was on par with pearl millet planted at 45 cm row spacing followed by chick pea sequence (4807 kg/ha) grown with zero tillage. Higher pearl millet equivalent yield with pearl millet + pegionpea (2:1) may be attributed to higher yield and better market price of inter crop (pigeonpea) which contributed towards the pearl millet equivalent yield (Dubey and Srivas, 1997) and where as inclusion of legume or crop of lower biomass might helped in maintaining soil nutrient status, it results higher productivity of systems. Similar results were also reported by Patil et al. (1996), Prabhakar Setty and Janardhana Gowda (1997) and Surendra Singh (2008).

Economics

On the basis of pooled data 2004-05 to 2006-07 the economics of various cropping systems were presented in Table 4. The highest net returns and benefit cost ratio were recorded under pearl millet + pigeonpea (2:1) intercropping system (Rs. 13,053 and 2.07/ha, respectively) closely followed by pearl millet sowing at 45 cm followed by chick pea sequence cropping system with zero tillage (Rs. 11,802 and 1.96/ha, respectively). The highest economic returns with pearl millet + pigeonpea inter cropping and pearl millet – chick pea sequence cropping systems was attributed to higher yields and better market prices of pigeonpea and chick pea. These results are in confirmation with the findings of Verma (1997).

In medium black soils of dry land conditions of North Karnataka, pearl millet + pigeon pea (2:1) intercropping system and sequence cropping of chickpea with zero tillage after pearl millet grown at 45 cm during *kharif* were found to be more profitable cropping systems over growing of chick pea alone during *rabi* as compared with normal cultivation practices by keeping the land fallow during *kharif*.

ACKNOWLEDGEMENT

The authors are grateful to the All India Coordinated Improvement Project, ICAR, Mandor, Rajasthan for providing the necessary financial assistance for conducting the experiment and Regional Agricultural Research Station, University of Agricultural Sciences, Dharwad for providing all the physical facilities to carry out the studies.

Table 3. Grain yields and pearl millet grain equivalent yields of different cropping systems during 2004-05 to 2006-07

Sl. No	Treatments	2004-05			2005-06			2006-07		
		Grain yield of PM (kg/ha)	Yield of sequence /inter crops (kg/ha)	PMEY of cropp-ing system (kg/ha)	Grain yield of PM (kg/ha)	Yield of sequence /inter crops (kg/ha)	PMEY of cropp-ing system (kg/ha)	Grain yield of PM (kg/ha)	Yield of sequence /inter crops (kg/ha)	PMEY of cropp-ing system (kg/ha)
1	Pearl millet alone at 45 cm row spacing	1686	-	1686	3288	-	3288	1756	-	1756
2	Pearl millet alone at 135 cm row spacing	1167	-	1167	2427	-	2427	1338	-	1338
3	Pearl millet alone at 45/225 cm row spacing	1476	-	1476	2465	-	2465	1477	-	1477
4	Pearl millet at 135 cm -Sunflower	1042	344	2133	2234	164	2716	1179	1202	5461
5	Pearl millet at 45/225 cm-Sunflower	1373	365	2530	2011	169	2506	1298	1358	6135
6	Pearl millet at 135 cm –Chick pea	1160	717	3390	2179	625	4261	1370	623	3745
7	Pearl millet at 45/225 cm – Chick pea	1339	688	3479	2094	568	3987	1360	552	3464
8	Pearl millet at 135 cm –Sunhemp	1157	270	1875	2234	215	2760	1341	954	4248
9	Pearl millet at 45/225 –Sunhemp	1376	178	1852	2072	145	2427	1217	928	4045
10	Pearl millet at 45 cm –Sunflower	1587	348	2630	3217	114	3552	1520	967	4965
11	Pearl millet at 45 cm – Chick pea	1762	778	4184	3071	707	5429	1566	851	4809
12	Pearl millet at 45 cm-Sunhemp	1565	228	2175	3141	219	3678	1663	866	4302
13	*Kharif* fallow –Sunflower	-	426	1348	-	603	2045	-	1300	4630
14	*Kharif* fallow – Chick pea	-	804	2501	-	701	2338	-	714	2722
15	*Kharif* fallow-Sunhemp	-	390	1041	-	404	991	-	996	3035
16	Pearl millet + Pigeon pea (2:1)	1442	1336	6538	1909	866	4838	1367	812	3995
	S.Em±	84.3	-	212.6	185.6	-	299.9	88.8	-	259.4
	C.D.(0.05)	246.2	-	613.8	541.8	-	866.1	259.2	-	718.9
	C.V.(%)	10.5	-	14.72	12.67	-	16.50	10.84	-	13.94

PM= Pearl Millet; PMEY= Pearl Millet Equivalent Yield

Table 4. Grain yield and economics of different cropping systems (Mean of 2004-05, 2005-06 and 2006-07)

Sl. No	Treatments	Grain yield of PM (kg/ha)	Yield of sequence /inter crops (kg/ha)	PMEY of cropping system (kg/ha)	Gross returns (Rs./ha)	Cost of cultivation (Rs./ha)	Net returns (Rs./ha)	B:C ratio
1	Pearl millet alone at 45 cm row spacing	2243	-	2243	11418	6835	4583	1.67
2	Pearl millet at 135 cm row spacing	1644	-	1664	8340	6671	1669	1.25
3	Pearl millet at 45/225 cm row spacing	1806	-	1806	9147	6671	2476	1.37
4	Pearl millet at 135 cm -Sunflower	1485	570	3437	17512	11886	5626	1.47
5	Pearl millet at 45/225 cm-Sunflower	1561	631	3724	19517	11886	7630	1.64
6	Pearl millet at 135 cm – Chick pea	1570	655	3799	19076	12165	6911	1.57
7	Pearl millet at 45/225 cm – Chick pea	1598	603	3643	18211	12165	6046	1.50
8	Pearl millet at 135 cm –Sunhemp	1577	480	2961	11148	11754	-606	0.95
9	Pearl millet at 45/225 –Sunhemp	1555	417	2775	10138	11754	-1616	0.86
10	Pearl millet at 45 cm –Sunflower	2108	476	3716	18962	12050	6912	1.58
11	Pearl millet at 45 cm– Chick pea	2133	779	4807	24132	12329	11802	1.96
12	Pearl millet at 45 cm-Sunhemp	2123	438	3385	13786	11917	1868	1.16
13	*Kharif* fallow –Sunflower	-	776	2674	12244	7815	4428	1.57
14	*Kharif* fallow – Chick pea	-	740	2521	12490	8094	4396	1.54
15	*Kharif* fallow-Sunhemp	-	597	1689	5700	7682	-1983	0.74
16	Pearl millet + Pigeon pea (2:1)	1573	1005	5124	25212	12160	13052	2.07
	S.Em±	-	-	163.1	-	-	842	0.08
	C.D.(0.05)	-	-	452.1	-	-	2431	0.24
	C.V.(%)	-	-	17.3	-	-	31.8	10.01

PM= Pearl Millet; PMEY= Pearl Millet Equivalent Yield

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J. Farming Systems Research & Development **17** (1&2) : 121-126 (2011)

YIELD AND SYSTEM PRODUCTIVITY AS INFLUENCED BY FENNEL (*FOENICULUM VULGARE MILL.*) BASED INTERCROPPING

R.S. Mehta, S.S. Meena and M.M. Anwer

National Research Center on Seed Spices, Ajmer (Rajasthan)

Abstract

A field study on yield and system productivity as influenced by fennel based intercropping was conducted at NRCSS, Ajmer (Raj.) during *rabi* season of 2004-05,2005-06 and 2006-07.The study comprising of thirteen treatment viz., sole fennel, sole onion, sole garlic, sole carrot, fennel+ garlic (1:1), fennel+ garlic (1:2), fennel+ garlic (2:2), fennel+ carrot (1:1), fennel + carrot (1:2), fennel + carrot (2:2), fennel + onion(1:1), fennel+ onion (1:2) and fennel + onion (2:2) was laid in randomized block design with three replications. The results revealed that all the sole crop *viz*., fennel, carrot, onion and garlic exhibited highest economic yield of respective crops as compared with different intercropping ratio. In different inter cropping system economic yield of fennel was recorded higher in 1:1 ratio. The highest equivalent yield, gross return, net return and BCR was exhibited by 1:1 intercropping ratio of fennel and carrot followed by 2:2 ratio of same crops. Fennel and carrot at all the ratios resulted higher equivalent yield, gross return, net return, BCR and LER over fennel intercropped by onion and garlic. Thus intercropping of fennel and carrot in 1:1 ratio is best for realizing higher system productivity, net return and BCR.

Key words: Inter cropping, Fennel, LER, Equivalent yield, Temporal resource

Fennel commonly known, as *Saunf is* major seed spice crop belonging to Apeaceae family. In India it is mainly cultivated in Rajasthan, Gujarat, MP and Karnataka .Gujarat ranks first in area and production of fennel in our country. The burgeoning population in India as well as in the world is resulting increase in demand for food, fibre, fuel, fodder and shelter. In present circumstance it is not possible to increase production by bringing more area under cultivation. The possible solution lies only to increase system productivity by using available area through vertical expansion of enterprises. The intercropping system is an important avenue in this direction which aimed at increasing productivity per unit area per unit time and insurance against total crop failure under aberrant weather conditions (Mullick *et al.* 1993). Therefore, integration of suitable vegetable crops with wide spaced seed spice crop is necessary. Among seed spices, fennel is a wide space crop best suited for intercropping with vegetable crops (Mehta *et al.* 2007). Therefore, the present study on effect of different intercropping ratio on system productivity was undertaken with a view to find out best intercropping ratio.

Materials and Methods

The field experiment was conducted at NRCSS, Ajmer (Raj) during three consecutive *rabi* season of 2004-05, 2005-06 and 2006-07.The soil of the experimental site was sandy loam with a pH of 8.92 having 0.21% organic carbon and 76.0, 33.4, and 234.1 kg per

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1.Scientist (SG) (email rsmagron@yahoo.co.in), 2 Sr. Scientist (email ssmnrcss5@yahoo.com) 3.Director (email: mmanwer1951@rediffmail.com)

ha available N, P_2O_5 and K_2O respectively. The experiment comprising of thirteen treatment viz., sole fennel, sole onion, sole garlic, sole carrot, fennel + garlic (1:1), fennel + garlic (1:2), fennel + garlic (2:2) fennel + carrot (1:1) ,fennel + carrot (1:2),fennel + carrot (2:2), fennel + onion (1:1), fennel + onion (1:2) and fennel + onion (2:2) was laid in randomized block design with three replications. Sowing of fennel using 10 kg seed of Ajmer Fennel -1 was done at 60 cm row to row spacing in 1:1 and 1:2 ratio of fennel with carrot / onion/ garlic but in 2:2 ratio sowing of fennel was done in pair of 40/80 cm. In between pairs two rows of respective component crops viz., carrot, onion and garlic were accommodated. Recommended dose of fertilizer for respective crop was applied in sole crops but in intercropping system the N and P was applied in proportion to the area occupied by each crop. The population of base crop was kept constant. In sole fennel, onion, garlic and carrot 90 kg N, 50 kg P_2O_5 and 40 kg K_2O per ha and in inter cropping 135 kg N, 75 kg P_2O_5 and 60 kg K_2O per ha was applied . I/3 rd N and full dose of P and K was applied as basal dose at the time of sowing of fennel and vegetable crop and remaining 2/3rd N was applied in two equal split at 30 and 60 DAS. The standard agronomic practices were adopted for raising healthy crop of fennel as well as carrot ,onion and garlic. Irrigation was applied as per requirement of fennel, which met the demand of component also. Harvesting of fennel was done in stages keeping in view the maturity of umbels.The yield of fennel, carrot, onion and garlic was converted into fennel equivalent yield as per prevailing rates in market and treatment evaluation was done accordingly. Economic analysis of the different treatment was done for drawing conclusion

RESULTS AND DISCUSSION

Yields of fennel and component crops

The highest yield of fennel and component crops was obtained in sole crops which was significantly higher over intercropping system. Among intercropping ratios the higher yield of fennel was recorded in 1:1 ratio being at par with 2:2 ratio but the yield of component crop was obtained higher in 1:2 intercropping ratio (Table 1). In sole fennel and component crops the higher yield obtained might be due to no competition for resources with any other crop except fennel leading to better absorption of nutrient and water. The higher yield in 1:1 ratio with all component crops was recorded due to sufficient space availability resulting in higher photo synthesis and translocation of photosynthates from source to sink as compared to other ratio. Tiwari *et al.* (2002) reported depressing effect on growth and performance of fennel when intercropped with vegetable crop. Similarly Nandekar *et al.* (1995) reported decrease in yield of base crop with intercropping. The higher yield on carrot, onion and garlic in 1:2 ratio was obtained due to more number of rows in between interspaces as compared to1:1 and 2:2 ratio resulting in better yield of component crops.

Equivalent yield and land equivalent ratio

Inter cropping with component crops found better which resulted significantly higher fennel equivalent yield and land equivalent ratio as compared to sole cropping of respective crops. Fennel with carrot in all intercropping ratio resulted higher fennel equivalent yield and LER as compared to onion and garlic over respective inter cropping ratio. The inter cropping in 1:1 ratio with all component crop proved superior resulting higher fennel equivalent yield over other ratio (Table 1 and Fig. 2). The highest fennel equivalent yield and LER was obtained in fennel and carrot in 1:1 intercropping ratio which might be on account of higher additional yield of carrot crop without not much reduction in the yield of fennel resulting higher fennel equivalent yield and LER. Similarly, the highest fennel equivalent yield in 1:1 ratio with carrot, onion and garlic was due to proportionately less reduction in yield of fennel as compared to 1:2 ratio resulting better yield of component crop leading to higher fennel equivalent yield. Bhati (1992) reported higher fennel equivalent yield in intercropping as compared to sole crops. Similarly, Ahlawat and Gangaiah (2010) also reported higher system productivity in chickpea intercropped with linseed over sole chickpea. Thomas *et al.* (2010) in a study of mustard and chickpea intercropping found that highest land equivalent ratio of 1.41 in mustard and chickpea intercropping over sole crops.

Economic analysis

Intercropping of fennel with carrot in 1:1, 1:2 and 2:2 ratio exhibited

Table 1. Effect of intercropping system on yield of fennel, component crops and fennel equivalent yield (Pooled data of 2004-05, 2005-06 and 2006-07)

Treatments	Fennel yield (q/ha)	Carrot/onion/ garlic yield (q/ha)	EY yield of onion/carrot/ garlic	Total EY of system (/ha)
Sole fennel	17.25	0	0	17.25
Sole Onion	0	185.26	9.26	9.26
Sole carrot	0	225.45	11.27	11.27
Sole garlic	0	60.25	15.06	15.06
Fennel + Onion (1:1)	15.25	123.45	6.17	21.42
Fennel + Onion (1:2)	13.06	140.65	7.03	20.09
Fennel + Onion (2:2)	14.86	108.38	5.42	20.28
Fennel + Carrot (1:1)	16.85	138.27	6.91	23.76
Fennel + Carrot (1:2)	13.69	142.45	7.12	20.81
Fennel + Carrot (2:2)	15.25	121.28	6.06	21.31
Fennel + Garlic(1:1)	14.25	28.25	7.06	21.31
Fennel + Garlic (1:2)	12.06	23.24	5.81	17.87
Fennel + Garlic (2:2)	13.86	26.24	6.56	20.42
S.Em±	0.55	4.67	0.30	0.65
CD (P=0.05)	1.62	13.69	0.87	1.91

Selling price of fennel Rs 40 /kg, Carrot Rs 2.0 /kg and onion Rs 2.0 /kg and Garlic Rs. 10 EY=Equivalent yield,

Table 2. Effect of intercropping system on economic indices and LER (Pooled data of 2004-05, 2005-06 and 2006-07)

Treatments	Cost of cultivation (Rs/ha)	Gross return (Rs. ha)	Net return (Rs/ha)	B: C ratio	LER
Sole fennel	26750	69000	42250	1.58	1.00
Sole Onion	18950	37040	18090	0.95	1.00
Sole carrot	22840	45080	22240	0.97	1.00
Sole garlic	45250	60240	14990	0.33	1.00
Fennel + Onion (1:1)	28238	85680	57442	2.03	1.55
Fennel + Onion (1:2)	29532	80360	50828	1.72	1.52
Fennel + Onion (2:2)	27436	81120	53684	1.96	1.45
Fennel + Carrot (1:1)	27435	95040	67605	2.46	1.59
Fennel + Carrot (1:2)	28240	83240	55000	1.95	1.43
Fennel + Carrot (2:2)	27250	85240	57990	2.13	1.42
Fennel + Garlic(1:1)	34850	85240	50390	1.45	1.29
Fennel + Garlic (1:2)	38250	71480	33230	0.87	1.08
Fennel + Garlic (2:2)	34150	81680	47530	1.39	1.24
S.Em±	-	-	-	-	-
CD (P=0.05)	.	.	.	.	.

Selling price of fennel Rs 40 /kg, Carrot Rs 2.0 /kg and onion Rs 2.0 /kg and Garlic Rs. 10
LER= Land equivalent ratio

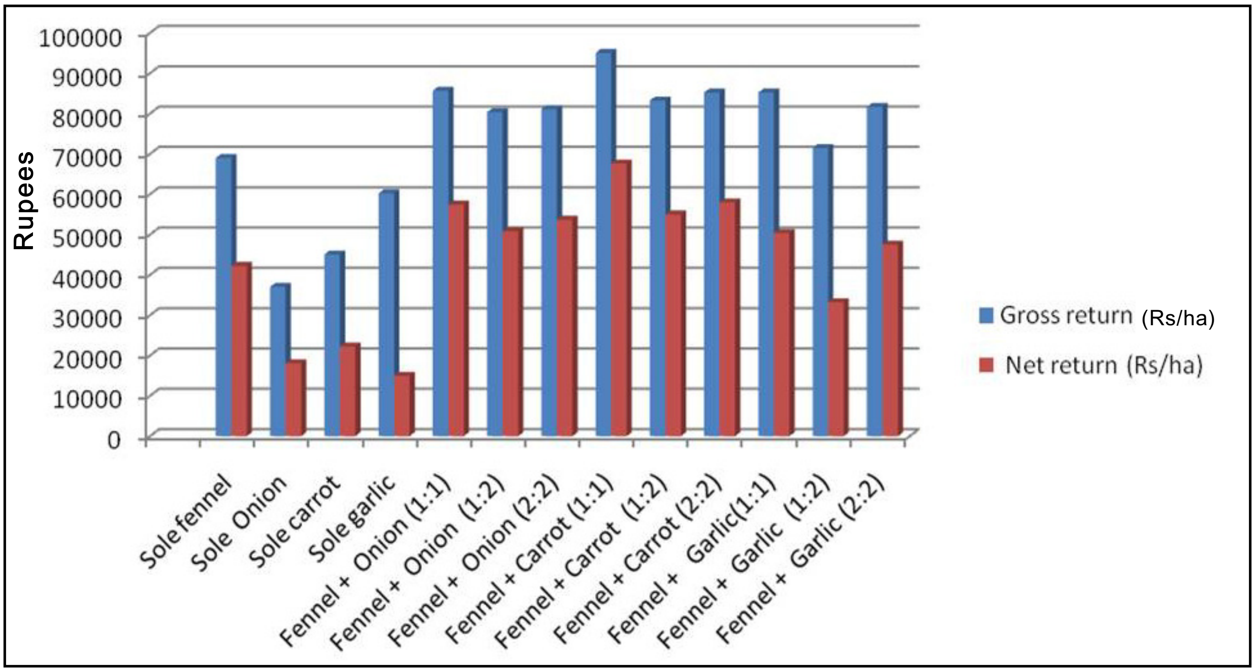

Fig. 1. Effect of intercropping system on gross return and net return

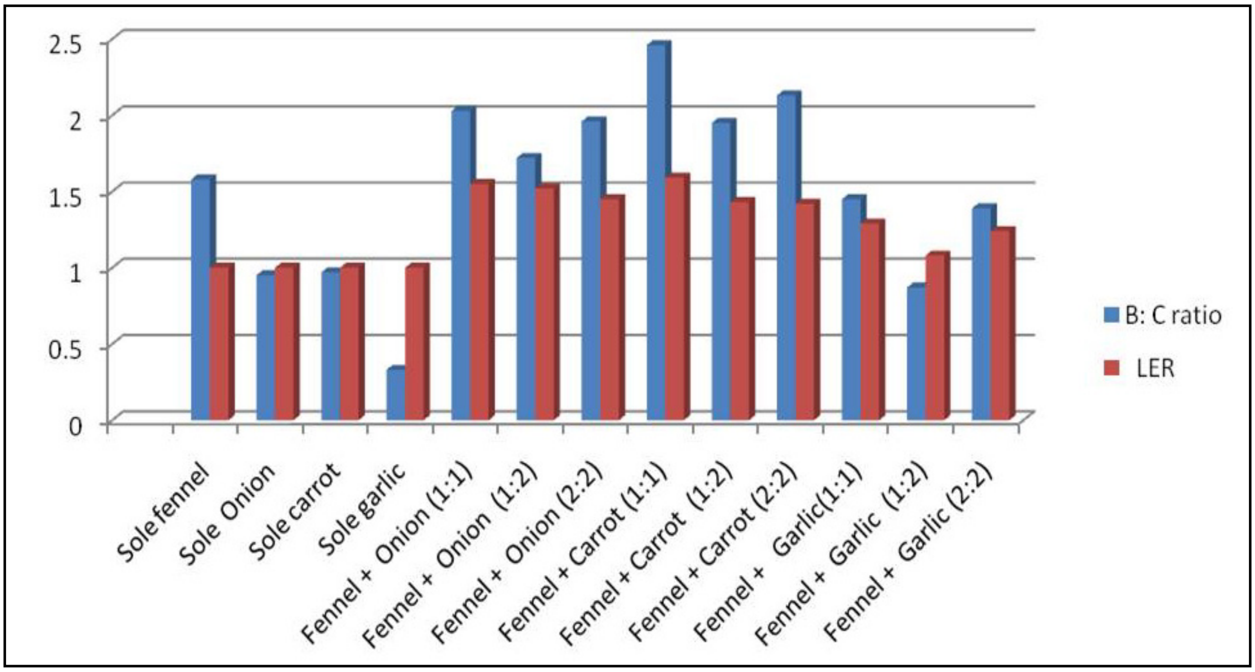

Fig. 2. Effect of intercropping system on B:C ratio and land equivalent ratio

significantly higher gross return, net return and BCR as compared to onion and garlic in all the three ratios. 1:1 ratio of fennel with carrot, onion and garlic proved superior over 1:2 and 2:2 ratio. (Table 2 and Fig. 1 and 2).The highest, gross return, net return and BCR was recorded with fennel and carrot in 1:1 ratio. Yadav *et al.* (2003) reported that intercropping of fenugreek with mustard resulted higher net return and BCR over sole cropping. Similarly, Khurana,and Bhattia (1995) found that intercropping with fennel increased net returns. Intercropping of fennel and carrot in 1:1 ratio is better for realizing higher growth yield and profit in fennel based intercropping system. Higher net return in chickpea intercropped with linseed over sole cropping was observed by Ahlawat and Gangaiah (2010).

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J. Farming Systems Research & Development **17** (1&2) : 127-133 (2011)

EFFECT OF MAIZE (*ZEA MAYS L.*) BASED INTERCROPPING SYSTEMS ON MAIZE YIELD AND ASSOCIATED WEEDS UNDER RAINFED UPLAND ECOSYSTEM

M. Haque and Birendra Kumar

Deptt. of Agronomy, Bihar Agricultural College, Sabour,
Rajendra Agricultural University, Bihar, Pusa, Samastipur

Abstract

A field experiment was conducted on Sandy loam soil during the rainy seasons of 2005 and 2006 to study the effect of maize (*Zea mays* L.) based intercropping system on maize yield and associated weeds under rainfed upland ecosystem. Intercropping system did not affect the growth and yield attributes of component crops. All the intercropping system recorded significantly higher maize-equivalent yield, productivity (kg/ha/day) significant reduction in weed population and weed dry biomass or weed dry weight than sole cropping of maize. Among the intercropping system, maize + Groundnut (1:2) registered higher maize-equivalent yield and was statistically comparable with the maize-equivalent yield obtained from maize + soybean (1:2) intercropping system. Intercropping system was biologically efficient by utilizing the land through increased LER as compared to sole cropping. Intercropping of maize either with soybean or groundnut in (1:2) row ratio significantly reduced the population and dry weight of weeds compared to pure cropping. Highest weed control efficiency was found with maize + soybean intercropping system.

Keywords: Eco-system, Intercropping, Productivity, Rainfed, Yield- Equivalent.

Inadequate soil moisture due to unpredictable occurrence of monsoon is one of the important limiting factors for the scientific crop production under rainfed ecosystem. Maize grown as sole crop under rainfed upland condition are found to be rather risky due to erratic rainfall accompanied with prolonged intermittent dry spells. The role of intercropping in maize is very important, as a strategy for stabilizing and enhancing production of dry land crops. The practice of intercropping of compatible crops is considered viable option to overcome the situation. Umrani et al. (1987) and Patil and Patil (1989) reported beneficial effects of intercropping at rainy season, legume with Pearl millet and Sunflower. Maize crop being a wide spaced row crop having slow initial growth usually suffers from weed infestation. Weed infestation is one of the major factors for low yield of maize. The losses caused due to weeds exceed the losses from any category of agricultural pests. In India weeds alone are responsible for about 33% of total crop losses amounting of Rs. 1980 crores per annum. Under such situation, intercropping offers ample scope for combating weeds without threat to the economics-system. Growing intercrops in widely row spaced maize crop not only reduces weed intensely but also gives additional yield advantage. Intercropping of maize with soybean and groundnut as a compatible crop combination may also be highly appropriate for increasing production and profitability. Keeping in view the situation, present investigation was conducted to assess the possibility of increasing crop production per unit area by in introducing intercrops with rainy season maize under rainfed upland & eco-system.

MATERIALS AND METHODS

The experiment was carried out at research farm of Birsa Agril. Univ. Kanke, Ranchi, (Jharkhand) during the rainy season of 2005-06 and 2006-07. The soil of the experimental plot was sandy loam in texture having available N 261.6 kg/ha, available P 21.5 kg/ha and available K 195kg/ha with pH 5.9. The total rainfall received during the respective years of experimentation were 889.3 and 934.9 mm. The experiment was laid out in split-plot design with three replications. The experiment comprised two intercropping systems along with sole cropping of maize, soybean and groundnut, viz. maize alone at 75 cm, soybean alone at 30 cm, groundnut alone in 30 cm, Maize + Soybean (1:2) and Maize + Groundnut (1:2) were kept in main-plots. Whereas five different weed management practices viz. weedy check, hand weeding at 15, 30 and 45 days after sowing (DAS), oxyfluorfen @ 0.2 kg a.i. /ha, pre-em, alachlor @ 2.0 kg a.i./ha, pre-em and butachlor @ 1.5 kg a.i./ha, Pre-em + quizalofop-ethyl @100 ml/ha, post-em were kept in sub-plots. Maize variety "Suwan" with 20 kg seed/ha, "Bragg" Soybean with 100kg/ha and "AK.12-24" groundnut with 80 kg seed/ha were sown on 11.07.05 and receiving 100kg N/ha + 60 kg P_2O_5/ha+ 40 kg K_2O/ha, 30 kg N/ha + 60 kg P_2O_5/ha + 40 kg K_2O/ha and 30kg N/ha + 50 kg P_2O_5/ha + 30 kg K_2O/ha, respectively. In maize one-third N was applied as basal along with recommended dose of P and K and the remaining N was applied in two splits only in the rows of maize each at knee high stage and pre taselling stage. But in soybean and groundnut entire N was applied as basal along with P and K. Pre-emergence and post-emergence herbicides were applied at next day and 30 days after sowing using volume of 800L water/ ha. For comparison between treatments, the yields of all the intercrops were converted into maize-equivalent yield on prevailing market price basis. Production efficiency values in term of kg/ha/days were obtained by maize-equivalent yield of system divided by total duration of crops in that system. Weed density (no. /m^2) and weed dry-biomass (gm/m^2 at 60 DAS) were recorded from 0.5m^2 randomly selected at two places in each plot. Weed control efficiency was calculated by using the formula

$$\text{WCE} = \frac{\text{DWC - DWT}}{\text{DWT}} \text{ x } 100$$

where WCE is the weed control efficiency, DWE and DWT are the dry weight of weed under control and treated plants.

RESULTS AND DISCUSSION

Growth, yield attributes and grain yield of component crops

Growth and yield attributing characters of component crops were unaffected by the intercropping system (Table-2). The grain yield of maize under intercropping system was statistically at par with the grain yield obtained under its pure cropping during both the years of experimentation. The reduction in yield attributes and grain yield of maize was of comparative for higher magnitude with groundnut, but it was of lower magnitude with soybean intercropping system. The variation in a magnitude of yield reduction in maize intercropped with soybean and maize might be due to their differential competitiveness nature with maize for the essentials of crop growth, different peak demand periods for light, nutrients and moisture. This offers almost least competition between component crops resulting in better

Table 1. Effect of intercropping system on yield of component crops (Maize,soybean and groundnut)

Treatment	Maize grain yield (q/ha)		Soybean seed yield (q/ha)		Groundnut pod yield (q/ha)		Maize-equivalent yield (q/ha)	
	2005	2006	2005	2006	2005	2006	2005	2006
Maize sole (75cm)	35.3	36.8	-	-	-	-	35.3	34.8
Soybean sole (30cm)	-	-	22.3	25.6	-	-	35.8	40.9
Groundnut (30cm)	-	-	-	-	17.9	20.2	39.3	44.4
Maize + soybean(1:2)	33.7	35.7	16.8	19.1	-	-	60.6	66.3
Maize+groundnut(1:2)	31.2	32.9	-	-	14.0	16.9	62.1	70.1
SEm±	NS	NS	2.7	2.6	1.9	1.3	2.3	2.6
Weedy check	20.1	22.0	15.3	16.9	12.1	12.9	32.5	35.4
Weeding(15, 30, & 45 DAS)	39.5	41.2	23.0	24.4	19.1	22.6	55.4	61.5
Oxyfluorfen @ 0.2 kg a.i. ha^{-1}, Pre-em	38.4	40.2	21.8	25.1	17.9	21.8	52.7	59.3
Alachlor@ 2.0 kg a.i. ha^{-1}, Pre-em	36.8	38.5	20.4	23.4	16.6	20.2	49.7	55.9
Butachlor@ 1.5 kg a.i. ha^{-1}, Pre-em + quizalofop-ethyl @100ml ha-1, post-em.	31.9	33.8	17.3	19.8	14.1	15.2	42.6	44.3
CD(P=0.05)	2.6	4.5	1.8	2.4	1.7	2.1	2.8	3.3

utilization of physical resources. Which inturn resulted in better growth and development of maize plant for improving the yield attributes and maize yield. Similar results were also reported by Singh et al (1998). Jat and Gour (2000) also observed the grain/pod yield of soybean and groundnut under pure stand was significantly superior to the yield recorded under intercropping with maize. The significant reduction in grain and pod yield of soybean and groundnut under intercropping system was due to less number of crop rows as compared to their pure cropping.

Weed management practices significantly influenced the growth, yield attributes and yield of component crops. Hand weeding thrice at 15, 30 and 45 days after sowing (DAS) being statistically at par with the pre-em application of oxyfluorfen @ 0.2 kg a.i./ ha recorded significantly higher values of growth, yield attributes and yield to the rest of the weed control measures. This

Table 2. Effect of intercropping system and weed management practices on growth and yield attributes of component crops (maize, soybean and groundnut)

Treatment	Maize						Soybean						Groundnut				
	Plant ht. (cm)		Grain/cab		Test wt (g)		Plant ht.		Seeds/ plant		Test wt (g)		Plant ht.		Pod/pl.		Test wt (g)
	2005	2006	2005	2006	2005	2006	2005	2006	2005	2006	2005	2006	2005	2006	2005	2006	
Maize sole (75cm)	141.4	141.4	144.0	432.0	34.3	34.9	-	-	-	-	-	-	-	-	-	-	-
Soybean sole(30 cm)	-	-	-	-	-	-	70.3	72.55	87.3	98.9	14.0	14.3	58.0	31.4	32.1		
Groundnut sole	-	-	-	-	-	-	-	-	-	-	-	-	58.9	59.1	-	-	-
Maize+soybean(1:2)	138.7	142.4	405	415	33.6	34.6	76.4	78.1	78.8	113.2	13.2	13.5	62.7	62.7	—	-	-
Maize + groundnut(1:2)	135.5	137.6	390	407	33.6	34.4	-	-	-	-	-	-	-	-	-	31.9	31.4
CD(P=0.5)	NS	NS	NS	NS	NS	NS	NS	NS	-	-	NS	NS	NS	NS	NS	NS	
Weedy check	109.9	104.7	11.3	12.3	31.3	32.0	54.8	57.0	31.3	41.4	12.1	-	12.8	43.9	47.2	26.1	28.8
Weeding (15,30 &45DAS)	157.8	160.3	149	15.8	35.2	36.2	86.4	81.6	123.5	150.2	14.7	-	14.0	69.2	68.2	33.5	35.2
oxyfluorfen @ 0.2 kg a.i./ha	149.3	155.3	14.3	15.2	34.9	25.6	80.1	83.9	119.0	151.3	14.3	14.7	67.3	66.5	32.9	33.8	
Alachlor @2.0kg a.i./ha pre-emg.	142.0	148.3	14.5	14.7	34.1	34.8	74.4	78.2	93.6	119.7	13.5	-	13.7	63.8	63.3	32.4	33.0
Butachlor @1.5 kg a.i./ha pre-emg.+quizalotip-ethyl @100ml/ha, post –emg.	133.8	139.3	13.0	13.6	31.9	32.7	71.3	75.8	61.9	90.5	13.5	-	13.5	59.9	59.3	31.2	31.9
CD (P=0,05)	12.0	19.9	0.69	1.42	0.94	1.5	6.0	5.4	3.6	-	1.09	-	1.05	5.26	3.85	1.1	2.1

Table 3. Effect of cropping system and weed management on weeds and crop productivity.

Treatment	Weed density/m² (no./m²)						Dry weight of weeds(g/m²)						Weeds control efficiency (%)		
	30 DAS			60 DAS			30 DAS			60 DAS			60 DAS		
	2005	2006	Pooled	2005	2006	Pooled	2005	2006	Pooled	2005	2006	Pooled	2005	2006	Pooled
Cropping system															
Maize sole (75cm)	41.1	38.8	39.8	55.8	48.8	52.3	15.5	16.6	16.1	19.2	25.2	22.2	40.4	30.1	35.2
Soybean sole (30cm)	34.7	33.7	34.2	54.9	49.0	51.9	12.7	15.7	14.2	18.1	22.3	20.2	44.1	38.2	41.1
Groundnut (30cm)	36.3	36.2	36.2	55.8	51.4	53.6	13.9	17.7	15.8	18.2	21.9	20.0	43.6	39.3	41.5
Maize + soybean(1:2)	22.1	20.9	21.5	40.8	33.3	37.0	10.0	12.8	11.4	12.3	15.4	13.9	61.8	57.1	59.5
Maize + groundnut(1:2)	24.7	21.3	23.0	46.5	40.3	43.4	11.0	14.0	12.6	13.8	17.8	15.8	57.3	50.7	54.0
SEm±	0.8	0.6	0.5	1.9	1.7	1.0	0.2	0.3	0.5	0.4	0.4	0.5	-	-	-
C.D. (P=0.05)	2.5	2.1	1.7	6.2	3.8	2.4	0.8	0.9	1.9	1.3	1.4	2.1	-	-	-
Weed management															
Weedy check	74.0	74.8	74.4	125.0	117.0	121.0	21.5	25.2	23.3	32.3	36.0	34.2	-	-	-
Weeding(15,30,& 45DAS)	14.9	12.7	13.8	27.0	21.9	24.4	9.2	11.9	10.5	11.1	14.3	12.7	65.5	60.3	62.9
Oxyfluorfen@ 0.2 kg a.i. ha^{-1}, Pre-em	18.1	15.9	17.0	31.5	24.3	27.9	9.7	11.9	10.8	11.7	15.6	13.6	63.9	56.6	60.2
Alachlor@ 2.0kg a.i. ha^{-1}, Pre-em	22.1	20.4	21.2	32.6	27.5	30.0	11.0	13.4	12.2	12.4	17.4	14.9	61.5	51.8	56.7
Butachlor@ 1.5 kg a.i. ha^{-1}, Pre-em+quizalofop-ethyl @100ml ha-1, post-em	29.6	26.9	28.3	37.7	32.2	34.9	11.9	14.5	13.2	14.1	19.2	16.7	56.3	46.7	51.5
SEm±	0.8	0.9	0.6	1.2	1.2	0.8	0.2	0.4	0.2	0.4	0.4	0.3	-	-	-
C.D.(P=0.05)	2.2	2.5	1.7	3.4	3.5	2.4	0.7	1.2	0.6	1.1	1.3	1.0	-	-	-

might be probably due to the creation of modified micro-climate interms of physical environment for mechanical manipulation of soil during hand weeding. Better penetration, long persistence and broad spectrum control of applied herbicides keep the weed population under control by arresting or inhibiting the germination of weed seeds, growth and development of weeds, which inturn provide weed-free environment to the crop resulted into better manifestation of crop growth and yield attributes and ultimately enhanced the crop yield. The results are in conformity with those reported by Verma and Katyal (1989) in Pearl millet.

Maize- equivalent yield

Intercropping systems recorded higher maize-equivalent yield compared to sole cropping in both the years (Table-1). Among the intercropping systems, maize + groundnut (1:2) recorded maximum maize-equivalent yield and was statistically at par with the equivalent yield obtained under maize + soybean intercropping systems (1:2). The higher maize-equivalent yield (MEY) under intercropping systems was due to better production of component crops interms if their higher yield. Shivay etal. (2001) also recorded the maximum maize-equivalent yield with maize + soybean intercropping.

Significant increase in MEY because of different weed control measures appears to be the result of higher productivity of component crops owing to better weed free environment for effective and efficient utilization of strategic inputs or resources and also better exploitation.

Weeds

The experimental plots were infested with both types of weeds i.e. grassy and non-grassy. Among the grassy weeds-*cylodon dactylon* (*L.*) *pers. Dactyloctenium aegyptium* (L.) wild, *Echinochloa crusgalli* (L.), *Echinichloa coloaum* (L.)

Link and *Eleusine indica* (L.) were prodominant where as non-grassy weeds included *Ageratum coryziodes* (L). *Amaranthus viridis* (L.), *Commelina benghalensis* (L.), *Celosia argentea* (L.), *Eupharbia hirta*, *Phyllanthus niruri* (L.) and *Cyperus rotundus* (L.). Intercropping systems significantly reduced the weed population and weed dry weight than their sole cropping in both years (Table 3). Maize + soybean (1:2) intercropping systems was the most effective in suppressing weeds and recorded the minimum weed population and weed dry-weight. Maize+ soybean (1:2) and maize + groundnut (1:2) intercropping systems were statistically alike in respect of weed dry weight

Maize + soybean (1:2) intercropping systems recorded maximum weed control efficiency closely followed by maize + groundnut intercropping systems (1:2) (Table 3). The reduction in weed population and weed dry biomass under intercropping systems may be attributed to shading effect and competition stress caused by the canopy of more number of crops plant in a unit area having smothering effect on associated weeds preventing the weed to attain full growth. Similar results were also reported by Kumar and Reddy (2000).

All the weed control measures significantly reduced the density and dry-weight of weed compared with weedy check. Hand weeding thrice at 15, 30 and 45 DAS proved the most effective and efficient in reducing the population of weeds and weed dry matter production. Performance of hand weeding and pre-emergence application of oxyfluorfen @ 0.2 kg a.i./ha was statistically alike and were significantly superior to the rest of the weed control measure (Table-2).

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J. Farming Systems Research & Development **17** (1&2) : 134-136 (2011)

CORRELATION AND PATH COEFICIENT ANALYSIS IN CAULIFLOWER (*BRASSICA OLERACEA VAR.BOTRYTIS* L.)

K.P. SINGH, R.N. JHA, B.K. VERMA AND P.N. MANDAL

Department of Horticulture, Bihar Agricultural College, Sabour, Bhagalpur, Bihar- 813 210 (INDIA)

ABSTRACT

Correlation and path coefficient analysis were conducted on 'Pushi' variety of Cauliflower. Yield was found to be highly and significantly positively correlated with all the ancillary characters viz; curd weight (0.9941), number of the leaves (0.9674), Leaf area (0.9661), curd diameter (0.9412), plant spread (0.9161), plant height (0.8239) and curd depth (0.8068). All the ancillary characters showed significantly positive correlations among themselves. The path coefficient analysis values also indicated that the maximum positive direct effect accrued due to leaf count followed by curd weight, plant height and curd depth. Whereas plant spread, leaf area and curd diameter showed direct negative effect. The value of residual effect was found to be 0.0801, indicating that the characters included for path analysis were sufficient for inducing the maximum yield of cauliflower.

Yield in plant is the end product of interaction of various correlated characters. Therefore, knowledge of interrelationship of characters may prove highly useful in an objective selection of desired characters. It is not only polygenetically controlled but also subject to the fluctuating environment. When a number of variables are considered in correlation, the association becomes more complex and less obvious. The use of path coefficient analysis is helpful under such situation. This analysis while shows the direct and indirect association reveals the most reliable yield contributing characters. A wide range of variability is available, which provides a great scope for improving yield of cauliflower through a systematic and planned selection programme for one or more direct or indirect yield components. Keeping in view the above facts, the present investigation was conducted to determine the nature and degree of association among the characters and their direct and indirect effects on curd yield of cauliflower.

MATERIALS AND METHODS

Experiment was conducted at Birsa Agricultural University, Kanke, Ranchi in the experimental area of the department during the period 2002 to 2005 to study the correlation and path coefficient analysis in cauliflower utilizing promising variety "Pushi". The seeds were sown in the third week of August in each years and seedlings were transplanted at a spacing of 60 cm x 30 cm. in last week of September in a Factorial Randomized Block Design with three replications. The plot size was 3m x 3m and number of plants/ plot was 50. All the cultural operations were done in time and timely plant protection measures were also adopted. The harvesting had been commenced from the 1st week of January and continued till the last week of January in every year of experimentation. The observation on curd yield and other ancillary characters were recorded. The pooled data were statistically analysed to determine the correlation coefficient and path coefficients as per method suggested by Al-Jibouri *et al.* (1958) and Dewey and Lu (1959), respectively.

The relationship between the yield of cauliflower and ancillary characters

Besides, the yield, other variables viz; plant height (x_1), plant spread (x_2), number of leaves (x_3), leaf area (x_4), weight of the curd (x_5), diameter of the curd (x_6) and depth of the curd (x_7), which were thought to influence the yield, were also primarily considered. Total correlation coefficients between the yield and other characters were calculated and the values so obtained are summarised in Table-1.

The pooled data clearly depicted that the yield was significantly and positively correlated with all the other characters with the maximum of 0.9941 (weight of the curd) followed by 0.9674 (number of leaves) and 0.9661 (leaf area). However, the minimum value observed was 0.8068 with depth of the curd (x_7). These findings are in conformity with those of Jamwal *et al.* (1992), Dutta and Korla (1991), Kumar & Korla (2001) and Sharma *et al.* (2006) in cauliflower. Others characters recorded intermediate values in this respect.

All other characters have also recorded highly significant inter association among themselves i.e.; an

Table 1. Correlation coefficients between different pairs of characters in cauliflower.

Characters	Plant Spread (x_2)	Number of leaves (x_3)	Leaf area (x_4)	Weight of the curd (x_5)	Diameter of the curd(x_6)	Depth of the curd (x_7)	Yield Q/ha. (y)
Plant height cm. (x_1)	0.8852**	0.8604**	0.8638**	0.8271**	0.9080**	0.6122**	0.8239**
Plant spread cm. (x_2)		0.9620**	0.9636**	0.9168**	0.9487**	0.7941**	0.9161**
Number of leaves (x_3)			0.9998**	0.9592**	0.9474**	0.8606**	0.9674**
Leaf area cm. (x_4)				0.9588**	0.9464**	0.8632**	0.9661**
Weight of the curd g. (x_5)					0.9386**	0.8011**	0.9941**
Diameter of the curd cm. (x_6)						0.6664**	0.9412**
Depth of the curd cm. (x_7)							0.8068**

**- Significant at 1% level *- significant at 5% level.

Table 2. Direct and indirect effects of different characters in Cauliflower.

Characters	Plant Spread (x_2)	Number of leaves (x_3)	Leaf area (x_4)	Weight of the curd (x_5)	Diameter of the curd(x_6)	Depth of the curd (x_7)	Yield Q/ha. (y)
Plant height cm. (x_1)	-0.0633	2.7453	-2.5510	0.6753	-0.0099	0.0033	0.8239
Plant spread cm. (x_2)	**-0.0715**	3.0695	-2.8458	0.7486	-0.0103	0.0043	0.9161
Number of leaves (x_3)		**3.1907**	-2.9528	0.7832	-0.0103	0.0047	0.9674
Leaf area cm. (x_4)			**-2.9532**	0.7828	-0.0103	0.0047	0.9661
Weight of the curd g. (x_5)				**0.8165**	-0.0102	0.0044	0.9941
Diameter of the curd cm. (x_6)					**-0.0109**	0.0036	0.9412
Depth of the curd cm. (x_7)						**0.0054**	**0.8071**

Bold figures are direct effect, Residual effect: 0.0801, R^2 = 0.9937 or 99.37%.

increase in any of these characters, led to a corresponding increase in the curd yield.

The yield and yield attributes were highly and significantly associated amongst themselves.

The analysis of path coefficients indicated that the maximum positive direct effect was found due to number of leaves followed by weight of the curd, plant height and depth of the curd, whose correlations with yield were also positive. Whereas, plant spread, leaf area and diameter of the curd showed negative direct effect. Whole correlations were found positive indicating that plant spread, leaf area and weight of the curd via number of the leaves exhibited positive association with curd yield. The value of residual effect was found to be 0.0801, indicating that the characters included for path analysis were sufficient for maximizing the cauliflower yield.

Thus, it may be inferred that number of the leaves and weight of the curd may be adjudged to be the best characters for the production of higher yield of cauliflower.

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J. Farming Systems Research & Development **17** (1&2) : 137-144 (2011)

EFFECT OF FYM, VERMICOMPOST, VERMIWASH AND NPK TREATMENTS ON GROWTH, MICROBIAL BIOMASS C AND YIELD OF SOYBEAN

Mahendra Singh[1], Narendra Kumar[1], Amit Mishra[1], Vivek Sharma[2], Shailendra Raj[2] and Vipin Kumar[2]

[1]*Department of Soil Science, College of Agriculture, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar 263 145, Uttarakhand, India*
[2]*IRRI India, SVBPA&T, Modipuram Meerut*

Abstract

A field experiments was conducted at the Crop Research Centre of G.B. Pant University of Agriculture and Technology, Pantnagar during *kharif* season 2006 and 2007 to study the effect of nutrient management in soybean (*Glycine max.* L. Merrill)" on its nodulation, growth and yield on cultivar PS- 1347. The experiment was laid out in randomized block design (RBD) with three replications. The application of FYM @ 5 t /ha, vermicompost @ 2.5t /ha and vermiwash @ 10% in combitions with 50% NPK showed superiority for nodule number and dry weight per plant, shoots dry weight, number of trifoliate, plant height, microbial biomass C, 100-seed weight and grain yield over the sole application of recommended NPK level in both years (2006 and 2007). The combined application of FYM @ 5 t /ha + VC @ 2.5 t /ha + V W @ 10% + 50% NPK recorded the highest nodule number (18.33, 49.00, 37.66: 33.66, 53.0, 35.66 per plant), nodule dry weight (142.41, 384.08, 235.42: 257.27, 304.0 mg per plant, respectively) But at 60 DAS in 2007-08 it was under FYM @ 5 t /ha + VC @ 2.5 t /ha + 50% NPK. This treatment also gave maximum number of trifoliate (16.2, 32.0 and 34.0: 19.66, 41.0 and 38.0 per plant), plant height (44.3, 76 and 75.63: 51.53, 79.66 and 78.66 cm per plant) during 2006 and 2007, respectively. All the applied treatment numerically increased microbial biomass C in comparison to recommended dose of NPK. The highest microbial biomass carbon (323.06 and 292.01 μg^{-1}) at 50% flowering stage than at harvesting stage (302.5 and 277.63 μg^{-1}) due to the increase in microbial population of soil during the both years 2006 and 2007, respectively. The maximum grain yield (3209.87 and 3230.88 kg /ha, respectively) recorded under the combined application of FYM @ 5 t /ha + VC @ 2.5 t /ha + V W @ 10% + 50% NPK. However, 100-seed weight remained unaffected.

(**Key words:** FYM, vermiwash, vermicompost, nodulation, soybean, microbial biomass C, yield)

Soybean (*Glycine max* L. Merrill) is one of the most important oil seed crop of the world. It contain exceptionally high and well balanced protein (42-45%) and edible oil (20- 22%) with higher biological value, unsaturated fatty acids viz, linoleic fatty acid (19.4%) and amino acids argentine, aspartic acids glutamic acid, glycine, isolucine, lucine and valine etc.(Smith and Circle, 1972). Soybean requires high amount of nutrients due to its high yield potential. The crop removes a large quantity of nitrogen, phosphorus and potash. A good crop producing 6720 kg/ha biomass removes about 514 kg nitrogen, 480 kg phosphorus and 485 kg potash/ha (Nelson, 1989). In case of nitrogen, full nitrogen requirement is not met by symbiosis. However, ability of soybean plant for symbiotic nitrogen fixation (about 240-250 kg/ha) (Chandel *et al.*, 1989). But it also gets reduced at seed development stage when requirement of nitrogen is maximum. Gracia and Hanway (1976) also reported that N, P and K fertilization of soybean during pod filling increased the yield up to 27 to 31 per cent. At higher rate of nitrogen, more protein has been synthesized and lipid metabolism favored. Organic manures are known to improve physical, chemical and biological properties of soil. Because of their low nutrient content and slow acting nature, organic manures alone could not the nutritional requirement of crops and therefore, chemical fertilizers also have their own importance. Farm yard manure is the most widely used organic source. It serves as a source of plant nutrients and has important role in improving soil fertility and productivity. Earthworms significantly increase soil fertility and productivity by decomposing and converting organic waste into useful compost. Vermicompost is rich in NPK and is widely used now a days. There is a great scope to increase soybean production utilizing judicious combinations of organic and inorganic fertilizer in appropriate dose. This can counter balance the correct storage of costly fertilizers and provide sustainable fertile soil for plant growth. With these ideas, the above investigation was undertaken to study the effect of various sources of nutrients on the growth and yield of soybean.

MATERIALS AND METHODS

An experiment was conducted at Crop Research Centre of Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, District Udham Singh Nagar, for two years during rainy season (*kharif*) 2006 and 2007 to study the effect of organic and inorganic sources of nutrients on soybean (PS 1347). The experimental soil was silty clay loam, well drained (pH 7.4), high in organic carbon (0.86%), medium in available phosphorus (19.19 kg /ha) and low in available potassium (130.71 kg / ha) and nitrogen (240.17 kg /ha) content. There were 16 treatments (Table 1) replicated thrice in randomized block design (RBD). NPK (20:60:40) through urea, single super phosphate and murate of potash, FYM and vermicompost were applied at the time of sowing and two sprays of vermiwash were given at 30 and 45 DAS. The microbial biomass C by Vance *et al.* (1987). Thinning and gap filling was done wherever necessary to maintain optimum plant population. For recording observation on various growth parameters, five plants were randomly selected and labeled from each plot. Nodules were carefully separated from the washed roots and counted at 30, 60 and 90 DAS, nodule of each replication after counting were dried in open glass Petri dishes at 65 ± 2 C for 48 hours in an oven till constant dry weight and shoot dry weight was recorded by taken five plants from sampling area of each plot after dry in shade than put in hot oven at 65 ± 2 C for 48 hours and take the weight gram per plant at 30, 60 and 90 DAS, plant height and number of branches per plant were recorded at 30, 60 and 90 DAS. Standard procedure was adopted for these biometric observations. After threshing and proper cleaning the plot grain, yield of individual plot was recorded with single pan balance and converted into kg /ha and one sample of 100 grain was drawn from each replication and weighed, recorded as 100-grain weight.

RESULT AND DISCUSSION

Combined application of vermicompost, vermiwash and FYM along with recommended NPK was numerically better in terms of nodule number and their dry weight over the single application of different composts and NPK. The findings corroborate with the findings of Mahto and Yadav (2005) who reported that application of vermicompost (25 q /ha equivalence) and DAP (100 kg/ha equivalence) + foliar spray of vermiwash (10%) at 30 DAS

Table 1. Effect of FYM, vermicompost, vermiwash and recommended NPK on nodule number and dry weight (mg/plant) of Soybean at 30, 60 and 90 DAS

Treatment	Nodule Number/plant						Nodule dry weight (mg/plant)					
	(2006-07)			(2007-08)			(2006-07)			(2007-08)		
	30	60	90	30	60	90	30	60	90	30	60	90
NPK 100%	15.6	25.0	15.6	26.0	36.6	17.3	131.7	182.0	140.6	210.1	282.0	167.0
NPK 50%	15.0	30.0	21.3	28.0	33.0	23.3	135.0	206.5	181.7	244.03	273.1	153.6
FYM @ 10 t/ha	16.6	33.3	22.6	28.0	41.0	21.0	136.4	200.1	181.4	215.5	330.1	161.3
VC @ 5 t/ha	15.3	35.0	25.0	27.0	37.0	28.3	137.5	253.8	192.6	227.0	320.5	181.6
VW @ 10% (Two sprays at 30 and 45 DAS)	13.3	36.0	24.6	28.0	38.6	29.0	131.4	240.5	197.7	250.2	307.2	195.6
FYM @ 5 t/ha + VC @ 2.5 t/ha	17.0	45.3	34.3	28.3	39.0	24.6	138.9	370.5	211.8	256.3	370.5	138.6
FYM @ % t/ha +VW @10%	16.3	37.3	27.0	23.0	40.6	29.3	135.5	303.5	200.1	220.1	303.5	166.0
VC @2.5 t/ha +VW @10%	15.6	32.0	20.0	28.3	40.6	27.3	130.0	363.8	145.0	200.4	363.8	164.0
FYM @ 5 t/ha + VC @ 2.5 t/ha + VW @ 10 %	16.0	38.6	23.6	28.0	40.6	32.0	138.8	383.3	143.7	230.4	316.6	188.3
FYM @ 5 t/ha + VC @ 2.5 t/ha + NPK 50%	17.3	48.3	37.0	29.6	41.3	26.3	137.7	377.0	158.5	213.8	377.0	163.0
FYM @ 5 t/ha +VW@ 10% +50% NPK	14.3	41.6	31.6	26.0	41.0	28.3	130.7	292.0	219.0	215.2	292.0	238.0
VC @ 2.5 t/ha + VW@10% + 50%NPK	16.0	40.0	31.3	28.6	40.3	27.0	135.1	322.0	214.9	208.4	322.0	184.6
FYM @5 t/ha +VC @2.5 t/h^a + VW@ 10% + 50% NPK	18.3	49.0	37.6	33.6	53.0	35.6	142.4	384.0	235.4	257.2	324.8	304.0
FYM @ 10 t/ha 50% NPK	17.3	48.6	36.6	29.3	40.3	32.3	137.2	372.2	234.5	205.1	372.2	251.6
VC @2.5 t/ha +50%NPK	16.6	41.0	33.3	30.0	49.0	28.3	136.0	342.0	228.7	213.5	342.0	233.3
VW@10% + 50%NPK	16.3	39.3	28.0	24.3	49.3	27.6	129.7	269.6	205.9	202.9	319.6	185.6
SEm (±)	6	2.68	1.92	2.17	2.24	1.95	9.5	2.48	9.06	7.42	4.13	20.72
CD (P=0.05)	NS	7.7	5.6	1.2	6.4	5.8	7.1	26.5	22.7	NS	59.8	55.6

increased nodule number per plant in vegetable pea by 23.6% over the control. The maximum nodule number (Table 1) were found with the treatments of FYM @5 t/ha + VC @ 2.5 t/ha + VW @ 10% + 50% NPK at all growth stages (30, 60 and 90 DAS) it may be due to the improvement in the soil porosity and more availability of nutrients to the plant.

Application of FYM @5 t/ha +VC @ 2.5 t/ha + 50% NPK numerically increased shoot dry weight at all the growth intervals of the soybean plant over the recommended dose of NPK. It may be due to the improvement in the soil porosity and more availability of nutrients to the crops for its growth and development. Khutate *et al.* (2005) observed that the application of 75% NPK + 25% vermicompost (5.76 q/ha) or FYM (50%) recorded the highest shoot dry weight per plant over the control. Shoot dry weight was increased with the advancement of plant age. This is the result of synthesis of more plant tissues due to more availability of N and P with the given treatments. In both the year (2006-07 and 2007-08) maximum shoot dry weight g per plant (Table 1) at all the growth stages except at 60 DAS in 2007 it was found in the treatment FYM @ 5 t/ha+ VC @ 2.5 t/ha+ VW @ 10% +50% NPK, it might be due to the improvement in the soil porosity and more availability of nutrients to the plant. These findings corroborate with Khutate *et al.* (2005) observed that the application of 75% NPK + 25% vermicompost (5.76 q/ha) or FYM (50%) recorded the highest shoot dry weight per plant over the control.

Addition of FYM @ 10 t/ha +50% NPK numerically increased number of trifoliate leaves per plant and plant height (cm) over the recommended dose of 100% and 50% NPK, it might be due to the improvement in soil porosity, structure and nutrients concentration in soil for uptake by the plant. Similarly, a field experiment conducted at Pantnagar on integrated nutrient management in soybean cv. PK-416 and maximum numbers of branches per plant were in recorded with the application of FYM @ 10 t/ha with recommended dose of NPK /ha which showed the essentiality of nitrogen for better growth of the crop (AICRP on Soybean, 1999). The maximum number of trifoliate leaves and plant height cm (Table 2) at all the growth intervals during the both year (2006 and 2007) recorded by the application of FYM @ 5 t/ha+ VC @ 2.5 t/ha+ VW @ 10% +50% NPK, it might be due to the improvement in the soil porosity and more availability of nutrients to the plant.

The microbial biomass is positively related with microbial biomass carbon. The microbial biomass carbon in soil at 50% flowering stage was more in comparison to the harvesting stage, which might be due to the fact and addition of FYM and vermicompost in soil microbial number and activity increased due to more available carbon and nutrients like, N and P to soil microorganisms which have synthesized more cellular components and provided more energy, later on the nutrients were exhausted by soil microorganisms and crop plant and reduced the microbial biomass in soil. This finding is supported by Wang Yan *et al.* (1998) who reported that soil microbial biomass increased greatly after application of organic manures at beginning of experiment and thereafter the biomass C decreased. The maximum microbial biomass carbon (Table 3) at both the stages was recorded with the application of FYM @ 5 t/ha + VC @ 2.5 t/ha+ VW @ 10% +50% NPK during both year (2006 and 2007), it

Table 2. Effect of FYM, vermicompost, vermiwash and recommended NPK on number of trifoliate leaves/plant of Soybean at 30, 60 and 90 DAS

Treatment	Number of trifoliate leaves/plant						Plant height (cm)					
	(2006-07)			(2007-08)			(2006-07)			(2007-08)		
	30	60	90	30	60	90	30	60	90	30	60	90
NPK 100%	11.2	24	25.33	9.33	29.66	28.66	31.46	66.33	69.42	31.16	67.66	69
NPK 50%	12	26.66	28	11	31	31.66	33.26	68.16	68.25	31.93	68.5	71
FYM @ 10 t/ha	12.66	24.66	25.66	9.66	29.33	30.66	31.46	70.03	70.98	33.9	72.2	71.33
VC @ 5 t/ha	14	27	29	10.33	39.66	33.66	37.86	68.16	69.78	41.13	72.23	71.33
VW @ 10% (Two sprays at 30 and 45 DAS)	11.33	22	20	12	32.33	33	36.03	72.33	69.25	37.46	67.4	69.66
FYM @ 5 t/ha + VC @ 2.5 t/ha	14.1	30	31.66	9	33.66	31	41.38	75.03	75.03	39.6	71.7	75
FYM @ % t/ha +VW @10%	14.66	26.33	28	11.66	33	33	36.03	70.4	73.03	40.44	73.2	68.66
VC @2.5 t/ha +VW @10%	14	24.03	26.66	12.33	40.33	33.66	37.83	72.06	70.69	32.53	70.03	66.66
FYM @ 5 t/ha + VC @ 2.5 t/ha + VW @ 10 %	13.66	24.33	26	10	39.66	33.33	31.66	67.03	68.33	39.98	69.63	73
FYM @ 5 t/ha + VC @ 2.5 t/ha + NPK 50%	13.66	29	30.66	12	34.33	33.33	41.78	72.3	71.96	45.53	70.73	71.66
FYM @ 5 t/ha +VW@10% +50% NPK	12.66	29.33	30.33	13.66	36	36	35.5	63.56	70.6	46.4	72.2	70.33
VC @ 2.5 t/ha + VW@10% + 50%NPK	12.66	24.33	25.66	13.33	37	35	33.16	69.33	69.18	48.53	71.16	66.33
FYM@ 5 t/ha +VC @ 2.5 t/ha + VW@ 10% + 50%NPK	16.2	32	34	19.66	41	38	44.36	76	75.63	51.53	79.66	78.66
FYM @ 10 t/ha 50%NPK	15	30.66	29.33	17	39	34.33	39.66	73.33	70.12	50.66	76	70.33
VC @ 2.5 t/ha +50%NPK	13	26	28	15.33	39.66	35.33	37.7	69.66	69.7	44.76	72.33	73.33
VW@10% + 50%NPK	12.33	25	27	16.66	37.33	34.66	37.99	68.13	70.02	51.4	71.9	72.66
SEm (±)	2.34	1.89	1.51	1.60	2.92	1.78	2.13	3.42	2.43	42.40	2.09	2.82
CD (P=0.05)	NS	5.56	4.48	4.64	8.45	5.23	6.26	NS	NS	122.61	6.05	8.25

Table 3. Effect of nutrient management on Microbial biomass C (µ g/g soil) at 50% flowering and at harvest and yield of soybean

Treatment	2006-07		2007-08		2006-07		2007-08	
	50% flowering	At harvest	50% flowering	At harvest	GY (kg/ha)	100-Seed Wt. (gm)	GY (kg/ha)	100-Seed Wt. (gm)
NPK 100%	255.5	245.5	256.3	262.9	2716.0	9.9	2213.0	10.6
NPK 50%	283.8	278.1	267.2	263.2	2870.3	10.1	2938.1	10.5
FYM @ 10 t/ha	289.2	279.4	274.4	275.5	2839.5	10.1	2868.0	10.7
VC @ 5 t/ha	282.9	271.6	265.7	261.8	2962.9	10.1	2757.6	10.5
VW @ 10% (Two sprays at 30 and 45 DAS)	281.3	270.6	268.9	268.5	2406.1	10.1	2878.3	11.0
FYM @ 5 t/ha + VC @ 2.5 t/ha	308.1	298.3	271.5	270.3	2870.3	10.4	2810.6	10.7
FYM @ % t/ha +VW @10%	278.1	270.3	278.2	264.1	2641.9	10.0	2572.3	11.0
VC @ 2.5 t/ha +VW @10%	304.0	269.7	283.3	260.0	2993.8	9.9	2533.2	11.3
FYM @ 5 t/ha + VC @ 2.5 t/ha + VW @ 10 %	303.5	297.5	282.9	266.7	2832.0	10.1	3127.3	11.5
FYM @ 5 t/ha + VC @ 2.5 t/ha + NPK 50%	323.0	280.6	274.6	274.1	3024.6	10.5	2931.2	10.5
FYM @ 5 t/ha +VW@10% + 50% NPK	305.6	296.6	261.5	266.1	2637.0	10.7	2912.1	11.0
VC @ 2.5 t/ha + VW@10% + 50%NPK	280.6	270.2	273.0	267.4	3024.6	10.3	2748.1	10.9
FYM @5 t/ha +VC @ 2.5 t/ha + VW@ 10% + 50%NPK	308.2	302.5	292.0	277.6	3209.8	10.5	3230.8	11.5
FYM @ 10 t/ha 50%NPK	305.4	298.2	273.2	268.6	2746.9	10.2	2815.1	8.2
VC @2.5 t/ha +50%NPK	283.5	275.1	273.5	265.9	2962.9	10.1	2859.2	8.4
VW@10% + 50%NPK	291.4	282.1	265.2	264.6	2685.1	10.1	2858.4	11.3
SEm (±)	7.54	2.61	7.93	5.33	167.2	0.29	165.9	0.86
CD (P=0.05)	22.9	7.6	22.9	15.3	470.7	0.8	486.3	2.5

might be due to the improvement in the soil physical properties like soil structure, aeration, porosity and structure, and more availability of nutrients concentration in soil to the plant. Similarly, Manna *et al.* (2001) and Ghosh *et al.* (2002) have reported that application of enriched compost significantly increased soil microbial biomass C in soil.

Combined application of FYM and vermicompost along with recommended dose of NPK maximum increased seed yield of soybean over the alone application of composts. This may be due to the improvement in soil physical and biological properties of soil. These findings corroborate with Bachhav and Sabale (1996) who conducted an field experiment in 1993-94 at Pune, Maharashtra, soybean cv. MACS 124 were given 50 kg N/ha as urea, FYM, Vermicompost, or 50% urea + 50% FYM, VC. Seed yield (3.29 t/ha) was highest with 50% each of urea and FYM. The maximum grain yield (Table 3) of soybean (kg/ha) recorded with the treatment of FYM @ 5 t /ha + VC @2.5 t /ha + VW @ 10% + 50% NPK in both years (2006-07 and 2007-08). This may be due to the improvement in soil physical and biological properties of soil. These findings corroborate with (Thomas and Lal., 2003) who observed that application of farm compost + poultry manure or vermicompost in combination with inorganic fertilizers showed synergistic effect on the growth of the crop (Soybean-Mustered-Cowpea) and showed increased in the yield attributes of crops during 1997 to 1998. Application of different treatments did not affect the 100-seed weight of soybean.

Therefore the productivity of soybean can be increased with the use of any of the organic sources of nutrients used along with recommended NPK fertilization.

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J. Farming Systems Research & Development **17** (1&2) : 145-152 (2011)

INFLUENCE OF PHOSPHORUS LEVELS AND PHOSPHORUS SOLUBILISING BACTERIA (PSB) APPLICATION METHODS ON PUE AND GRAIN YIELD OF RICE BASED CROPPING SYSTEMS

R. Mahender Kumar, P. Krishnamurthy, P.C. Latha, K. Surekha, J.S. Prasad and S.P. Singh

Directorate of Rice Research, Rajendranagar, Hyderabad-500 030

Abstract

A field experiment was conducted during 2001-02 to 2003-04 in vertisols at Directorate of Rice Research (DRR) farm to evaluate the direct and residual effect of Phosphorus Solubilisisng Bacteria (PSB) in rice based cropping systems (rice-rice and rice–black gram). Phosphorus levels (0, 30 and 60 kg/ha) applied as inorganic fertilizers through Single super phosphate as main plot treatments and methods of Phosphorus Solubilising Bacteria (PSB) application (seed treatment, root dipping, field application and control – without PSB) as sub-plot treatments on grain yield in two crop rotations viz., rice (Oryza sativa. L) - rice and rice – blackgram (Vigna mungo) . The pooled analysis of the data indicated, P levels as well as method of PSB application significantly influenced the rice equivalent yields. Rice – rice system out yielded the rice –blackgram system and recorded 33 percent higher grain yield. Application of P @ 30 and 60 kg /ha increased REY to the tune of 36 and 59 percent over control (Without P). Further among the PSB treatments, all three methods of PSB application found promising and recorded significantly higher rice equivalent yields of (6.42-7.58) over without PSB application (5.33 t/ha) indicating the effectiveness of the PSB for enhancing the productivity in both the systems. Similar trend of the results was found in terms of gross returns and net returns (Rs/ha) in both the systems. Method of PSB application and P application@ 30 and 60 kg ha ^{1} significantly enhanced the B: C ratio in both the systems. Hence PSB treatment can be recommended for higher productivity and PUE in rice based cropping systems (rice-rice and rice – black gram systems)

Key words: Phosphorus levels , Phosphorus Solubilising Bacteria (PSB) Phosphorus use efficiency, rice based cropping systems

Phosphorus deficiency is wide spread nutritional problem greatly affecting crop production. Every year large amounts of P fetilisers , up to 35 million tons of P_2O_5 are applied to soils for crop production globally, and only 10-20 % of the applied P fertilizer can be absorbed by plants (Holford ,1997). The remaining is rapidly transformed in to unavailable P forms , which are not readily absorbed by plant roots. The observed plateauing /decline in total and partial factor productivity of rice in intensively cultivated areas even though attributable to several causes, soil degradation (nutrient imbalances and deteriorated soil structure) was found to be major factor involved. Soil fertility is the major determinant in deciding the need for external inputs. Majority of Indian soils analyse low for N (228 districts), low to medium for P(178 districts), medium to high for K (47 districts) (Chonkkar and Rattan 2000). Phosphorus is one of the key nutrients for production and productivity of rice and rice based cropping system in India. Phosphorus deficiency is a wide spread nutritional problem greatly affecting crop production. Plethora of rice based cropping systems have been practiced in high potential irrigated areas for high economic returns maintaining soil fertility and mitigating irrigation water shortage in rabi season. In rice –rice, the main cropping sytem in India , requires heavy amount of plant nutrients that results in decline in net returns per unit area (Anonymous, 2001). Appropriate crop rotation / opportunistic rice based cropping systems (RBCS) can be mandated with a view to improving soil nutrient availability and their efficiencies. Nutrient specific microbial treatments are known to enhance nutrient availability and its utilization efficiency by the crop. Many bacteria (Bacillus, Pseudomonas) and fungi (Asperigillus, Pencillium) actively take part in the process of solubilisation of soil "P"(Gaur,1985) The introduction of 'P' solubilizer species Bacillus megatherium biovar phosphaticum, in the rhizosphere of crop helps in increasing the availability of P from insoluble sources of soil bound phosphates. Cropping sequences rather than component crops need to be considered for holistic view of balanced fertilization. There is a need for system based nutrient management especially using PSB application in enhancing production and productivity of rice and rice based cropping systems. Hence, the present study was carried out to evaluate the dose of P application along with different methods of P application to rice and its direct as well as residual effect on rice and blackgram .

Materials and methods

A field experiment was conducted to study the effect of Phosphorus levels (0, 30 and 60 kg/ha) applied as inorganic sources (Single super phosphate) as main plot treatments and methods of Phosphorus Solubilising Bacteria (PSB) application (Nursery seed treatment (NT), root dipping (RD), field application (FA) and control – without PSB) as sub-plot treatments on grain yield in two rotations (rice - rice and rice – blackgram) in clay soils (vertisols) at Directorate of Rice Research (DRR) farm during 2001-2002 to 2003-2004. The soil was having organic carbon content of 0.52 %, pH 8.0, Cation – exchange capacity (CEC) 48 meq/100 g soil and initial nutrient status of 62.5 kg N ha , 12.2 kg P/ha, 280 kg K/ha. The crops were fertilized with the recommended dose of nutrients applied through urea, single super phosphate and muriate of potash and grown with recommended package of practices. The wet season (*kharif*) rice received N and K @ 100 and 40 kg/ha while dry season (*rabi*) rice crop with 120 and 40 kg N and K, blackgram with 20 and 40 kg N and K/ha. The amount of P was applied as per the treatments as basal with different methods of PSB application only during wet season. The treatments were imposed in split–plot design and replicated thrice. Grain yield was recorded and converted to rice equivalent yields (REY) on the basis of prevailing market prices (rice - Rs 5.50/kg and Blackgram Rs. 25.00/kg) and gross returns and B:C ratio's were computed for analysis. Phosphorus use efficiency is computed based on the yields obtained in P applied plots and amount of P applied in comparison to control.

Results and Discussion

PSB treatment and level of P application significantly enhanced rice yield in all three seasons (*kharif 2001 to 2003)* over untreated control in rice - blackgram as well as rice system (Table 1). The grain yield of rice at P_{30} and P_{60} was significantly higher in both the systems. The grain yield of rice due to P application ranged from 3.19 to 5.09 t ha^{-1} in rice – BG and 3.17 to 5.23 t/ha in rice-rice systems against 2.26 to 3.18 t/ha and 2.36 to 3.68 t/ha respectively in treatments without P. The rice equivalent yields of *rabi* season clearly indicated the superiority of P_{60} in rice –

Table 1. Grain yield of rice (t/ha) as influenced by P levels and method of PSB application during *kharif* season

Rice–Black gram system

Level of P	NT				RD				FA				Control			
	2001	**2002**	**2003**	**Mean**	**2001**	**2002**	**2003**	**Mean**	**2001**	**2002**	**2003**	**Mean**	**2001**	**2002**	**2003**	**Mean**
P0	4.09	3.41	2.05	3.18	2.04	3.16	1.9	2.37	2.56	2.58	1.81	2.32	2.88	2.41	1.5	2.26
P30	5.17	5.09	3.07	4.44	4.13	4.51	2.57	3.74	3.88	4.22	2.23	3.44	3.53	4.17	1.87	3.19
P60	6.11	5.15	4.02	5.09	5.46	4.91	3.2	4.52	5.17	5.07	2.88	4.37	3.67	4.49	2.15	3.44
Mean	5.12	4.55	3.05	4.24	3.88	4.19	2.56	3.54	3.87	3.96	2.31	3.38	3.36	3.69	1.84	2.96
CD (0.05%)		2001				2002				2003						
Year	P levels (M)	0.43	PSB treat(S)	0.32	P levels (M)	0.25	PSB treat(S)	0.51	P levels	0.22 (M)	PSB	0.49 treat(S)				
	MXS	0.63	SXM	0.63	MXS	NS	SXM	NS	MXS	NS	SXM	NS				

Rice–Rice system

Level of P	NT				RD				FA				Control			
	2001	**2002**	**2003**	**Mean**	**2001**	**2002**	**2003**	**Mean**	**2001**	**2002**	**2003**	**Mean**	**2001**	**2002**	**2003**	**Mean**
P0	4.73	3.7	2.6	3.68	4.08	3.51	2.44	3.34	3.15	2.42	1.95	2.51	3.41	2.11	1.57	2.36
P30	5.69	5	4.99	5.23	4.55	4.6	3.66	4.27	4.71	3.59	3.71	4.00	4.21	3.25	2.05	3.17
P60	6.11	5.19	4.39	5.23	5.47	5.11	3.94	4.84	5.64	4.97	3.93	4.85	4.94	3.7	2.87	3.84
Mean	5.51	4.63	3.99	4.71	4.70	4.41	3.35	4.15	4.50	3.66	3.20	3.79	4.19	3.02	2.16	3.12
CD (0.05%)		2001				2002				2003						
Year	P levels (M)	0.43	PSB treat(S)	0.32	P levels (M)	0.25	PSB treat(S)	0.51	P levels (M)	0.36	PSB treat(S)	0.59				
	MXS	0.63	SXM	0.63	MXS	NS	SXM	NS	MXS	0.73	SXM	0.78				

BG (2.18 to 3.37 t/ha) while P_{30} and P_{60} treatment found promising in rice-rice system (3.25-4.18 t/ha) as compared to without P application.

All the methods of PSB treatments significantly enhanced the rice yields in *kharif* and rice equivalent yields in *rabi* in both rice-rice and rice – B G cropping systems. The grain yield of rice in *kharif* was significantly higher in NT method (4.24 t/ha) followed by RD and FA (3.38 t/ha) over control – without PSB (2.96 t/ha). The trend of the results are similar in rice-rice system. During *rabi* season, REY of blackgram was higher in FA (2.38 t/ha), NT (2.21 t/ha) and R.D (1.93 t/ha) over control (1.58 t/ha). While in case of rice –rice system, the grain yield of N.T (3.98 t/ha) followed by RD (3.84 t/ha) and FA (3.30 t/ha) were higher as compared to without PSB application (2.91 t/ha). The response of inoculation of phosphobacteria at P_0 indicates that native phosphorus in the soil is well mobilized by the Phophobactria inoculation (Antony raj *et al.*, 1994). In addition, better root development, uptake of nutrients and higher yield attributes might have contributed for higher yields as there is increasing evidences that PSB are able to produce plant growth promoting substances like auxins, gibberilins (Gyaneshwar *et al.*, 2002)

The pooled analysis of the data indicated that in both the systems , P levels as well as method of PSB application significantly influenced the total rice equivalent yields of the cropping system. Rice – rice system out yielded the rice – blackgram system and recorded 33 percent higher grain yield. The total REY were higher with P-60 and followed by P-30 (5.62 -8.43 t/ha) as compared to P-0 (3.87 and 6.05 t/ha). Application of P @ 30 and 60 kg/ha increased REY to the tune of 36 and 59 percent over control (Without P). Further among the PSB treatments, all three methods of PSB application found promising and recorded significantly higher rice equivalent yields of (3.66-8.47 t/ha in Rice – BG and 5.33-9.37 t/ha in rice-rice) over without PSB application (3.44–5.62 and 4.81–7.11 t/ha respectively) indicating the effectiveness of the PSB for enhancing the productivity in both the systems .

Phosphorus Use Efficiency (PUE) kg grain /kg P applied

Phosphorus use efficiency will indicate the efficient utilization of the native Phosphorus as well as applied P. Mean over the cropping systems , method of P application significantly influenced the PUE (kg grain /kg P applied) in both the systems (60.42 to 70.90 kg grain/kg P) at P_{30}; 48.63 to 56.91 kg grain/kg P applied at P_{60}) over control- without PSB application (45.77 and 37.22 kg grain/kg P applied respectively). Similar results were also reported with different sources of P application in rice-black gram system (Mahender Kumar *et al.*, 2002) The increased PUE through inoculation may be due to mobilization of native as well as fixed forms of P from applied SSP. PUE was superior under lower doses of P as compared to higher dose of phosphorus with inoculation, indicating that there is decrease in PUE in higher P application (Fig.1). This can be explained by the fact that the crop exhibits greater capacity for nutrient absorption at lower dose of Phosphorus (Dubey, 2000).

P U E (kg grain per kg P applied) was significantly higher with all three methods of PSB application. The better response of applied ‘P’ in both the system with PSB application was due to rapid root development, deeper root system

Table 2. Rice Equivalent Yields (t/ha) as influenced by P levels and method of PSB application during *rabi* season

Rice–Black gram system

Level of P	NT				RD				FA				Control			
	2001	**2002**	**2003**	**Mean**	**2001**	**2002**	**2003**	**Mean**	**2001**	**2002**	**2003**	**Mean**	**2001**	**2002**	**2003**	**Mean**
P0	2.185	1.28	0.73	1.40	2.18	1.02	0.67	1.29	2.47	1.08	0.915	1.49	2.42	0.71	0.41	1.18
P30	2.89	1.35	1.375	1.87	3.06	1.185	1.655	1.97	2.89	1.255	3.165	2.44	2.71	0.675	0.785	1.39
P60	3.1	3.29	3.73	3.37	3.525	2.355	3.47	3.12	3.145	3.145	3.31	3.20	2.97	1.11	2.465	2.18
Mean	2.73	1.97	1.95	2.21	2.92	1.52	1.93	2.12	2.84	1.83	2.46	2.38	2.70	0.83	1.22	1.58
CD (0.05%)		2001				2002				2003						
Year	P levels (M)	0.43	PSB treat(S)	0.32	P levels (M)	0.25	PSB treat(S)	0.51	P levels (M)	0.37	PSB treat(S)	0.22				
	MXS	0.63	SXM	0.63	MXS	NS	SXM	NS	MXS	0.45	SXM	0.49				

Rice –Black gram system

Level of P	NT				RD				FA				Control			
	2001	**2002**	**2003**	**Mean**	**2001**	**2002**	**2003**	**Mean**	**2001**	**2002**	**2003**	**Mean**	**2001**	**2002**	**2003**	**Mean**
P0	3.066	3.54	4.61	3.74	2.553	2.87	4.49	3.30	3.15	2.51	3.83	3.16	1.973	2.36	3.02	2.45
P30	3.752	4.19	4.3	4.08	3.453	4.4	4.68	4.18	2.126	3.5	4.01	3.21	3.101	3.08	3.57	3.25
P60	4.246	4.37	3.79	4.14	3.84	4.51	3.73	4.03	2.996	3.41	3.34	3.25	3.253	3.29	3.29	3.28
Mean	3.69	4.03	4.23	3.98	3.28	3.93	4.30	3.84	3.04	3.14	3.73	3.30	2.78	2.91	3.29	2.99
CD (0.05%)		2001				2002				2003						
Year	P levels (M)	0.43	PSB treat(S)	0.32	P levels (M)	0.25	PSB treat(S)	0.51	P levels (M)	0.46	PSB treat(S)	0.82				
	MXS	0.63	SXM	0.63	MXS	NS	SXM	NS	MXS	0.92	SXM	1.04				

Table 3. Rice Equivalent Yields (t/ha), Benefit cost ratio and PUE (kg grain /kg P applied) as influenced by P levels and method of PSB application during 2002 to 2004

		REY (t/ha)			Gross returns (Rs/ha)			Net returns (Rs/ha)			B:C Ratio			PUE (kg grain /kg P)		
		R -BG	**R-R**	**Mean**	**R -BG**	**R-R**	**Mean**	**R -BG**	**R-R**	**Mean**	**R -BG**	**R-R**	**Mean**	**R -BG**	**R-R**	**Mean**
P-0	NT	4.58	7.42	6.00	25205	40777	32991	10205	22777	16491	0.68	1.27	0.97			
	RD	3.66	6.65	5.16	20112	36566	28339	4562	18016	11289	0.29	0.97	0.63			
	FA	3.81	5.33	4.57	20933	29305	25119	4933	10304	7619	0.31	0.54	0.43			
	Control	3.44	4.81	4.13	18931	26472	22702	3931	8472	6202	0.26	0.47	0.37			
	Mean	3.87	6.05	4.96	21295	33280	27288	5908	14892	10400	0.39	0.81	0.60			
P-30	NT	6.32	9.31	7.82	34725	51194	42960	19125	32594	25860	1.23	1.75	1.49	57.70	63.13	60.42
	RD	5.71	8.45	7.08	31369	46462	38916	15319	27412	21366	0.95	1.44	1.20	68.22	59.98	64.10
	FA	5.88	7.51	6.70	32346	41287	36817	17346	23287	20317	1.16	1.29	1.23	69.17	72.62	70.90
	Control	4.58	6.42	5.50	25196	35308	30252	9645	16758	13202	0.62	0.90	0.76	37.97	53.56	45.77
	Mean	5.62	7.92	6.77	30909	43563	37236	15359	25013	20186	0.99	1.35	1.17	58.27	62.32	60.29
P-60	NT	8.47	9.37	8.92	46572	51502	49037	30572	32502	31537	1.91	1.71	1.81	64.75	32.5	48.63
	RD	7.64	8.87	8.26	42013	48765	45389	27113	30865	28989	1.82	1.72	1.77	66.37	36.97	51.67
	FA	7.58	8.39	7.99	41659	46136	43898	25209	27686	26448	1.53	1.50	1.52	62.80	51.01	56.91
	Control	5.62	7.11	6.37	30894	39136	35015	13994	20236	17115	0.83	1.07	0.95	36.25	38.38	37.32
	Mean	7.33	8.44	7.88	40285	46385	43335	24222	27822	26022	1.52	1.50	1.51	57.54	39.72	48.63
Means of PSB applications	NT	6.46	8.70	7.58	35501	47824	41663	19967	29291	24629	1.27	1.58	1.42	61.23	47.82	54.52
	RD	5.67	7.99	6.83	31165	43931	37548	15665	25431	20548	1.02	1.38	1.20	67.30	48.48	57.89
	FA	5.76	7.08	6.42	31646	38909	35278	15829	20426	18128	1.00	1.11	1.06	65.99	61.82	63.90
	Control	4.55	6.11	5.33	25007	33639	29323	9190	15155	12173	0.57	0.81	0.69	37.11	45.97	41.54
	Mean	5.61	7.47	6.54	30830	41076	35953	15163	22576	18869	0.97	1.22	1.09	57.90	51.02	54.46
Mean (Overall)		5.48	7.40	6.44	30166	40706	35436	15163	22576	18869	0.93	1.20	1.06	57.90	51.02	54.46
C.D (0.05%)	CS	NS			NS						NS			NS		
	P levels	0.57			3142						0.18			NS		
	PSB	0.32			1780						0.11			12.65		

CS=cropping system

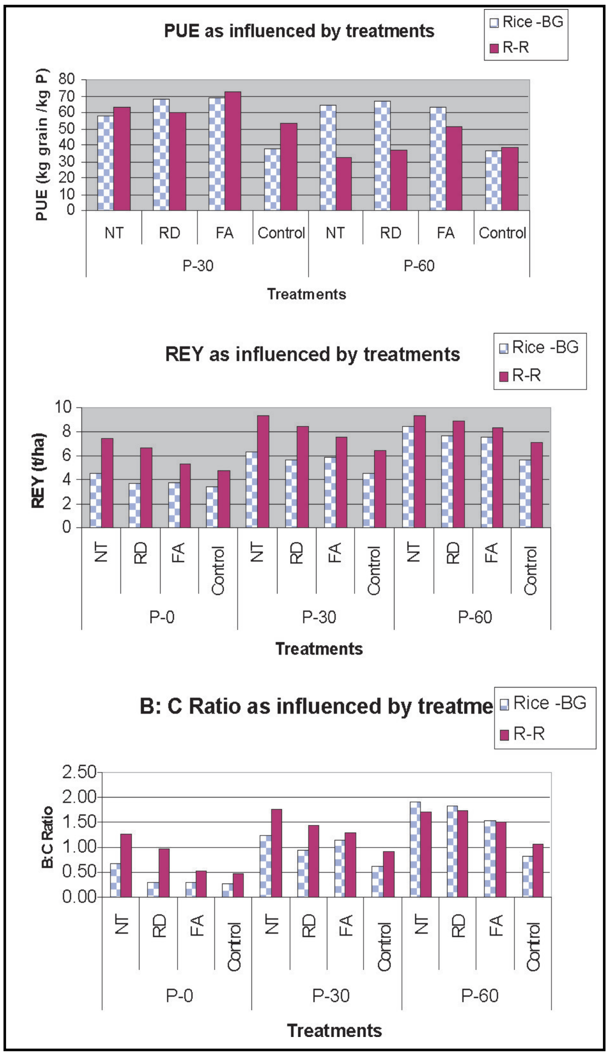

Fig. 1. PUE, REY and B:C ratio as influenced by cropping systems, P levels and method of PSB application

leading to higher uptake of nutrients. Hence PSB treatment can be recommended for higher productivity and PUE in rice based cropping systems. Such increases in PUE due to PSB application had also been reported by Pal (2000). Use of better source of P, application of PSB for enhancing phosphorus use efficiency (PUE) with adopting suitable highly efficient rice based cropping systems are few viable technologies for sustaining and enhncing production productivity of the various rice based cropping systems.

Economic analysis

On the basis of the pooled data of 2002-04 presented in table 3, clearly indicated that the highest gross returns of Rs. 40 706 ha^{-1} and net returns Rs. 22576 ha^{-1} were recorded in rice- rice system as compared to rice black gram system (Rs. 30166 and 15163 ha^{-1} respectively). Variations in grain yield of rice and blackgram crops due to treatment effects (Levels of P and method of PSB application) as well as differential cost of cultivation increased the gross and net returns from rice-rice system as compared to rice-blackgram system. Among the levels of P application, P_{60} recorded significantly highest gross and net returns in both cropping systems (Rs. 40285 and 24222 in rice blackgram; Rs. 46385 and 27822 ha^{-1} in rice–rice system) over P_{-30} and without P application. Similar trend of highest B:C ratio was obtained with P_{60} (1.52 in rice –black gram; 1.50 in rice–rice system). With regard to different methods of PSB application, all the methods (NT, RD and FA) recorded significantly higher gross returns, (Rs. 36817–42960 in P_{30}; Rs. 43898–49037 in P_{-60}), net returns (Rs. 20317–25860 in P_{-30}; Rs. 26448–31537 in P_{-60}) and B:C ratio (Rs. 1.23–1.49 in P_{30}; Rs. 1.52–1.81) at all levels of P application over P_0 in both the systems (Fig. 1).

It is concluded that PSB application enhanced the P-use efficiency in both the systems and found to be a viable and implementable technology to enhance production and productivity of rice and rice based cropping systems. Hence, PSB treatment is a cost effective implement able technology and can be recommended for higher productivity and enhancing PUE in rice based cropping systems.

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J. Farming Systems Research & Development **17** (1&2) : 153-157 (2011)

CROPPING SYSTEM DIVERSIFICATION, ITS PRODUCTION POTENTIAL AND ECONOMICS UNDER SAURASHTRA REGION OF GUJARAT

B.M. Dabhi, R.M. Solanki and B.K. Sagarka

Cropping System Research Centre, Department of Agronomy, Junagadh Agricultural University, Junagadh-362 001 (Gujarat)

Abstract

A field experiment with 10 crop sequences was conducted during 2001-2005 at Cropping System Research Centre, Junagadh Agricultural University, Junagadh (Gujarat). All these cropping sequences were evaluated for their production potential, calorific value, production efficiency, land use efficiency and economics. Groundnut pod equivalent yield (9993 kg/ha), calorific value (38483 K cal), gross (Rs. 173535/ha) and net realization (Rs. 66544/ha) were recorded maximum through groundnut-onion-green gram crop sequence, while highest groundnut haulm equivalent yield (10256 kg/ha) was produced under groundnut-pearlmillet-cowpea crop sequence. Higher production efficiency (269.8 Rs./ha/day) and B : C ratio (1.11) were observed under groundnut-wheat-fallow crop sequence. Numerically higher land use efficiency of 87.7% was measured in soybean-fenugreek-groundnut crop sequence.

Key words: Crop sequence, production potential, production efficiency

Intensive agriculture in the last few decades has needed to paid depletion of natural resources especially, land, water and nutrients. On the other hand, for meeting the food requirements of ever increasing population, the available land has to be intensively cultivated for augmenting agricultural production. Diversification of cropping system is necessary to get higher yield and return, to maintain soil health, preserve environment and meet daily requirements of human and animals. Thus not only the number of crops but the types of crops included in the cropping sequence are also important. For this, exhaustive cereals crops need to shifted to other crops like oilseeds, pulses, vegetable and fodder crops. A study was therefore conducted to assess the possibility of increasing the cropping intensity by introducing short duration pulses, vegetables and oilseeds in the cropping systems and to increase the productivity and income of the farmers of the Saurashtra region through suitable cropping systems.

Materials and Methods

An experiment with 10 different crop sequences was initiated during 2001 in randomized block design with three replications. The experiment was conducted for 5 consecutive years at the Cropping System Research Centre, Junagadh Agricultural University, Junagadh (Gujarat). Initially soil had organic carbon 0.28%, pH 7.8, EC 0.31 dS/m, available nitrogen 191.0 kg/ha, available P_2O_5 33.0 kg/ha and available K_2O 173.0 kg/ha. Crops were raised with recommended package of practices. Pre sowing irrigation was applied to ensure good germination of *rabi* and summer crops. The total rainfall received during the years 2001, 2002, 2003, 2004 and 2005 was 853, 537, 1275,971 and 1197 mm with 51, 22, 42, 43 and 41 rainy days, respectively. To compare crop sequences, the yield of all crops were converted into groundnut pod equivalent on price basis and data of different seasons and years were pooled and analyzed statistically. Land use efficiency was obtained by taking total duration of crop in individual crop rotation divided by 365 days. The production efficiency values in terms of Rs./ha/day were calculated by net returns of the rotation divided by total duration of the crop in that rotation (Tomar and Tiwari, 1990). The crop energy (K cal 100/g) was calculated as follows: Groundnut (567), pearlmillet (361), soybean (432), onion (50), wheat (346), garlic (145), fenugreek (333), coriander (288), green gram (334), black gram (347) and cowpea (323) based on data of (IASRI, New Delhi).

RESULTS AND DISCUSSIN

Effect on main product

Different crop sequences exerted their significant influence on groundnut pod equivalent yield during all the seasons and on pooled data basis except, during summer season (Table 1). During the kharif season groundnut-wheat-fallow crop sequence recorded significantly higher pod equivalent yield of 3592 kg/ha, followed by groundnut-onion-green gram crop sequence, groundnut-wheat-black gram, groundnut-garlic-fallow and groundnut-pearlmillet-cowpea crop sequence. The lowest groundnut pod equivalent of 448 kg/ha was realized in pearlmillet-wheat-fallow crop sequence.

Table 1. Influence of ropping sequences on main and by product of various crops (Mean of 5 years)

Treatment	Yield (kg/ha)							
	Groundnut Pod equivalent				Groundnut haulm equivalent			
	Main Product				By Product			
	Kharif	Rabi	Summer	Total	*Kharif*	*Rabi*	Summer	Total
G'nut - W- Fallow	3592	2478	0	6070	5039	2453	0	8392
PM - W- F	448	2446	0	2894	5075	2519	0	7714
G'nut -O- GG	3333	5120	1540	9993	4572	0	906	5478
S-O- G'nut	1431	5506	940	7877	1317	0	3233	4550
G'nut - W-BG	3282	2364	836	6481	4672	2338	743	7753
PM - Cor- G'nut	499	1880	998	3378	5441	1332	3412	10085
S-FG- G'nut	1287	621	734	2644	1285	1229	2445	4959
PM - G- F	492	2965	0	3457	5141	0	0	5141
G'nut - PM -C	3089	1404	1112	5605	4289	4705	1262	10256
G'nut - G-F	3144	2953	0	6097	4194	0	0	4194
C.D. (P=0.05)	929	1811	NS	1923	1749	1034	741	2080

Note: 1) G'nut- Groundnut, PM- Pearlmillet, GG- Green gram, BG-Back gram, C- Cowpea, Cor.- Coriander, FG- Fenugreek, Wheat, G- Garlic, O- Onion, S- Soybean, F-Fallow

Whereas in *rabi* season, soybean-onion-groundnut crop sequence registered significantly the highest groundnut pod equivalent yield of 5506 kg/ha which remained at par with groundnut-onion-green gram crop sequence. The groundnut pod equivalent yield of fenugreek when raised after soybean was the least (621 kg/ha). Narwal and Malik (1987) reported beneficial effects of legumes or green manuring on succeeding crop. Onion grown after soybean recorded higher groundnut pod equivalent yield as compared with that after groundnut. Jamwal (2000) reported that wheat crop give higher yield in green gram-wheat crop sequence than other crop sequences.

When data were pooled over years and seasons, the highest groundnut pod equivalent yield of 9993 kg/ha was recorded under groundnut-onion-green gram crop sequence, followed by soybean-onion-green gram crop sequence. The lowest groundnut pod equivalent was produced in soybean-fenugreek-groundnut crop sequence. The highest groundnut pod equivalent under groundnut-onion-green gram crop sequence might be due to higher yield of onion. Samui *etal.*, (2004) reported the highest rice equivalent yield under rice-potato-groundnut crop sequence .

Effect on by product

Groundnut-haulm equivalent yield was significantly influenced by different crop sequences during all the seasons and in pooled results (Table 3). During kharif season, groundnut-coriander-groundnut crop sequence recorded significantly higher groundnut haulm yield of 5441 kg/ha and found comparable with rest of the crop sequences except, soybean-onion-groundnut crop sequence, soybean-fenugreek-groundnut crop sequence. Whereas in *rabi* season, groundnut-pearlmillet-cowpea crop sequence registered significantly the highest groundnut haulm equivalent yield of 4705 kg/ha. During summer season, pearlmillet-coriander-groundnut sequence recorded significantly higher groundnut haulm equivalent yield of 3412 kg/ha, followed by soybean-onion-groundnut crop sequence.

In terms of total groundnut haulm equivalent yield over season, groundnut-pearlmillet-cowpea crop sequence obtained significantly maximum groundnut haulm equivalent yield of 10256 kg/ha which was comparable with pearlmillet-coriander-groundnut sequence and groundnut-wheat-fallow sequence.

Land use efficiency and production efficiency

Land use efficiency of all 10 sequences revealed that highest land utilization efficiency of 87.7 per cent was observed in soybean-fenugreek-groundnut crop sequence, followed by soybean-onion-groundnut crop sequence, because these sequences occupied the field for longer duration (320 days). It was least (52.1%) in pearlmillet-wheat-fallow sequence (190 days). Tomar and Tiwari (1990) and Jamwal (2000) also reported higher land use efficiency under pigeonpea-wheat and clusterbean crop sequences and groundnut-*toria*-wheat sequence, respectively which occupied the field for longer duration.

Highest production efficiency of 269.8 Rs./ha/day (Table 2) was obtained through groundnut-wheat-fallow sequence, followed by groundnut-onion-green gram sequence. The results confirms the findings of Yadav *etal.*, (2005) and they reported that rice-what crop sequence having highest production efficiency in terms of Rs./ha/day.

Table 2. Influence of different crop sequences on land use efficiency, production efficiency, total calories and economics (Five year mean)

Treatment	Duration days	Land use efficiency (%)	Production efficiency (Rs./ha/ day)	Economics (Rs./ha)			Total calories (K cal)	B:C ratio
				Gross return	Total cost	Net return		
G'nut - W- Fallow	215	58.9	269.8	110131	52129	58002	31226	1.11
PM - W- F	190	52.1	90.6	60445	43231	17214	22063	0.40
G'nut -O- GG	280	76.7	237.7	173535	106991	66544	38483	0.62
S-O- G'nut	310	84.9	121.8	146001	108234	37767	34644	0.35
G'nut - W-BG	300	82.2	130.6	116597	77406	39191	32038	0.51
PM - Cor- G'nut	285	78.1	-17.4	71105	76073	-4968	14820	-0.07
S-FG- G'nut	320	87.7	-94.6	50164	80433	-30269	13368	-0.38
PM - G- F	245	67.1	-48.6	57765	69464	-11899	12022	-0.17
G'nut - PM -C	300	82.2	95.2	109315	80746	28569	29599	0.35
G'nut - G-F	265	72.6	82.1	100790	79045	21745	18613	0.28
C.D. (P=0.05)							5681	

Energetic value

Significantly maximum calorific values of 38483 K cal (Table 2) was obtained in groundnut-onion-green gram crop sequence this indicates that groundnut-onion-green gram crop sequence have higher value, high quality produce with highest biological efficient crop sequence, followed by soybean-onion-groundnut sequence. Yadav *etal.*, (2005) also observed highest energetic values in maize-potato-sunflower crop sequence.

Economic analysis

Among all 10 crop sequences, the highest gross realization (Rs. 17535/ha) and net return (Rs. 66544/ha) were recorded with groundnut-onion-green gram crop sequence, It was owing to higher total sequence productivity among the rest of the crop sequences (Table 2), followed by soybean-onion-groundnut crop sequence and groundnut-wheat-black gram sequence. Whereas, groundnut-wheat-fallow crop sequence stand in second position with realizing net return of Rs. 58002/ha. The benefit cost ratio was more in groundnut-wheat-fallow sequence, followed by groundnut-onion-green gram. It showed that groundnut-onion-green gram or soybean-onion-groundnut rotation is input responsive crop rotations resulted with higher gross return/ha.

Thus groundnut-onion-green gram or soybean-onion-groundnut sequence is more biologically efficient crop sequences having more calorific values and cash ensuing crops. However, the farmers still prefer groundnut-wheat or groundnut-wheat-black gram crop sequences because of better stability and assured government procurement policy with greater remunerative profit margins than groundnut-onion-green gram sequence which is most risky, price fluctuation is more and less assured crop sequences in Saurashtra region of Gujarat.

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J. Farming Systems Research & Development **17** (1&2) : 158-162 (2011)

EFFECT OF DIFFERENT ESTABLISHMENT TECHNIQUES ON SOIL FERTILITY AND RICE PRODUCTIVITY IN ALFISOLS OF BHADRA COMMAND AREA, KARNATAKA

A. Sathish, H. Chandrappa, A.Y. Hugar and Nagaraja Kusagur

Agricultural Research Station, Kathalagere, Davanagere District, University of Agricultural Sciences (Bengaluru), Karnataka

Abstract

A field experiment was conducted during summer season of 2007 and 2008 at Agricultural Research Station, Kathalagere under canal irrigation to study the effect of different establishment techniques like zero tillage, drum seeder, normal planting, transplanter, SRI method and aerobic rice cultivation on soil fertility and rice productivity. The soil fertility levels were significantly higher in SRI method (0.67 % organic carbon, 24.99 kg/ha available P and 199 kg/ha available K) as a result of better crop establishment and bio mass addition to the soil. The better soil fertility level yielded higher grain and straw yields in SRI method followed by aerobic method. Among all the establishment techniques, SRI method was found to be beneficial not only in terms of improving soil fertility levels but also showing higher yields which leads to higher economic returns.

Key words: Establishment techniques, SRI method, Aerobic method, soil fertility, productivity

Rice-rice cropping system is the predominant cropping system being adopted by the farmers in Bhadra command area, Karnataka. General practice of rice cultivation in these areas is under puddled condition. This method of transplanting rice under puddled condition is complicated and highly labour intensive. Timely availability of water and labour are essential for transplanting in time to get good yields. In addition to non availability of resources, submergence of land alters the physico chemical properties of soils. Puddling decreases the soil aggregates and pore size, creates hard pan in the sub surface thereby restricting germination and rooting of the succeeding crops (Giri *et al.*, 1993). The inorganic fertilizers which are applied to the soil under puddled condition are subjected to different losses. Mainly Nitrogen is lost through leaching, denitrification, volatilization and ammonia fixation. This system requires more inputs like water, fertilizers and seeds which add to the cost of cultivation for achieving higher productivity. In order to derive maximum benefit by using the available resources in a limited way by reducing the use of inputs and also maintaining the soil physico chemical characteristics, different establishment techniques like zero tillage, drum seeder, transplanter, SRI method and aerobic rice cultivation have been tried all over India.

The present study was undertaken at Agricultural Research Station, Kathalagere, Davanagere district, Karnataka to findout the effect of different establishment techniques on soil fertility and rice productivity in fine, mixed, Typic Haplustalfs of Bhadra command area, Karnataka.

Material and Methods

A field experiment was conducted during summer season of the years 2007 and 2008 at Agricultural Research Station, Kathalagere under canal irrigation from Bhadra right canal to study the effect of different establishment techniques on soil fertility and rice productivity in moderately shallow, dark reddish brown, sandy clay soils. The initial soil fertility levels were (pH - 5.27, EC - 0.09 dSm^{-1}, organic carbon - 0.60 % , available phosphorus - 22 kg/ha, available potash 197 - kg/ha) taken as reference. The experiment was laid out in a randomized block design with six treatments namely zero tillage, drum seeder, normal transplanting, transplanter, SRI method and aerobic rice cultivation and replicated four times.

Direct dry seeding was done by zero till drill in zero tillage method (25 cm X 25 cm spacing), sprouted seeds in puddled soil in drum seeder method and seeds were sown directly in unpuddled condition under aerobic method (25 x 25 cm^2). In case of SRI method (25 x 25 cm^2), normal method and transplanter method (20 X 10 cm^2) seedlings raised in nursery were used for transplanting. Gross plot size was 8 x 6 m^2. After the harvest of the crop, observations were taken for quantifying yield levels. Soil samples were collected after the harvest of crop and analyzed for different parameters like pH, electrical conductivity, organic carbon, available phosphorus and available potash content by following the standard methods to study the changes in the soil fertility levels. All the data on soil properties (both individual years as well as pooled data) were statistically analyzed.

RESULTS AND DISCUSSION

Soil reaction and electrical conductivity

Soil pH and EC values during the year 2007 did not bring any significant variation between the treatments compared. However, during the year 2008 and in the pooled data there was slight significant variation in terms of increase in the pH and EC values due to the effect of treatments (Table 1). The improvement was more pronounced in SRI method of rice cultivation. The EC values are well below the normal rice soils and these values are fluctuating due to the dissolved salts contributing from soil, water and release of ionic species due to reduction process (Nambiar, 1985).

Organic carbon

Organic carbon content has significantly increased (0.60 % to 0.67 %) in all the treatments when compared to initial level and not much difference was noticed within the treatments, this may be due to balanced application of fertilizers to all the treatments and continuous rice cropping over the years. Highest organic carbon content in case of SRI method (0.67 %) was observed which may be attributed to better crop growth and in turn more biomass addition to soil (Sharma and Sharma, 2002).

Available phosphorus

The available phosphorus content varied significantly among treatments. There was build up of available phosphorus in soil over the years which may be due to the influence of organic matter in increasing the labile P in soil through complexing of cations like Ca^{2+} and Mg^{2+} which are mainly responsible for fixation of P, similar to the studies of Bajpai *et al.*, (2006). There was slight increase in available P content when compared to initial status (22 kg/ha.) in SRI method (24.99 kg/ha.), which is possibly due to the magnitude of yield triggered P uptake by rice (Table 1).

Table 1. Effect of different establishment techniques on changes in soil properties (2007-2008 & Pooled data)

Sl.	Treatments	pH			EC (dSm^{-1})			OC(%)			Available Phosphorus (Kg/ha)			Available Potassium(Kg/ha)		
No.		2007	2008	Pooled data	2007	2008	Pooled data	2007	2008	Pooled data	2007	2008	Pooled data	2007	2008	Pooled data
T_1	Zero tillage	5.76	5.73	5.75	0.17	0.17	0.17	0.64	0.65	0.64	21.67	21.86	21.76	192.41	193.38	192.90
T_2	Drum seeder	5.74	5.74	5.74	0.18	0.17	0.18	0.62	0.65	0.63	22.49	21.82	22.14	195.49	198.08	196.78
T_3	Normal planting	5.77	5.89	5.82	0.19	0.19	0.19	0.64	0.65	0.64	21.19	22.30	21.75	195.08	194.61	196.09
T_4	Transplanter	5.67	5.64	5.65	0.19	0.23	0.21	0.63	0.62	0.63	22.43	23.26	22.85	187.83	187.22	186.27
T_5	SRI method	5.87	5.87	5.87	0.21	0.24	0.22	0.65	0.68	0.67	25.99	23.99	24.99	198.33	199.70	199.01
T_6	Aerobic	5.73	5.77	5.75	0.19	0.21	0.20	0.58	0.60	0.59	20.04	21.06	20.55	183.81	187.80	186.18
	Initial status		**5.20**			**0.09**			**0.60**			**22.0**			**197.0**	
	SEm±	0.055	0.041	0.0346	0.0092	0.013	0.081	0.0098	0.012	0.0078	0.135	0.54	0.321	1.574	1.12	0.5654
	CD @ 5%	NS	0.09	0.0346	NS	0.04	6.089	0.029	0.04	10.06	0.408	1.64	21.78	4.743	3.39	94.62

Similar observations were also made by (Stalin *et al.*, 2006).

Available potassium

There was significant variation among treatments with respect to available K status(Table 1). In general there was an improvement in available K content during 2008 when compared to 2007, though decline in K status among all other treatments was noticed when compared to initial level (197 kg/ha.) which may be due to higher removal by crop and inadequate substitution through fertilizers and mineralization (Mishra and Sharma, 1997) indicating the significance replacement of these nutrients in adequate quantity for achieving higher yields (Sharma *et al.*,2006). But in case of SRI method there was slight increase in available K content (199.01 kg/ha) when compared to the initial level of 197 kg/ha and in all other treatments over the years, which may be attributed to application of FYM and inorganic fertilizers together confirming the results of Bhardwaj and Omanwar (1994).

Grain and Straw yields

The grain and straw yields were shown in Table 2. The mean grain and straw yields were highest in SRI method (6139 and 9286 kg/ha respectively) when compared to all other methods of rice cultivation. Rice grain yields were significantly different during both the year 2007 and 2008, where as straw yields were non significant during 2007 and significant during 2008. The higher yields in SRI method was attributed to higher availability of nutrients under this system which has contributed more number of effective tillers and more number of seeds per panicle. Lowest mean grain and straw yields were observed in Zero tillage method (4107 and 7568 kg/ha respectively)which may be due to lower germination, poor crop establishment and competition from weeds. Aerobic method also showed improvement in yield levels (5368 and 8772 kg/ha grain and straw respectively) when compared to normal planting.

In conclusion, there was build up of organic carbon, available phosphorus

Table 2. Grain and straw yield of rice (kg/ha) as influenced by different establishment techniques (2007-2008)

Treatments	Grain			Straw		
	2007	2008	Mean	2007	2008	Mean
T_1	4000	4214	4107	6129	9007	7568
T_2	5071	4414	4743	6593	9743	8168
T_3	6207	4450	5329	6893	9600	8247
T_4	5579	4114	4847	6600	8943	7772
T_5	6300	5979	6139	6843	11729	9286
T_6	4943	5793	5368	5879	11664	8772
SEm±	279.26	256.97		326.44	639.6	
CD @ 5%	804.10	774.4		NS	1927.4	

and steady increase in available potassium status in these soils. The pooled data of all these three parameters varied significantly over different establishment methods. Among all the establishment techniques, higher soil fertility levels (0.67 % organic carbon, 24.99 kg/ha. available P and 199 kg/ha. available K) were observed in SRI method of rice cultivation may be due to proper crop establishment and biomass addition to the soil. Higher grain and straw yields were obtained in SRI method followed by Aerobic method of rice cultivation, which consumes fewer inputs like seeds and water. These methods in addition to reducing the cost of cultivation, it also builds up soil fertility levels and improves the soil physico-chemical properties and economic condition of the farmers.

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J. Farming Systems Research & Development **17** (1&2) : 163-169 (2011)

EFFECT OF TILLAGE PRACTICES, TIME OF FIRST IRRIGATION AND NITROGEN DOSES ON WHEAT CROP (*TRITICUM AESTIVUM*) UNDER RICE (*ORYZA SATIVA*) - WHEAT CROPPING SYSTEM

RAJEEW KUMAR[1] , R.D. MISRA[2], D.S. PANDEY[3], S.B. BHARDWAJ[4]

G.B. Pant University of Agriculture & Technology, Pantnagar-263145

ABSTRACT

Numerous researches have been undertaken on studying suitable tillage practices keeping in view various levels of irrigation and fertilizer doses in different seasons. In this attempt, an endeavor to explore suitable tillage practices, time of first irrigation and nitrogen doses for wheat (*Triticum aestivum*) crop grown under rice-wheat cropping system has been made. This field experiment was conducted at Crop Research Centre of G.B. Pant University of Agriculture & Technology, Pantnagar during the *rabi* seasons of 2000-01, 2001-02 and 2002-03. The experiment was conducted in split-split plot design, where three tillage practices viz. conventional tillage, zero tillage with rice residue retention and zero tillage with rice residue burning were kept in main plot. Sub plot contained time of first irrigation given at 10, 20 and 30 days after sowing. Sub-sub plot contained three doses of nitrogen i.e. 120, 150 and 180 kg/ha. Results revealed that maximum wheat yield (4.42 and 4.32 Mg/ha during 2001-02 and 2002-03 respectively) was obtained with rice residue retention under zero tillage , which was at par with conventional tillage and significantly higher than rice residue burning under zero tillage. First irrigation at 20 days after sowing resulted in significantly higher grain yield (4.15 and 4.38 Mg/ha during 2001-02 and 2002-03 respectively) than first irrigation at 30 days after sowing and at par with first irrigation at 10 days after sowing. Application of 180 kg N/ha had maximum grain yield (4.14 and 4.20 Mg/ha during 2001-02 and 2002-03 respectively), which was at par with nitrogen dose of 150 kg /ha but significantly higher than 120 kg N/ha. Nitrogen uptake by was highest with residue burning in zero tillage , first irrigation at 30 days after sowing and 180 kg/ha of nitrogen application, which was significantly higher than nitrogen uptake in conventional tillage, first irrigation at 10 DAS and nitrogen doses of 120 kg/ha respectively. Yield contributing characters viz. effective tillers/m2, fertile spikelets/spike, sterile spikelets/spike, grains/spike, grain weight/spike and 1000 grain weight followed the similar trend as recorded in case of grain yield.

Key words: Tillage practices, Irrigation, Fertilizer, Split Plot Design, Green Manure

Wheat (*Triticum aestivum*) is a major contributor in food security system of the country, occupying nearly 27.7 million hectare and producing 74.9 million tones yield (Anonymous, 2007). Based on the present population growth rate (i.e 1.5% per annum) and per capita consumption of 180 g of wheat per day in the country, the demand for wheat is expected to be around 109 MT by 2020 (Nagarajan 2005). Wheat grown in rotation with rice is the major crop sequence for the Indo-Gangetic plains and this system has been proved a boon for national food security, but badly taxing the two most important natural resources *ie.* soil and water (Prasad and Nagarajan, 2004), which resulted to stagnate wheat yield of the system. Farmers started zero tillage wheat sowing after combine harvesting of rice for time saving for field preparation and cost saving of wheat

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[1] JRO Agronomy, [2] Emeritus Scientist, Agronomy, [3] Professor, Agronomy and [4] JRO Statistics

[1] Corresponding author: Email: shuklarajeew@rediffmail.com

production. Earlier they practiced zero tillage after partial or complete burning of rice straw to facilitate seed-bed preparation and to avoid possible yield losses of wheat but the residue burning causes nutrient and resource loss and adversely affects soil properties, thus calling attention for proper residue management (Gupta et al.,2004). On the other hand saving in irrigation water in rice-wheat cropping system is challenging issue because of rapid depletion of ground water and constant recession in the water table. Zero tillage save water approximately 10 cm/ha, or 1 million l/ha and this savings are generally reported for the first irrigation (Hobbs *et al.,* 1997). Chemical fertilizer especially nitrogen is still the main components for meeting the increased crop nutrient needs of the country. Thus the changing scenario for wheat growing condition needs an understanding of the responses of wheat in respect to tillage practices, time of first irrigation and nitrogen doses. To find out the effect of these three components of wheat production, this investigation was undertaken at *tarai* region of Uttaranchal.

MATERIALS AND METHODS

A field experiment was conducted during the *rabi* seasons of 2000-2001, 2001-02 and 2002-2003 at Crop Research Center of G.B Pant University of Agriculture & Technology, Pantnagar on a silty clay loam soil (Typic Hapludolls), having organic carbon 1.21%, available N 224 kg/ha, Olsens P 29 kg/ha, and available K 240 kg/ha, bulk density 1.43 Mg/m^3 . Rice crop var. Pant Dhan - 4 was sown previous to wheat crop during all the years and recommended package and practices were followed in rice crop. Average yield of rice crop was 4.58 Mg/ha, 5.1 Mg/ha, 5.3 Mg/ha during 2000-01, 2001-02, 2002-03 respectively. In wheat, the experiment was conducted in split split plot design with four replications, where tillage practices *viz* conventional tillage, zero tillage (with rice residue retention) and zero tillage (with rice residue burning) were kept in main plot; three irrigation treatments *viz.* first irrigation at 10, 20 and 30 days after sowing were kept in sub-plots; and three nitrogen doses *i.e* 120, 150 and 180 kg/ha were kept in sub-sub-plot. Under zero tillage wheat sowing plots , rice crop was harvested by combine, however in case of conventional tillage plots hand harvesting of rice crop was done, burning of crop residue was done in desired plot. The seed of variety PBW-343 was sown @ 100 kg/ha in the first week of November during all the years. The sowing was done by the seed drill in conventional tillage plot and zero-till cum ferti-seed drill in zero tillage plots. The row to row spacing of 21 cm was maintained. Nitrogen (as per treatment), P_2O_5 (60 kg/ha) and K_2O (40 kg/ha) were applied. The sources of N, P and K were urea, diammonium phosphate and muriate of potash. Half dose of N was applied at the time of sowing and rest half dose of nitrogen was top dressed after first irrigation. Irrigation after first irrigation was given at 0.9 IW/CPE (Irrigation depth was 6 cm and CPE was recorded from meteorological observatory). Crop was harvested in first week of April during all the years. Grain yield and N uptake were recorded during all the three years but the yield contributes were recorded only during 2001-02 and 2002-03. The statistical analysis was done following the method given in Steel and Torrie (1984) for Split-split plot design.

RESULTS AND DISCUSSION

Effect of tillage practices

The entire yield contributing characters viz. effective tiller/m^2, fertile spikets/spike, sterile spike lets/spike, grains/spike, grain weight/spike and 1000 grain weight were significantly influenced by tillage practices during all the years except sterile spikelets/spike and 1000 grain weight during 2002-03 (Table 1). Residue retention in zero tillage had significantly more numbers of effective tillers/m^2 than residue burning in zero tillage and conventional tillage during 2001-02. However during 2002-03, conventional tillage produced maximum numbers of effective tillers/m^2, which were at par with residue retention under zero tillage and significantly higher than residue burning under zero tillage. Residue retention and residue burning under zero tillage had non significant differences on number of effective tillers during 2002-03. Fertile spikelets/spike under conventional tillage were at par with residue retention under zero tillage but significantly higher than residue burning under zero tillage. The maximum number of sterile spikelets/ spike was recorded at residue burning with zero tillage, which was significantly higher as compared to other tillage practices. Tillage practices had similar effect on number of grains per spike as recorded in case of effective tillers/m^2 and on grain weight/spike as in case of fertile spikelets/spike, on 1000 grain weight as in case of sterile spikelets/spike. Significant effect of tillage practices on grain yield and total nitrogen uptake was observed during 2001-02 and 2002-03. Tillage practices failed to give significant effect on grain yield, total nitrogen uptake during 2000-01 (Table 2). Maximum wheat yield was recorded at residue retention under zero tillage followed by conventional tillage during all the years, which was at par between them selves and significantly higher than residue burning under zero tillage. Residue burning and residue retention under zero tillage produced at par nitrogen uptake by wheat, which was significantly higher than conventional tillage. These findings of tillage practices could be due to the various favorable factors under zero tillage with residue retention. Zero tillage facilitate advancing the sowing dates, proper seed placement and availability of high moisture, which might have helped the crop for better yield contributing characters and yield. Residue retention may increase infiltration rate, soil organic matter which facilitate easy nutrient availability to the plants, resulted better plant growth and development and yield. These results confirmed by the findings of Kumar and Yadav (2005).

Time of first irrigation

Time of first irrigation had significant effect on effective tiller/m^2, grains/spike, grain weight/spike during 2001-02 and 2002-03, fertile spikelets/spike and sterile spikelets/spike only during 2002-03. Non significant differences in 1000 grain weight were recorded due to time of first irrigation during both the years (Table 1). Highest numbers of effective tillers/m^2 were observed when first irrigation was given at 20 days after sowing, which was significantly higher than the first irrigation at 10 days after sowing and 30 days after sowing during 2001-02 and 2002-03. The first irrigation at 10 days after sowing and 30 days after sowing was statistically at par for effective tillers/m^2. Fertile spikelets per spike was significantly higher under first irrigation at 20 days after sowing than 10 days after sowing and 30 days after

Table 1. Effect of tillage practices, time of first irrigation and nitrogen doses on yield contributing characters of wheat crop

Treatments	Effective tillers/m^2		Fertile Spikelets/ spike		Sterile Spikelets/ spike		Grains/ spike		Grain weight weight (g) / Spike		1000 grain weight (g)	
	2001-02	2002-03	2001-02	2002-03	2001-02	2002-03	2001-02	2002-03	2001-02	2002-03	2001-02	2002-03
Tillage Practices												
Conventional tillage	268	319	18.3	18.3	3.2	3.4	47.7	50.4	1.89	1.79	37.8	37.3
*ZT with residue retention	325	306	19.6	18.3	3.2	3.2	51.0	48.8	2.12	1.80	41.1	37.6
ZT with residue burning	255	298	17.6	16.0	3.8	3.2	46.9	43.7	1.69	1.76	37.2	37.4
C.D. (0.05)	28.9	18.2	0.77	1.6	0.17	NS	1.87	5.2	0.07	0.03	0.63	NS
Time of first Irrigation												
10 DAS	277	297	18.5	17.3	3.5	3.5	47.4	45.4	1.89	1.69	38.9	37.5
20 DAS	300	325	18.9	17.7	3.3	3.2	49.2	46.5	1.99	1.83	39.0	37.6
30 DAS	271	300	18.1	18.0	3.4	3.2	49.3	50.9	1.82	1.84	38.2	37.2
C.D. (0.05)	18.5	20.5	0.66	NS	0.17	NS	1.63	4.3	0.13	0.10	NS	NS
Nitrogen doses												
120 kg/ha	269	285	18.0	16.2	3.5	3.4	47.0	42.3	1.76	1.76	37.8	36.7
150 kg/ha	286	309	18.6	17.9	3.4	3.2	49.3	48.8	2.01	1.76	39.2	37.9
180 kg/ha	292	317	18.9	18.3	3.2	3.2	49.4	51.2	1.94	1.82	39.0	37.7
C.D (0.05)	15.6	22.2	0.53	1.5	0.15	NS	1.21	6.5	0.09	0.04	1.10	NS

*ZT- Zero tillage, DAS – Days after sowing

sowing during 2001-2002. First irrigation at 20 days after sowing produced statistically at par sterile spikelets/spike compared as first irrigation at 30 days after sowing but it was significantly lower than first irrigation 10 days after sowing during 2001-2002. First irrigation at 20 and 30 days after sowing had statistically at par grains per spike, which was significantly more over first irrigation at 10 days after sowing during both the years. First irrigation at 20 days after sowing registered significantly higher grain weight per spike over first irrigation at 10 and 30 days after sowing during 2001-02, however during 2002-03, non significant differences on grain weight per spike was observed between first irrigation at 20 and 30 days after sowing. Time of first irrigation significantly affected wheat yield and total nitrogen uptake during 2001-02 and 2002-03. However during 2000-01, the non significant effect on wheat yield and total nitrogen uptake was observed due to time of first irrigation (Table 2). Maximum wheat yield was observed when first irrigation was given at 20 days after sowing. This was significantly higher than first irrigation at 30 days after sowing during both the years and at par with first irrigation at 10 days

Table 2. Effect of tillage practices, time of first irrigation and nitrogen doses on grain yield and nitrogen uptake by wheat crop

Treatments	**Grain yield (Mg/ha)**			**Nitrogen uptake (Kg/ha)**		
	Wheat					
	2000-01	**2001-02**	**2002-03**	**2000-01**	**2001-02**	**2002-03**
Tillage Practices						
Conventional tillage	3.93	4.06	4.11	133.8	138.2	141.5
*ZT with residue retention	3.99	4.42	4.32	139.0	150.8	155.3
ZT with residue burning	4.12	3.72	3.94	138.3	155.9	158.3
C.D (P=0.05)	NS	0.19	0.13	NS	8.2	15.3
Time of First Irrigation						
10 DAS	3.97	4.09	4.03	136.8	136.5	141.9
20 DAS	4.05	4.15	4.38	139.4	156.2	157.3
30 DAS	3.99	3.94	3.97	136.2	159.5	158.3
C.D (P=0.05)	NS	0.13	0.11	NS	8.2	15.3
Nitrogen Doses (kg/ha)						
120	3.95	3.92	3.99	130.9	139.9	141.0
150	3.99	4.13	4.11	138.6	145.2	153.3
180	4.10	4.14	4.20	140.5	152.6	162.4
C.D (P=0.05)	NS	0.13	0.10	7.9	10.7	12.8

*ZT- Zero tillage, DAS – Days after sowing after sowing during 2001-02. First irrigation at 10 and 30 days after sowing gave significant differences in grain yield during 2001-02 and non significant difference during 2002-03. Total nitrogen uptake by wheat crop was highest on first irrigation at 30 days after sowing during all the years, which was at par with first irrigation at 20 days after sowing and significantly higher than first irrigation at 10 days after sowing during 2001-02 and 2002-03. Effect of first irrigation at 20 days after sowing on grain yield was might be due to maintenance of water during critical crop growth stages, which results maximum number of effective tillers, yield contributes and increased wheat yield. First irrigation at 20 days after sowing also allows the plant to increase its photosynthesis and gives extra time to the plant for carbohydrate translocation to the grain, therefore modification in first irrigation at 20 days after sowing resulted decrease in grain yield. Similar results were also be noticed by Hussain *et al* (2003).

Nitrogen Doses

Nitrogen doses had significant effect on effective tiller/m^2, fertile spikelets/spike grains/spike, grain weight/spike during 2001-02 and 2002-03. Sterile spikelets/spike and 1000 grain weight were significantly influenced by nitrogen doses only during 2002-03 (Table 1). Maximum numbers of effective tillers/m^2 were recorded at 180 kg N/ha which was significantly higher as compared to 120 kg N/ha and at par with 150kg N/ha. Effective tillers/m^2 obtained at 120 and 150 kg N/ha had non significant difference. All yield contributing characters viz. fertile spikelets/spike, grains/spike, grain weight/spike and 1000 grain weight was highest at 180 kg N/ha which was significantly higher than 120 kg N/ha. Yield contributing characters obtained at 150 kg/ha and 180 kg N/ha had non significant difference. In contrast to other yield contributing characters, sterile spikelets/spike was found maximum at 120 kg N/ha which was significantly higher than 180 kg N/ha and at par with 150 Kg N ha during 2001-02. Non significant effect of nitrogen doses on grain yield was observed during 2000-01, however during 2001-02 and 2002-03 nitrogen doses significantly influenced the grain yield (Table.2). Maximum wheat yield was recorded at 180 kg N/ha followed by 150 kg N/ha during all the years, which was at par between them selves and significantly higher than 120 kg N/ha. Significant effect of nitrogen doses on total nitrogen uptake was observed during all the years. Nitrogen uptake was highest at 180 kg N/ha at par with 150 kg N/ha and significantly more over 120 kg N/ha during all the years. These results might be due to the fact that crop responses to N fertilization which not only increases plant shoot and root growth but also increases yield contributing characters and finally yield and nutrient uptake. These results are in close agreement with findings of Ali *et al.* (2003) and Gupta *et al.* (2007).

It was concluded from the experiment that residue retention under zero tillage responded more as compared to conventional tillage and residue burning under zero tillage in respect to wheat yield and yield contributing characters. First irrigation at 20 days after sowing responded maximum as compared to 10 and 30 days after sowing. Wheat crop responded up to the application of nitrogen @ 180 kg /ha but the application of 150 kg N/ha gave statistically similar grain yield.

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J. Farming Systems Research & Development **17** (1&2) : 170-175 (2011)

EFFECT OF CROP DIVERSIFICATION AND INTENSIFICATION IN RICE-WHEAT CROPPING SYSTEM ON SYSTEM PRODUCTIVITY, PROFITABILITY AND ENERGY USE EFFICIENCY

RUBY SAHA, JAGDISH SINGH AND KALYAN SINGH

Institute of Agricultural sciences, B.H.U., Varanasi, U.P.

ABSTRACT

An experiment was conducted to study the effect of crop diversification and intensification in rice-wheat cropping system on production potential, profitability and energy use efficiency on sandy clay loam soil at Agricultural Research farm, B.H.U., Varanasi, U.P. The treatments comprising 14 crop sequences were arranged in a randomized block design under three replications. The overall productivity of the system in terms of RGEY was noticed significantly highest in rice-potato-black gram (312.73 q ha^{-1} yr^{-1}) over rest of the cropping sequence except rice-maize (cob) + veg. Pea (1:2) – green gram cropping sequence (301.91 q ha^{-1} yr^{-1}). The net energy return was maximum under rice-maize (cob) + veg. Pea (1:2) – green gram cropping sequence (163.78 '000 MJ ha^{-1} yr^{-1}) followed by rice-potato-black gram. Energy output: input ratio was also highest in rice-maize (cob) + veg. Pea (1:2) – green gram cropping sequence (4.01). Early pigeon pea – wheat-maize (fodder) cropping sequence registered maximum land utilization efficiency (97.81%) followed by rice-rapeseed-onion cropping sequence (90.68%) and the value was lowest in rice-wheat cropping sequence (68.49%).

Key words: crop diversification, system productivity, energy use efficiency.

Among different cropping sequences, rice-wheat is the most stable and dominant cropping sequence being practiced in Indo-Gangetic plains. Besides degrading the soil health and fertility this system needs high input resources for higher production, which leads to higher cost of cultivation.

As replacing rice completely by any other crop is practically as well as economically not feasible. So, diversification of rice-wheat system by oilseed, grain-legumes as well as some short duration vegetable crops can be done to get higher production along with variable produce without increasing the cost of cultivation. The system may also be diversified through crop intensification in order to increase the agricultural – production and to restore the soil health and fertility.

MATERIALS AND METHODS

A field experiment on diversification in rice-wheat system was conducted at the Agricultural Research Farm, Institute of Agricultural Sciences, BHU, Varanasi (UP) during 2006-07 in randomized block design, replicated thrice with 14 crop sequences as treatments viz; rice-wheat (T_1), rice (early) – pea (grain) – black gram (T_2), rice (early) – rapeseed – maize (cob) – sesbania (T_3), rice-wheat-green gram ($T\text{-}_4$), rice-mustard-black gram (T_5), maize (cob) – rapeseed-wheat (T_6), rice (basmati) – potato-black gram (T_7), rice-wheat + mustard (5:1) – black gram (T_8), early pigeon pea – wheat – maize (fodder) (T_9), rice-basmati- maize (cob) + veg. Pea (1:2) – green gram (T_{10}), rice (basmati) – rapeseed – onion (T_{11}), rice (basmati) - vegetable pea- sunflower (hybrid) (T_{12}),

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Mailing address: Ruby Saha, M2/9, Vinayak Appartment, GH-4, Vasundhara-9, Ghaziabad – 201012E- mail ID: ruby_58@rediffmail.com

rice (early) + black gram-wheat + mustard (5:1) – green gram (T_{13}), rice(early) + sesamum (1:1) – wheat + lentil (3:2) – black gram (T_{14}). The soil of experimental field was sandy clay loam having pH-7.39, organic C-0.49 %, available nitrogen (181.00 kg N ha^{-1}), available P (19.95 kg P ha^{-1}) and available potassium (221.02 kg K ha^{1}).

The crops were raised with recommended practices. No fertilizer was added to green manure crops. For comparison of different crop sequences, the yield data for different seasons were pooled and converted into rice grain equivalent yield (RGEY) on price basis (Verma and Mudgal, 1983). Land use efficiency was obtained by dividing total duration of crop in each crop rotation by 365 days. Production efficiency of the sequence was obtained as per the method given by Tomar and Tiwari (1990). Economics of the inputs and output was worked out to arrive at the net return and output:input ratio. The crop energy was calculated as per method described by Sriram *et al.* (1991).

RESULT AND DISCUSSION

System productivity

Rice grain equivalent yield was recorded maximum in rice-potato-black gram sequence which was closely followed by rice-maize (cob) – veg. Pea (1: 2) green gram. RGEY of these two crop sequences was significantly higher than rest of the crop sequences (Table-1). Saroch *et al.* (2005) also reported more productivity by replacing wheat in rice wheat cropping system with vegetables. Inclusion of pulses in crop sequence increased the grain yield of both the crop sequence. This can be attributed to the legume effect of black gram and green gram on succeeding rice crop (Yadav *et al*, 2005).

Economic analysis:

The maximum gross return was recorded in rice-potato-black gram cropping sequence (Table-2) which was significantly higher than other cropping sequence except rice-maize (cob) + vegetable pea (1 : 2) – green gram cropping sequence . The net return was highest in rice-maize (Cob) + vegetable pea (1:2) – green gram cropping sequence (Rs. 140846 ha^{1}) which was significantly superior to rest of the cropping sequences followed by rice-potato-black gram cropping sequence (Rs. 130864 ha^{1}). While, both the net return as well as gross return was recorded minimum in maize (cob) – rapeseed- wheat cropping sequence. Similarly, output: input ratio was also maximum in rice – maize (cob) + vegetable pea (1: 2) – green gram cropping sequence (2.88) followed by rice-potato-black gram (2.18) and the lowest value was in maize (cob) – rapeseed – wheat cropping sequence (0.53).

Energy efficiency

Amount of energy consumed and obtained on unit area basis had also been helpful in comparing the various crop sequences. Energy output was recorded maximum in rice-maize + vegetable pea – green gram sequence (218240 MJ/ha) and lowest in early pigeon pea – wheat – maize. The net energy return was maximum under rice-maize (cob) + vegetable pea (1:2) – green gram cropping sequence (163780 MJ/ha) followed by rice-potato- black gram. Energy output : input ratio was recorded maximum in rice-maize + vegetable pea (1:2) – green gram cropping sequence (4.01) (Table-3).

Thus, the study revealed that rice – maize (cob) + vegetable pea (1:2) – green gram and rice-potato-black gram are

Table 1. Effect of different cropping sequences on equivalent yield in different seasons and system productivity (RGEY)

	Treatment: Cropping Sequence			**Equivalent yield (q ha^{-1})**			**System productivity (RGEY) (q ha^{-1} year $^{-1}$)**
	Kharif	***Rabi***	**Summer**	***Kharif* RGEY**	***Rabi* WGEY**	**Summer GEY**	
T_1:	Rice (Swarna)	Wheat (HUW – 234)	-	50.56	39.50	-	116.39
T_2:	Rice (Early) (NDR – 97)	Pea (Grain) (MM-2)	Black gram (Azad urd-1)	31.72	28.88	9.72	138.17
T_3:	Rice (Early) (NDR – 97)	Rapeseed (PT-303)	Maize(X-3342)-*Sesbania*) (GM) (Local)	31.60	21.60	9.47	124.42
T_4:	Rice (Basmati) (HUBR 2-1)	Wheat (PBW-343)	Green gram (HUM-16)	62.00	38.20	12.10	198.27
T_5:	Rice (Basmati) (HUBR 2-1)	Mustard (Pro-4001)	Black gram (Azad urd-1)	59.33	37.00	9.53	178.18
T_6:	Maize (cob) (X-3342)	Rapeseed (PT-303)– Wheat (HUW – 234)	-	9.78	50.10	-	93.28
T_7:	Rice (Basmati) (HUBR 2-1)	Potato (K Badshah)	Black gram (Azad urd-1)	63.11	112.15	10.45	312.73
T_8:	Rice (Swarna)	Wheat (HD-2824) + Mustard (Sanjukta) (5:1)	Black gram (Azad urd-1)	50.83	44.90	9.63	183.44
T_9:	Early Pigeon pea (UPAS-120)	Wheat (PBW-343)	Maize (F) (Local)	19.93	34.30	4.38	121.38
T_{10}:	Rice (Basmati) (Pusa Basmati-1)	Maize (cob) (X-3342) + vegetable pea (E. apporva) (1:2)	Green gram (HUM-16)	62.88	98.78	12.40	301.91
T_{11}:	Rice (Basmati) (HUBR 2-1)	Rapeseed (PT-303) – Onion (Nasik red)	-	62.67	119.40	-	261.67
T_{12}:	Rice (Basmati) (HUBR 2-1)	Vegetable pea (Early apporva)	Sunflower (Adventa)	59.11	52.50	9.59	204.15
T_{13}:	Rice (NDR-97) + Black- gram (Azad urd-1) (1:1)	Wheat(HUW – 234) + Mustard (Sanjukta) (5:1)	Green gram (HUM-16)	43.09	47.00	11.90	192.82
T_{14}:	Rice(NDR –97) + Sesamum(T4)(1:1)	Wheat (HUW – 234) + Lentil (ML-1) (3:2)	Black gram (Azad urd-1)	47.27	34.94	9.44	162.14
S Em ±				1.90	2.09	-	8.36
CD (P = 0.05)				4.79	5.04	-	20.17

Table 2. Effect of different cropping sequences on economics of different rice based cropping sequences.

	Treatment: Cropping sequence			Total cost of cultivation (Rs ha^{-1})	Total Gross return (Rs ha^{-1})	Total net return (Rs ha^{-1})	Output: input ratio
	Kharif	***Rabi***	**Summer**				
T_1:	Rice (Swarna)	Wheat (HUW – 234)	-	36004.00	80314.80	44310.80	1.23
T_2:	Rice (Early) (NDR – 97)	Pea (Grain) (MM-2)	Black gram (Azad urd-1)	43782.00	86770.20	42988.20	0.98
T_3:	Rice (Early) (NDR – 97)	Rapeseed (PT-303)	Maize(X-3342)-*Sesbania*) (GM) (Local)	49536.00	80232.80	30696.80	0.62
T_4:	Rice (Basmati) (HUBR 2-1)	Wheat (PBW-343)	Green gram (HUM-16)	46937.00	128803.30	81866.30	1.74
T_5:	Rice (Basmati) (HUBR 2-1)	Mustard (Pro-4001)	Black gram (Azad urd-1)	45179.00	111675.40	66496.40	1.47
T_6:	Maize (cob) (X-3342)	Rapeseed (PT-303) – Wheat (HUW – 234)	-	41098.00	63551.80	22453.80	0.53
T_7:	Rice (Basmati) (HUBR 2-1)	Potato (K Badshah)	Black gram (Azad urd-1)	60139.00	191003.40	130864.40	2.18
T_8:	Rice (Swarna)	Wheat (HD-2824) + Mustard (Sanjukta) (5:1)	Black gram (Azad urd-1)	45574.00	120104.00	74530.00	1.64
T_9:	Early Pigeon pea (UPAS-120)	Wheat (PBW-343)	Maize (F) (Local)	36083.00	69788.80	33705.80	0.93
T_{10}:	Rice (Basmati) (Pusa Basmati-1)	Maize (cob) (X-3342)+ vegetable pea (E. apporva) (1:2)	Green gram (HUM-16)	48891.00	189737.00	140846.00	2.88
T_{11}:	Rice (Basmati) (HUBR 2-1)	Rapeseed (PT-303) – Onion (Nasik red)	-	54056.00	160228.40	106172.40	1.96
T_{12}:	Rice (Basmati) (HUBR 2-1)	Vegetable pea (Early apporva)	Sunflower (Adventa)	51994.00	130924.50	78930.50	1.52
T_{13}:	Rice (NDR-97) + Black- gram (Azad urd-1) (1:1)	Wheat(HUW – 234) + Mustard (Sanjukta) (5:1)	Green gram (HUM-16)	41726.00	124130.40	82404.40	1.97
T_{14}:	Rice(NDR –97) + Sesamum(T4)(1:1)	Wheat (HUW – 234) + Lentil (ML-1) (3:2)	Black gram (Azad urd-1)	41203.00	98433.85	57230.85	1.39
S Em ±				1970.62	5451.31	3180.98	0. 06
CD (P = 0.05)				4754.42	13152.09	7674.58	0. 15

Table 3. Effect of different cropping sequences on Energy efficiency, System production efficiency and Land utilization efficiency (2006-07).

Treatment:	Cropping sequence			Energy '000 MJ ha^{-1} of the system			Energy output: intput ratio	System production efficiency (kg $ha^{-1}day^{-1}$)	Land use efficiency (%)
	Kharif	*Rabi*	Summer	Input	Output	Net energy return			
T_1:	Rice (Swarna)	Wheat(HUW–234)	-	47.24	132.39	85.15	2.80	46.56	68.49
T_2:	Rice (Early) (NDR – 97)	Pea (Grain) (MM-2)	Black gram (Azad urd-1)	47.05	84.55	37.50	1.80	51.56	73.42
T_3:	Rice (Early) (NDR – 97)	Rapeseed (PT-303)	Maize(X-3342)- *Sesbania*) (GM) (Local)	67.81	116.07	48.26	1.71	46.25	73.70
T_4:	Rice (Basmati) (HUBR 2-1)	Wheat (PBW-343)	Green gram (HUM-16)	60.95	142.30	81.35	2.33	63.96	84.93
T_5:	Rice (Basmati) (HUBR 2-1)	Mustard (Pro-4001)	Black gram (Azad urd-1)	50.92	102.61	51.69	2.02	60.40	80.82
T_6:	Maize (cob) (X-3342)	Rapeseed (PT-303)– Wheat (HUW – 234)	-	54.51	74.88	20.37	1.37	35.07	72.88
T_7:	Rice (Basmati) (HUBR 2-1)	Potato (K Badshah)	Black gram (Azad urd-1)	65.71	177.41	111.70	2.70	107.84	79.45
T_8:	Rice (Swarna)	Wheat (HD-2824) + Mustard (Sanjukta) (5:1)	Black gram (Azad urd-1)	61.40	152.38	90.98	2.48	56.44	89.04
T_9:	Early Pigeon pea (UPAS-120)	Wheat (PBW-343)	Maize (F) (Local)	40.83	72.84	32.01	1.78	34.00	97.81
T_{10}:	Rice (Basmati) (Pusa Basmati-1)	Maize (cob) (X-3342) +vegetable pea (E. apporva) (1:2)	Green gram (HUM-16)	54.46	218.24	163.78	4.01	92.61	89.32
T_{11}:	Rice (Basmati) (HUBR 2-1)	Rapeseed (PT-303) – Onion (Nasik red)	-	60.82	133.44	72.62	2.19	79.05	90.68
T_{12}:	Rice (Basmati) (HUBR 2-1)	Vegetable pea (Early apporva)	Sunflower (Adventa)	54.28	147.66	93.38	2.72	70.40	79.45
T_{13}:	Rice (NDR-97)+ Black-gram (Azad urd-1) (1:1)	Wheat(HUW – 234) + Mustard (Sanjukta) (5:1)	Green gram (HUM-16)	53.78	117.24	63.46	2.18	63.64	83.01
T_{14}:	Rice(NDR –97) +Sesamum (T4) (1:1)	Wheat (HUW – 234) + Lentil (ML-1) (3:2)	Black gram (Azad urd-1)	50.65	98.28	47.63	1.94	53.16	83.56

remunerative and suitable cropping sequences for the area. If suitable and disease resistant genotypes of green gram and black gram is used on these sequence, it will be more preferred over the traditional rice-wheat sequence. So, diversification and intensification of rice – wheat system by including oilseed, pulses and other vegetable crop is beneficial than cereals after cereals. Similar results were also reported by (Kumpawat, 2001 and Raskar *et al.*, 2001).

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J. Farming Systems Research & Development **17** (1&2) : 176-181 (2011)

EFFECT OF HERBICIDES ON THE YIELD AND NUTRIENT UPTAKE PATTERN OF FRENCH BEAN (*PHASEOLUS VULGARIS* L.) IN WESTERN U.P

NARINDER PANOTRA[1], O.P. SINGH[2] AND ASHWANI KUMAR[3]

Department of Agronomy, Janta Vedic College, Baraut (Baghpat)-250611

ABSTRACT

Investigation was carried out to study the effect of various herbicides on weed population, weed dry weight, yield attributes and yield of French bean under irrigated conditions of western U.P during the *rabi 2003-04* and *2004-05*. Among the different weed control treatments applied, then the application of fluchloralin @ 1.0 kg *a.i*/ha and pendimethalin @ 1.0 kg *a.i*/ha reduced the population of *Anagallis arvensis*, *Melilotus alba* L., *Melilotus indica* L. and *Phalaris minor* significantly as weedy check and other herbicide treatments in comparison, there by resulting significant increase in weed control efficiency, growth and yield attributes *viz.* plant height, no. of branches/plant, dry matter accumulation, no. of pods/plant and seeds/pod, seed and straw yield of french bean. The N uptake by weeds was also significantly reduced, where as significant increase in N uptake was observed in French bean at various crop growth stages over weed check. Application of fluchloralin @ 1.0 kg *a.i*/ha or pendimethalin @ 1.0 kg *a.i*/ha used then increased the yield of French bean (1.03 to 1.04 t/ha) significantly over weedy check, besides realised at B: C. ratio of 2.10 to 2.15 during two cropping season.

Key word: Weeds management, French bean, Yield attributes Nutrient uptake and Ecomomics.

French bean *(Phaseolus vulgaris* L.*)* is one of the most important pulse crop cultivated in hilly tracts of Jammu and Kashmir, Himachal Pradesh, Uttar Pradesh and parts of Maharashtra as a *kharif* season crop due to its specific adaption to a cool and long growing season (Tripathi *et al.*, 1986). In north eastern plains of India, this has been introduced as non–traditional winter season crop. In spite of its popularity, its productivity in India is very low being only 300 kg/ha as compared to the world average of 520 kg/ha. (Ali and Kushwaha, 1987).

Among the agronomic practices, weed management practice is an important tool for realizing maximum yield potential. The losses in general, due to weed depend on composition of weed flora, extent of infestation and the crop canopy. Among several weed management options chemical weed control is considered as cheapest and easiest method to keep the weeds below threshold level and therefore, it becomes imperative to undertake the present investigation with the aim to find out the most effective means of weed control in French bean crop under subtropical agro-eco systems of western U.P.

MATERIALS AND METHODS

A field experiment was conducted at the research farm, Janta Vedic College. Baraut, Baghpat (U.P.) which is 20.6^{0}N and 77.15^{0}E longitude at an elevation of 236.6 m above the sea level. The region average annual rainfall was 651 mm extending over the period of mid July to October and few scattered showers during winter months from south-west monsoon. Whereas, the average minimum and maximum temperature

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[1]Ph.D. Scholar; [2]Reader; [3]M.Sc Dr. Narinderpanotra@gmail.com

vary from 5^{0}C to 45^{0}C. The soil of the experimental field was sandy loam in texture, slightly alkaline in reaction, low in organic carbon (0.35%) and available nitrogen (235 kg/ha) and was medium in available phosphorus (13.2 kg/ha) and potassium (260.2 kg/ha). French bean variety "PDR-14" was sown in rows 30 x 10cm apart on 25 October during both the years 2003-04 and 2004-05 using 120 kg seed/ha.. Recommended doses of 120 kg N, 60kg P_2O_5 and 50 kg K_20 were uniformly applied to all the treatments. Full dose of P and K and half dose of N were applied as basal at the time of sowing and rest half of the N total as per treatment was applied before second irrigation 47 DAS. The experiment of 12 treatments comprising of weedy check, hand weeding at 30 DAS, weed free, fluchloralin @ 0.75 kg *a.i.*/ha, fluchloralin @ 1.0 kg *a.i.*/ha, fluchloralin @ 0.75 kg *a.i.*/ha with hand weeding at 30 DAS, pendimethalin @ 0.75 kg *a.i.*/ha, pendimethalin @ 1.0 kg *a.i.*/ha, pendimethalin @ 0.75 kg *a.i.*/ha with hand weeding at 30 DAS, oxyfluorfen @ 0.15 kg *a.i.*/ha, oxyfluorfen @ 0.20 kg *a.i.*/ha, oxyfluorfen @ 0.15 kg *a.i.*/ha with hand weeding at 30 DAS was arranged in a randomized block design with three replications. Herbicide treatments were applied pre–planting and pre–emergence with the help of knapsack sprayer fitted with flat fan T-jet nozzle at a spray volume of 500 litres. In weed free plots, weeds were removed manually as and when required with the help of *khurpi.* Other standard agronomical package and practices were followed uniformly in both the years. Weed and crop dry matter (DM) productions were measured at mid season and final harvest at different yield and yield attributing panted measured at the time of harvest and adjusted to 14% moisture contents. For midseason sampling, weed and crop DM were measured from two using 0.25 m^2 quadrats/each plot. At 90 DAS leaf area was measured by taking 10 leaves randomly from each plot and measure leaf area index (LAI), the N uptake through weeds as well as French bean crop were measured by micro-kjeldan method (Jackon, 1973)

RESULTS AND DISCUSSION

Population of weeds and dry weight of weeds in French bean

The weed flora observed in the experimental field was *Anagallis arvensis*, *Melilotus alba* L., *Melilotus indica* L. and *Phalaris minor* (Table 1). Among the herbicides used, the application of fluchloralin @ 1.0 kg *a.i.*/ha applied pre-planting provided effective weed control and improved weed control efficiency, which was at par with pendimethalin @ 1.0 kg *a.i.*/ha applied pre-emergence as compared to weedy check treatment in French bean. The maximum reduction of weeds population was recorded in fluchloralin @ 1.0 kg *a.i.*/ha or pendimethalin @ 1.0 kg *a.i.*/ha treatment, which had 79.52% and 78.38% more used weed control efficiency over pendimethalin 0.75 kg/ha and 60.81% and 70.28% over 0.75 kg/ha with hand weeding at 30 days after sowing. Almost similar results were noticed for weed dry weight (g/m^2) in french bean crop. Among various different weed control treatments used, than the treatment of fluchloralin @ 1.00 kg *a.i.*/ha or pendimethalin @1.00 kg *a.i.*/ha caused 100 per cent reduction in weed dry weight and weed population at harvest. Similar findings were reported by Mishra *et. al.* (1999) and Prajapati *et. al.* (2003).

Table 1. Effect of various treatments on weed population dry weight of weeds and weed control efficiency in French bean at 60 DAS

Treatments	Weed Population (no./m²) in French bean	Dry weight of weeds (g/m²) in French bean	WCE (%)
Weedy Check	20.01(4.53)	17.53 (4.25)	
Hand weeding at 30 DAS	10.17(3.27)	13.22(3.70)	24.58
Weed free	0.00(0.71)	0.00(0.71)	100.00
Fluchloralin (0.75 kg *a.i.*/ha)	7.69(2.86)	6.45(2.64)	63.20
Fluchloralin (1.00 kg *a.i.*/ha)	4.04(2.13)	3.59(2.02)	79.52
Fluchloralin (0.75 kg *a.i.*/ha) + HW 30 DAS	5.85(2.52)	4.57(2.25)	73.93
Pendimethalin (0.75 kg *a.i.*/ha)	7.48(2.82)	6.87(2.71)	60.81
Pendimethalin (1.00 kg *a.i.*/ha)	4.26(2.18)	3.79(2.07)	78.38
Pendimethalin (0.75 kg *a.i.*/ha) + HW 30 DAS	5.91(2.53)	5.21(2.39)	70.28
Oxyfluorfen (0.15 kg *a.i.*/ha)	8.01(2.92)	7.96(2.91)	54.59
Oxyfluorfen (0.20 kg *a.i.*/ha)	6.67(2.68)	5.51(2.45)	68.57
Oxyfluorfen (0.15 kg *a.i.*/ha) + HW 30 DAS	7.04(2.74)	5.59(2.48)	68.11
Sem ±	0.10	0.11	1.23
CD (P=0.05)	0.22	0.25	4.27

Figures in parenthesis are transformed values subjected to (“x+0.5) transformation

Plant growth and yield attributes

The weed control measures exhibited significant variation in respect of growth parameters. Fluchloralin @ 1.00 kg *a.i.*/ ha (Table 2) produced taller plant closely followed by pendimethalin @ 1.00 kg *a.i.*/ ha as compared to weedy check treatment respectively. The superiority of fluchloralin @ 1.00 kg *a.i.*/ha treatment at 90 DAS stage in term of shoot height might have accrued to increase and at par with that of pendimethalin @ 1.00 *a.i.*/ha. Their results were confirmed to Mishra *et al.* (1998). The efficacy of fluchloralin @ 1.0 kg/ha or pendimethalin @ 1.0 kg/ha use was also seen in other growth parameters *viz.* number of branches/plant (6.16 to 6.23) and leaf area index (1.06 to 1.07). The dry matter production which is the resultant of all these growth characters *viz.* plant height, number of branches/ plant and leaf area index, the highest dry matter from fluchloralin 1.00 kg/ha and pendimethalin 1.0 kg/ha treatments. The effect of all these growth parameters reflected on various yield attributes also and number of pods/plant, 1000-seed weight, Harvest Index 65.6 to 66.4 %, 75.12 to 75.23 % and 75.47 to 75.93 %, were higher over other weed management options. Maximum seeds yield was recorded with fluchloralin @ 1.00 kg *a.i.*/ ha or pendimethalin @ 1.00 kg *a.i.*/ha (1.03 to 1.04 t/ha) as compared to other treatments (Table 3).

Table 2. Growth and yield attributes of french bean at 90 DAS as influenced by various herbicides

Treatments	Plant height (cm)	No. of branches / plant	Dry accumu-lation/ plant(g)	Leaf area index	No. of pods/ plants	1000-seed weight (g)	Harvest index
Weedy Check	20.09	4.09	7.01	0.73	2.76	237.9	28.99
Hand weeding at 30 DAS	22.69	4.79	7.19	0.85	3.08	252.5	31.87
Weed free	27.35	6.48	9.99	1.08	5.70	323.7	39.85
Fluchloralin (0.75 kg *a.i.*/ha)	24.43	5.07	7.38	0.87	4.17	269.8	33.47
Fluchloralin (1.00 kg *a.i.*/ha)	26.73	6.23	9.96	1.07	5.53	316.7	38.41
Fluchloralin (0.75 kg *a.i.*/ha) + HW 30 DAS	25.05	5.50	8.62	0.98	4.91	297.5	36.47
Pendimethalin (0.75 kg *a.i.*/ha)	24.66	5.40	8.10	0.87	4.29	271.5	33.59
Pendimethalin (1.00 kg *a.i.*/ha)	26.65	6.16	9.96	1.06	5.51	316.2	38.18
Pendimethalin (0.75 kg *a.i.*/ ha) +HW 30 DAS	25.17	5.68	8.64	0.96	4.88	297.1	36.38
Oxyfluorfen (0.15 kg *a.i.*/ha)	23.76	5.47	7.33	0.84	3.24	256.7	32.12
Oxyfluorfen (0.20 kg *a.i.*/ha)	25.04	5.49	8.33	0.94	4.78	279.1	35.11
Oxyfluorfen (0.15 kg *a.i.*/ha) + HW 30 DAS	24.16	5.41	8.36	0.92	4.53	273.8	33.88
Sem ±	0.71	0.19	0.45	0.03	0.17	4.22	0.66
CD (P=0.05)	1.57	0.43	1.01	0.07	0.38	9.29	1.46

Table 3. Effect of different weed control treatments on yield of french bean and economics.

Treatments	Stover yield (t/ha)	Yield (t/h)	Cost of cultivation	Net Return (Rs/ha)	B:C ratio
Weedy Check	1.06	0.53	22095	4583	1.21
Hand weeding at 30 DAS	1.13	0.58	23145	5468	1.24
Weed free	1.59	1.06	26295	23985	1.91
Fluchloralin (0.75 kg *a.i.*/ha)	1.24	0.75	22695	13860	1.61
Fluchloralin (1.00 kg *a.i.*/ha)	1.57	1.04	22945	26435	2.15
Fluchloralin (0.75 kg *a.i.*/ha) + HW 30 DAS	1.47	0.86	23745	17693	1.63
Pendimethalin (0.75 kg *a.i.*/ha)	1.24	0.75	23085	13335	1.60
Pendimethalin (1.00 kg *a.i.*/ha)	1.57	1.03	23428	25772	2.10
Pendimethalin (0.75 kg *a.i.*/ ha) + HW 30 DAS	1.47	0.86	24135	17010	1.70
Oxyfluorfen (0.15 kg *a.i.*/ha)	1.15	0.60	23140	6440	1.28
Oxyfluorfen (0.20 kg *a.i.*/ha)	1.47	0.82	23195	15740	1.68
Oxyfluorfen (0.15 kg *a.i.*/ ha) + HW 30 DAS	1.28	0.76	24190	12635	1.52
SEm±	0.04	0.03	-	-	-
CD (P=0.05)	0.09	0.09	-	-	-

Nitrogen uptake (kg/ha) by weeds at harvest

Application of fluchloralin @ 1.00 kg *a.i.*/ha used accumulated lowest (0.00 kg N/ha) amount of nitrogen and at par with that of pendimethalin @ 1.00 kg *a.i.*/ha (0.00 kg N/ha) during both years respectively (Table 4).

Nitrogen uptake (kg/ha) by French bean at harvest

Weed-management practices significantly affected the N uptake of french bean crop, the highest N uptake was recorded under the treatment of fluchloralin 1.00 kg/ha and pendimethalin 1.00 kg/ha (52.5n to 52.9 kg/ha), which was significant at par to weed free situation. This was apparently due to the lesser weed crop competition and thus better crop growth, yield and ultimates higher uptake by the crop. The remaining weed management option did not prove significance in terms of N uptake value were significantly inferior to 1.0 kg fluchloralin or pendimethalin application.

Economics

The application of fluchloralin @ 1.0 kg *a.i.*/ha was showed higher gross return, net return and B. C. ratio and at par with that of pendimethalin @ 1.0 kg *a.i.*/ha than other weed control treatments. The highest B. C. ratio of 2.10 to 2.15 was recorded with

Table 4. Total N content (%) and N-uptake (kg/ha) by weeds and French bean as influenced by various herbicides at harvest stage

Treatments	N content (%)		N uptake (kg/ha)	
	Weeds	French bean	Weeds	French bean
Weedy Check	1.95 (1.56)	2.91	40.28(6.38)	20.01
Hand weeding at 30 DAS	1.81(1.52)	3.49	27.44(5.28)	25.12
Weed free	0.00 (0.71)	4.68	0.00 (0.71)	55.81
Fluchloralin (0.75 kg *a.i.*/ha)	1.62(1.46)	3.98	10.46(3.31)	35.14
Fluchloralin (1.00 kg *a.i.*/ha)	0.00(0.71)	4.51	0.00(0.71)	52.95
Fluchloralin (0.75 kg *a.i.*/ha + HW 30 DAS)	1.54(1.43)	4.17	7.06(2.57)	43.07
Pendimethalin (0.75 kg *a.i.*/ha)	1.60(1.45)	3.96	10.48(3.31)	34.76
Pendimethalin (1.00 kg *a.i.*/ha)	0.00(0.71)	4.47	0.00(0.71)	52.52
Pendimethalin (0.75 kg *a.i.*/ha + HW 30 DAS)	1.55(1.43)	4.14	7.68(2.86)	42.58
Oxyfluorfen (0.15 kg *a.i.*/ha)	1.66(1.47)	3.75	13.22(3.70)	29.63
Oxyfluorfen (0.20 kg *a.i.*/ha)	1.56(1.43)	4.04	8.23(2.95)	40.16
Oxyfluorfen (0.15 kg *a.i.*/ha + HW 30 DAS)	1.59(1.44)	4.03	9.52(3.16)	36.24
S em ±	0.05	0.10	0.79	1.61
CD (P=0.05)	NS	0.28	1.74	3.54

fluchloralin @ 1.00 kg *a.i.*/ha or pendimethalin @ 1.00 kg *a.i.*/ha. This show that French bean is more responsive towards the inputs use and under good management and it can give even higher returns (Table 3).

It may be concluded that the application of fluchloralin @ 1.00 kg *a.i.*/ha and pendimethalin @ 1.00 kg *a.i.*/ha recording higher productivity and profitability of French bean.

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J. Farming Systems Research & Development **17** (1&2) : 182-200 (2011)

EFFECT OF ENRICHED AND CONVENTIONAL COMPOST PREPARED FROM DIFFERENT ORGANIC WASTES ON GROWTH, YIELD AND YIELD ATTRIBUTES OF SOYBEAN CROP AND PHYSICO-CHEMICAL PROPERTIES OF SOIL

Amit Mishra[1], Narendra Kumar[2], Ramesh Chandra[2], Mahendra Singh[2],
Vivek Sharma[1] Shailendra Raj[1] and Deepika Mishra[3]

[1]*IRRI India, Modipuram Meerut, Department of Soil Science,*
[2]*Department of Soil Science, G.B.P.U.A&T., Pantnagar,*
[3]*Meerut Collage, Meerut*

Abstract

The enriched and conventional compost prepared from organic wastes (Pine needle, Sugar cane trash, pressmud and Paper mill baggasse). The pressmud enriched compost was found best among all composts. The effects of these compost were tested in soybean crop. The application of pressmud enriched compost @ 10 t /ha resulted in higher nodule number and dry weight, grain yield (28.46 q /ha), total N uptake (230.6 kg/ha) and total P uptake (39.52 kg/ha) by soybean var PK 1042 in comparison with other composts. The microbial biomass carbon (334.15 µg/g) in soil was higher at 50 % flowering stage than at harvesting stage (300.29 µg/g) due to increase in microbial population of soil. All the enriched compost performed better than conventional composts for all the parameters under study.

Key Words : Enriched compost, conventinonal compost, pressmud, pine needle, sugarcane trash and paper mill baggasse

The Uttaranchal State also has a considerable amount of organic wastes such as paper mill bagasse, sugarcane trash, pine leaves and press mud etc. Pal (1995) reported that the Pine (*Pinus rorburghii*) is a dominant species in U.P. hills (presently Uttaranchal State) and occupies about 30 per cent of the total forest area. Most of these organic wastes are either burnt or used as fillers due to slow rate of decomposition.

Soybean (*Glycine max* (L.) Merrill) is an important crop because it is a rich source of fat and protein forever growing population of the world. It contains about 30-40 per cent protein of high biological value and 20-25 per cent oil.

The rapid increase in food production over the past three decades was at the cost of corresponding increase in the removal of nutrients from the soil. The annual mining of major nutrients (N, P, K) at the present situation of crop production has been estimated at the rate of 125 kg ha^{-1} while the annual addition is hardly 90 kg ha^{-1}, resulting in the depletion of reserves from the soil (Tandon, 1994). Such negligence has not only caused exhaustion of soil nutrients reserve but also resulted in imbalance among the available nutrients leading to soil problems.

Keeping in view the importance of organic manures in agriculture, an attempt has been made to prepare enriched manure from organic waste materials such as sugarcane trash, paper mill bagasse, press mud and pine leaves and to study their effect on soybean productivity and soil properties.

Materials and Method

The field trial was conducted at C_6 block of the Crop Research Centre of the

Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, District Udham Singh Nagar, Uttaranchal during *kharif* 2004. The Crop Research Centre is located in the *Tarai* region of Uttaranchal; it lies between $28^0 52'$ to $29^0 25'$N latitude, $75^0 58'$ to $79^0 42'$ E longitude and at 243.8 m altitude. The climate of Pantnagar is subhumid and mean annual rainfall is about 1400 mm.

The soil of experiment site is Hapludoll and texture is silty clay loam. At the start of the experiment the soil was low in available N&K and medium in P and soil reaction was neutral. Table (1) The experiment was initiated with soybean crop. The experiment was conducted in a randomized block design with three replication.The treatments of experiment is as on T1 control, T2 FYM, T3 Recommended dose of fertilizer, T4 Paper mill bagasse conventional compost, T5 Paper mill bagasse enriched compost T6 Pine needle conventional compost T7 Pine needle enriched compost T8 Pressmud conventional compost T9 Pressmud enriched compost T10 Sugarcane trash conventional compost T11 Sugarcane trash enriched compost T12 Mixed enriched compost. The conventional and enriched compost in the field were applied at the rate of 10 t/ha. The dose of recommended NPK was 20:60: 40 kg/ha.

Enriched compost was prepared from pressmud, pine needle, paper mill bagasse, sugarcane trash and fresh cow dung taking in the ratio of 1 : 4 :: cow dung : organic wastes as shown in Table 2. The C:N ratio was maintained at 30:1 by adding urea in each cemented pit. One per cent single super phosphate and 5 per cent lime (calcium carbonate) were also added for enrichment of the compost.

The moisture was initially adjusted at 60 per cent and maintained at 50 to 60 per cent during decomposition period. Liquid inoculum of cellulose decomposing fungi (*Humicola sp.* and *Trichoderma viride)* was applied at the rate of 500 mg mycelium per kg of materials to hasten

Table 1. Properties of the experimental site soil

S. No.	Properties	Value
1.	Texture	Silty clay loam
2.	pH (1 : 2, Soil : Water ratio)	7.20
3.	Bulk density Mg m^{-3}	1.43
4.	Electrical conductivity dSm^{-1} (1:2)	0.41
5.	Organic carbon (%)	0.73
6.	Available N (kg ha^{-1})	220.50
7.	Available P (kg ha^{-1})	18.20
8.	Available K (kg ha^{-1})	125.10
9.	Bacteria ($CFUg^{-1}$ of soil)	15.24×10^6
10.	Fungi (CFU g^{-1} of soil)	5.33×10^4
11.	Actinomycetes (CFU g^{-1} of soil)	13.24×10^5
12.	Microbial biomass carbon (µg g^{-1})	251.9

Table 2. Chemical properties of different composts after 90 days incubation

Compost	pH	Organic C (%)	Total N (%)	C:N ratio	Total P (%)	Total S (%)	Total K (%)
Local compost (LC)	7.21	35.84	0.85	42.16	0.40	0.77	0.29
Papermill baggasse conventional compost (PMBC)	7.42	35.73	0.91	39.26	0.25	0.46	0.33
Papermill baggasse Enriched compost (PMBEC)	7.33	34.22	1.48	23.12	0.49	0.71	0.48
Pine needle conventional compost (PCC)	7.34	37.81	0.84	45.01	0.18	0.59	0.31
Pine needle enriched compost (PEC)	7.46	33.13	1.13	29.31	0.33	0.97	0.76
Press mud conventional compost (PMCC)	7.60	35.73	1.46	24.48	0.94	0.69	0.69
Press mud enriched compost (PMEC)	7.42	29.47	3.04	9.69	2.03	1.07	1.148
Sugar cane trash conventional compost (STCC)	7.25	35.38	1.02	35.09	0.45	0.41	0.27
Sugar cane trash enriched compost (STEC)	7.43	31.9	1.84	17.33	1.29	0.61	0.42
Mixed enriched compost (MEC)	7.35	32.12	1.74	18.45	1.03	0.87	0.96
Enriched compost (EC)	7.28	33.64	1.87	17.93	1.09	0.92	0.81

the decomposition process. The turning of composting material was done after 15 days intervals.

The mixed compost was prepared by taking equal amount of organic wastes in the ratio (1:1:1:1) by adopting above procedure.

The composite soil samples (0-15) were collected from each plot with a 5 cm augar after harvest of soybean.

RESULTS

Assessment of chemical properties of different prepared

All composts prepared for the study have neutral pH. Highest organic carbon content (37.81%) was recorded in pine needle conventional compost, while the pressmud enriched compost showed minimum organic carbon content (29.47%).

The total nitrogen content in all the composts ranged from 0.84 to 3.04 per cent, minimum being in pine needle conventional compost and maximum in pressmud enriched compost. All the enriched composts showed more total nitrogen content than conventionally prepared composts. The composts prepared by enrichment method have markedly lower C:N ratio than conventionally prepared composts.

The maximum C:N ratio of 45.01 was found in pine needle conventional compost followed by the local compost (42.16). The narrowest C:N ratio of 9.69 was recorded in pressmud enriched compost. The total phosphorus in all the composts ranged from 0.25 to 2.03 per cent, with maximum in pressmud enriched compost. The highest amount of potassium (1.08%) was recorded in pressmud enriched compost and lowest in sugarcane trash conventional compost.

The total sulphur content in different composts ranged from 0.27 to 1.14 per cent, lowest value was recorded in sugarcane conventional compost and highest in pressmud enriched compost. The enrichment technique increased the total phosphous, potassium and sulphur content in composts comparing with conventionally prepared composts.

Effect of different composts on soybean plant height

The data revealed that the effect of all applied treatments at three growth stage (30, 60 & 90 DAS) on plant height of soybean was non-significant in comparison with control. The application of enriched composts performed better than conventional composts.

Trifoliate leaves

It is evident from the data that all the given treatments, except sugarcane trash conventional compost performed significantly better as compared with control for developing trifoliate leaves on soybean plant. However, application of sugarcane trash conventional compost produced 7.8 per cent more trifoliate leaves than control. The maximum number of trifoliate leaves (9.66) was registered with T_9 treatment (pressmud enriched compost), which was 67.4 per cent more than control. (Table 3).

The perusal of data at 60 & 90 DAS revealed that the effect of different treatments on number of trifoliate leaves was non-significant in comparison to control.

Nodule number

The data recorded at 30 DAS, revealed that all the treatments, except pine needle conventional compost, performed significantly better than control treatment for nodule number per plant. The maximum nodule number per plant (21.33) was recorded with sugarcane trash enriched compost followed by pressmud enriched compost (20.66). The sugarcane trash enriched compost gave 24.3 per cent significantly more nodule number than recommended dose of NPK. This treatment also produced 8.5 per cent more number of nodules than conventionally prepared sugarcane trash compost. The addition of pressmud enriched compost resulted in 27.8 per cent significantly more nodule number as compared with conventional pressmud compost. The pine needle and paper mill bagasse enriched compost produced numerically 22.5 and 20.79 per

Table 3. Effect of different composts on height of soybean plant and plant trifoliate leaves at different intervals

	Treatments	Plant height (cm)			Plant Trifoliate leaves		
		30 DAS	60DAS	90DAS	30DAS	60DAS	90DAS
T_1	Control	36.50	71.44	70.33	5.77	11.55	17.66
T_2	Local compost	40.25	74.48	70.22	7.78	13.33	21.44
T_3	Recommended NPK	40.75	79.66	71.44	7.89	12.67	19.78
T_4	Paper mill bagasse conventional compost	39.50	70.44	73.89	8.55	13.44	17.00
T_5	Paper mill bagasse enriched compost	41.84	73.53	77.22	8.89	13.00	21.11
T_6	Pine needle conventional compost	37.66	74.67	72.99	9.11	13.11	17.33
T_7	Pine needle enriched compost	39.64	74.55	74.11	9.22	13.34	18.00
T_8	Pressmud conventional compost	42.83	75.55	72.22	9.33	13.22	18.33
T_9	Pressmud enriched compost	43.55	76.74	78.00	9.66	13.78	21.67
T_{10}	Sugarcane trash conventional compost	38.02	72.22	73.11	6.22	13.89	18.22
T_{11}	Sugarcane trash enriched compost	46.36	74.67	75.22	8.33	14.86	23.55
T_{12}	Mixed enriched compost	40.83	74.84	71.11	9.00	14.56	20.11
	SEm	2.75	4.25	4.40	0.68	0.75	1.45
	CD at 5 %	NS	NS	NS	2.01	NS	NS

cent, respectively more nodule number in comparison to conventionally prepared pine needle and paper mill bagasse composts. The application of mixed enriched compost also gave 7.80 and 3.5 per cent more nodule number per plant than recommended dose of NPK and local compost, respectively.(Table 4)

At 60 DAS, the perusal of data (Table 4) indicated that recommended dose of NPK, pressmud and sugarcane trash enriched composts significantly increased nodule number per plant as compared with control. However, remaining treatments were numerically better than control. The maximum nodule number (54.32 nodules plant^{-1}) was recorded with application of pressmud enriched compost (T_9) followed by sugarcane trash enriched compost. The application of pressmud enriched compost showed 23.76 and 36.34 per cent significantly more nodule number than pressmud conventional compost and local compost, respectively. The addition

Table 4. Effect of different composts on nodule number and nodule dry weight of soybean plant at different intervals

	Treatments	Nodule Number			Nodule dry weight (mg $plant^{-1}$)		
		30 DAS	**60DAS**	**90DAS**	**30DAS**	**60DAS**	**90DAS**
T_1	Control	12.16	36.28	13.29	70.50	176.33	162.77
T_2	Local compost	17.83	39.86	18.44	113.33	311.33	182.44
T_3	Recommended NPK	17.16	48.89	21.44	108.50	380.67	161.11
T_4	Paper mill bagasse conventional compost	16.83	37.00	28.00	106.83	173.67	164.22
T_5	Paper mill bagasse enriched compost	20.33	41.89	30.00	132.00	289.67	221.78
T_6	Pine needle conventional compost	14.83	37.00	20.88	115.00	271.33	137.33
T_7	Pine enriched compost	18.16	40.11	33.52	125.66	384.00	231.33
T_8	Pressmud conventional compost	16.16	43.89	28.00	101.16	192.00	172.33
T_9	Pressmud enriched compost	20.66	54.32	34.00	137.33	445.67	195.11
T_{10}	Sugarcane trash conventional compost	19.66	39.94	24.00	127.33	277.33	137.99
T_{11}	Sugarcane trash enriched compost	21.33	51.00	31.45	137.76	405.00	258.45
T_{12}	Mixed enriched compost	18.50	38.19	22.11	123.66	229.00	179.67
	SEm	1.35	3.04	5.77	9.95	35.68	36.21
	CD at 5 %	3.98	8.94	NS	29.20	104.64	NS

of sugarcane trash enriched compost indicated significant increases in nodule number than conventional sugarcane trash compost and local composts by giving 27.69 and 27.94 per cent, respectively more nodule number per plant. The treatments having pine needle and paper mill bagasse enriched composts were numerically better than conventionally prepared pine needle and paper mill bagasse composts.

At 90 DAS, the nodule number per plant decreased as compare with 60 DAS. The effect of different treatments on nodule number was found non-significant over the control.

Nodule dry weight

The data on the effect of different compost treatments on nodule dry weight per plant at 30, 60 and 90 DAS are shown in Table 4. At 30 DAS, the data indicated that all the given treatments showed significant effect on nodule dry mass per plant as compared with control.

However, all the enriched composts were statistically at par with each other. The maximum nodule dry weight (137.76 mg plant^{-1}) was recorded with treatment having sugarcane trash enriched compost which was 27.0 per cent significantly higher than recommended NPK. The pressmud enriched compost gave significantly 35.6 per cent more nodule dry mass than conventionally prepared pressmud compost. Paper mill bagasse and pine needle enriched composts were also numerically better than conventionally prepared paper mill bagasse and pine needle composts by giving 23.4 and 9.26 per cent more nodule dry weight, respectively. The mixed enriched compost also increased 9.1 and 13.9 per cent nodule dry weight than local compost and recommended NPK, respectively.

The perusal of data revealed that at 60 DAS, the effect of all given treatments, except all conventionally prepared composts and mixed enriched composts, was significantly more in terms of nodule dry mass per plant over the control. However, all conventionally prepared composts, except paper mill bagasse, were numerically better than control. All the enriched composts were also significantly superior than conventionally prepared composts for nodule dry weight. The maximum nodule dry weight (445.67 mg plant^{-1}) was recorded with application of pressmud enriched compost. The application of pressmud enriched compost produced 132.11 and 42.9 per cent significantly more nodule dry biomass than pressmud conventional compost and local compost, respectively. This compost also gave 17.10 per cent more nodule dry weight over recommended NPK. The addition of sugarcane trash enriched compost significantly increased 96.0 per cent nodule dry weight per plant than conventionally prepared sugarcane trash compost. The addition of paper mill bagasse and pine enriched composts registered 66.8 and 41.52 per cent, respectively significantly more nodule dry weight than conventionally prepared paper mill bagasse and pine needle conventional composts.

At 90 DAS, the data clearly indicated (Table 4) that application of different composts have non-significant effect on nodule dry mass over the control.

Yield and yield attributes

Grain yield

The applications of all composts, except paper mill bagasse, pressmud and sugarcane trash conventional composts, have significant effect on the grain yield of soybean over the control. However, the treatments with paper mill bagasse, pressmud and sugarcane trash conventional composts were also numerically better than control. The highest grain yield (28.46 q ha^{-1}) was obtained with pressmud enriched compost followed by the recommended dose of NPK (27.42 q ha^{-1}). Both these treatments were statistically comparable with each other. The treatment with recommended NPK gave 19.7 per cent more yield as compared with local compost. The application of pressmud enriched compost also produced 27.11 and 24.22 per cent significantly more grain yield than pressmud conventional and local composts, respectively. The paper mill bagasse enriched compost was significantly superior over paper mill bagasse conventional compost by giving 14.8 per cent higher grain yield. The addition of sugarcane trash enriched compost resulted 16.12 per cent significantly higher grain yield than conventionally prepared sugarcane trash compost. The mixed enriched compost was also gave significantly 15.9 per cent more grain yield than local compost. However, the application of local compost produced 15.8 per cent higher grain yield than control. All the conventionally prepared composts were comparable with local compost (Table 5)

The data on biological yield of soybean (Table 5) indicated that effect of all given treatments were non-significant in comparison with control. However, applications of all compost gave numerically higher biological yield than control. The maximum biological yield (52.31 q ha^{-1}) was recorded with application of pressmud enriched compost which was similar to that obtained with recommended NPK. Addition of local compost gave more biological yield over control treatment. The addition of pressmud enriched compost gave 21.51 and 18.35 per cent, respectively more biological yield than pressmud conventional and local composts. The applications of all enriched composts were seemed over conventionally prepared compost.

Test weight of grain

The data pertaining to the effect of different composts on test weight of soybean grain (Table 5) showed non-significant effect over control.

Physicochemical properties of soil after soybean harvesting

pH & Electrical conductivity

The effect of applied treatments on soil electrical conductivity & pH were found non-significant over the control treatment. However, electrical conductivity of soil numerically decreased with application of different

Table 5. Effect of different composts on yield and yield attributes of soybean

	Treatments	**Grain yield (q ha^{-1})**	**Biological yield (q ha^{-1})**	**Test weight (g)**
T_1	Control	19.78	38.19	67.73
T_2	Local compost	22.91	44.20	84.61
T_3	Recommended NPK	27.42	52.08	95.81
T_4	Paper mill bagasse conventional compost	21.00	39.54	85.58
T_5	Paper mill bagasse enriched compost	24.12	44.89	93.98
T_6	Pine needle convent-ional compost	22.91	42.54	89.47
T_7	Pine needle enriched compost	25.86	50.93	94.90
T_8	Pressmud convent-ional compost	22.39	43.05	87.44
T_9	Pressmud enriched compost	28.46	52.31	97.67
T_{10}	Sugarcane trash conventional compost	21.52	38.88	84.67
T_{11}	Sugarcane trash enriched compost	24.99	48.60	95.07
T_{12}	Mixed enriched compost	26.55	45.86	96.81
	SEm	1.02	4.71	8.74
	CD at 5 %	2.99	NS	NS

composts when compared with control. The maximum reduction in electrical conductivity (0.35 dSm^{-1}) was registered with application of pressmud enriched compost which was 18.6 and 14.6 per cent lower than control and recommended dose of NPK, respectively (Table 6).

Bulk density

It is evident from the data that application of composts decreased bulk density of soil but the effect was found non-significant over the control treatment. However, all applied treatments numerically decreased the bulk density of soil (Table 6)

Table 6. Effect of different composts on soil electrical conductivity, pH and bulk density, Organic carbon, Available NPK after harvesting of soybean

	Treatments	EC (dSm^{-1})	pH	Bulk density Mg m^{-3}	OC (%)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
T_1	Control	0.43	7.58	1.41	0.70	224.74	17.61	103.28
T_2	Local compost	0.38	7.71	1.39	0.78	246.69	18.75	122.98
T_3	Recommended NPK	0.40	7.50	1.40	0.81	278.05	29.47	128.42
T_4	Paper mill bagasse conventional compost	0.38	7.48	1.35	0.86	258.19	24.19	127.06
T_5	Paper mill bagasse enriched compost	0.39	7.55	1.35	0.78	267.60	28.12	129.10
T_6	Pine needle conventional compost	0.39	7.50	1.36	0.98	246.69	25.22	116.86
T_7	Pine enriched compost	0.37	7.34	1.39	0.88	272.83	28.23	123.74
T_8	Pressmud conventional compost	0.36	7.50	1.38	0.84	257.15	25.16	118.90
T_9	Pressmud enriched compost	0.35	7.58	1.32	0.79	309.14	29.92	134.53
T_{10}	Sugarcane trash conventional compost	0.36	7.52	1.33	0.94	260.28	25.58	110.07
T_{11}	Sugarcane trash enriched compost	0.37	7.50	1.34	0.71	278.05	28.34	120.26
T_{12}	Mixed enriched compost	0.36	7.57	1.35	0.87	300.01	25.71	127.06
	SEm	0.16	0.96	0.29	0.15	13.66	2.27	16.30
	CD at 5 %	NS	NS	NS	NS	40.07	6.67	NS

Organic carbon

The data related with per cent organic carbon in soil (Table 6) showed that application of all compost treatments were at par with control. However, the given treatments were numerically better than control. The maximum per cent organic carbon in soil (0.98) was found with application of pine needle conventional compost. The pine needle conventional compost gave 40.0 and 24.58 per cent more organic carbon in comparison to control and local compost, respectively. In general, application of all conventional composts accumulated more organic soil carbon than all enriched composts, except mixed enriched compost.

Available nitrogen

The data concerning with available nitrogen in soil (Table 6) showed that effect of recommended dose of NPK and enriched composts was significant on available nitrogen in comparison to control. However, all conventionally prepared composts were also numerically better than control. The maximum available nitrogen content (309.41 kg ha^{-1}) was recorded with treatment having pressmud enriched compost, which was 20.32 and 25.42 per cent significantly higher in comparison with pressmud conventional and local composts, respectively. This treatment also gave an increase of 11.11 per cent in available nitrogen in soil than recommended dose of NPK. The application of pine needle enriched compost also increased 10.5 per cent available N over pine needle conventional compost. However, the addition of paper mill bagasse and sugarcane trash enriched composts were numerically comparable with conventionally prepared bagasse and sugarcane trash composts. The mixed enriched compost significantly gave 21.6 per cent increase in available N than local compost.

Available phosphorus

The data on available phosphorus (Table 6) indicated that all given compost treatments, except local compost and paper mill conventional compost, significantly increased available phosphorus in soil over control. It is also evident from the data that different enriched composts were superior than conventionally prepared composts. The maximum available phosphorus (29.92 kg ha^{-1}) was registered with application of pressmud enriched compost which was 18.9 and 59.8 per cent more than pressmud conventional and local composts, respectively. However, all enriched composts were statistically comparable with each other and parallel with recommended dose of NPK.

Available potassium

It is evident from data (Table 6) that effect of given treatments on available potassium in soil was non-significant over the control. However, all the compost treatments seemed to be numerically better than control.

Total nutrient uptake by soybean crop

Nitrogen uptake

It is clearly indicated from the data (Table 7) that application of all treatments, except local compost, paper mill bagasse, and sugarcane trash conventional composts, significantly increased total nitrogen uptake by soybean crop than control. However, remaining treatments also performed numerically better over control. The maximum total nitrogen uptake (230.60 kg ha^{-1}) was found with pressmud enriched compost, which was significantly higher than other treatments. The pressmud enriched

Table 7. Effect of different composts on total nutrient uptake by soybean

Treatments		N uptake (kg ha^{-1})	P uptake (kg ha^{-1})	K uptake (kg ha^{-1})
T_1	Control	109.66	23.80	34.99
T_2	Local compost	134.96	28.99	44.94
T_3	Recommended NPK	208.52	36.92	61.54
T_4	Paper mill bagasse conventional compost	138.15	26.50	38.94
T_5	Paper mill bagasse enriched compost	166.97	31.25	49.75
T_5	Pine needle conventional compost	151.13	28.38	44.02
T_6	Pine needle enriched compost	181.51	34.51	58.21
T_8	Pressmud conventional compost	163.65	29.34	46.24
T_9	Pressmud enriched compost	230.60	39.32	64.32
T_{10}	Sugarcane trash conventional compost	130.36	26.75	36.81
T_{11}	Sugarcane trash enriched compost	155.47	32.78	50.01
T_{12}	Mixed enriched compost	184.72	32.75	51.76
	SEm	12.17	1.87	10.04
	CD at 5 %	35.71	5.49	NS

compost gave 40.91 and 10.58 per cent, respectively more grain N uptake than pressmud conventional compost and recommended NPK dose. The paper mill bagasse, pine needle and sugarcane trash enriched composts did not have significant effect on N-uptake in comparison to conventionally prepared paper mill bagasse and sugarcane trash compost but resulted in 22.0, 20.5 and 12.0 per cent, respectively more total N-uptake over their conventional composts. The application of mixed enriched compost was comparable with recommended NPK but it showed significant effect in comparison with local compost, paper mill bagasse, sugarcane trash conventionally prepared composts.

Phosphorus uptake

The data illustrated in Table (7) showed that application of recommended NPK, all enriched composts and pressmud conventional compost have significant effect on phosphorus uptake by crop than control. However, remaining treatments were also numerically better than control. The treatment with pressmud enriched compost performed significantly better than its conventionally prepared compost by showing 34.01 per cent increase in total P uptake by crop. This treatment was statistically comparable with recommended NPK.

The application of pine needle and sugarcane trash enriched composts produced 21.6 and 22.54 per cent significantly more total P uptake than their conventionally prepared composts. Addition of paper mill bagasse enriched compost also increased 17.92 per cent total P uptake than its conventionally prepared compost. The mixed enriched compost was also superior than local compost by giving 13.0 per cent more P uptake in grain.

Potassium uptake

The data presented in Table 7 showed that addition of all the treatments did not affect the K uptake by crop. However, all applied treatments were numerically better than control.

Microbial biomass carbon

It is evident from the data that irrespective of given treatments mean microbial biomass carbon increased at both the stages from its initial level of 251.28 to 289.95 mg g^{-1} soil at 50 per cent flowering stage and to 273.85 mg g^{-1} soil after harvesting of soybean crop.

At 50 per cent flowering stage

The application of pine needle, pressmud, sugarcane trash and mixed enriched composts significantly increased microbial biomass carbon in soil than control. However, other treatments also showed numerically better performance as compared with control. The maximum microbial biomass carbon (334.15 mg g^{-1}) was recorded with use of pressmud enriched compost which was 23.8 and 21.4 per cent higher than pressmud conventional and local composts, respectively. This treatment was also significantly superior over other treatments, except pine needle, sugarcane trash and mixed enriched composts. This treatment also gave 15.21 per cent higher microbial biomass than recommended NPK. The addition of pine needle and sugarcane trash enriched composts resulted in 12.5 and 12.9 per cent significantly more biomass carbon than their conventionally prepared composts. The mixed compost gave 11.8 per cent significantly more microbial biomass than local compost (Table 8).

At harvesting

The data revealed that application of pine needle, pressmud and sugarcane trash enriched composts showed significantly higher effect on microbial biomass carbon than control. However, other treatments were also numerically better than control. The highest microbial biomass carbon (300.29 mg g^{-1}) was obtained with pressmud enriched compost, which was significantly more than conventionally prepared composts and paper mill enriched compost. This treatment registered 7.4 and 7.9 per cent, respectively more microbial biomass carbon than recommended NPK and local compost. The sugarcane trash and pine needle enriched composts produced 9.73 and 9.03 per cent, respectively more microbial biomass carbon than their conventional composts. (Table 8)

Microbial population

The perusal of data indicated that in general mean population of bacteria, actinomycetes and fungi in soil after the harvest of soybean crop, irrespective, of treatments was higher than the initial microbial population.

Bacteria

The pertaining to Table 20 showed that all given treatments significantly increased bacterial population in soil over control. The number of bacteria ranged from 25.89 to 39.0 x 10^6 CFU g^{-1} soil in control and pressmud enriched compost. The application of pressmud enriched compost resulted significantly more bacterial population than local compost, recommended NPK and sugarcane enriched compost by 29.1, 16.19 and 12.9 per cent, respectively. This treatment also produced 9.1 per cent more population in comparison to pressmud conventional compost. The

Table 8. Effect of different composts on microbial biomass at 50% flowering stage and after harvest of crop and microbial population of soil after harvesting of soybean

Treatments		**Bacteria CFUg^{-1} x 10^{6} soil**	**Actinomycetes CFUg^{-1} x 10^{4} soil**	**Fungi CFUg^{-1} x**	**Microbial biomass C (μ gg^{-1}) 10^{5} soil**	
T_1	Control	25.89	12.47	18.07	264.69	253.90
T_2	Local compost	30.29	13.98	23.26	275.07	278.28
T_3	Recommended NPK	33.66	16.11	27.91	290.03	279.54
T_4	Paper mill bagasse conventional compost	35.19	16.48	27.15	276.58	255.28
T_5	Paper mill bagasse enriched compost	38.97	19.45	34.56	281.56	260.29
T_5	Pine needle conventional compost	36.33	18.13	29.27	273.80	267.59
T_6	Pine needle enriched compost	39.10	22.30	33.34	308.04	291.78
T_8	Pressmud convent-ional compost	35.84	17.43	31.72	269.85	257.01
T_9	Pressmud enriched compost	39.11	22.52	36.92	334.15	300.29
T_{10}	Sugarcane trash conventional compost	34.65	17.51	27.81	279.48	263.56
T_{11}	Sugarcane trash enriched compost	38.70	20.94	35.58	315.54	289.22
T_{12}	Mixed enriched compost	36.64	20.79	30.60	307.61	280.5
	Mean	35.45	18.18	29.68	289.95	273.85
	Initial	15.24	13.24	5.33	251.3	
	SEm	1.48	1.98	3.39	9.43	10.84
	CD at 5 %	4.34	5.83	9.95	27.65	31.79

treatments with pine needle, paper mill bagasse and sugarcane trash enriched compost also significantly enhanced soil bacterial population than local compost and recommended NPK. The sugarcane trash enriched compost gave 11.7 more bacterial population than sugarcane trash conventional compost. Both paper mill bagasse and pine needle enriched composts were numerically better than their conventional compost by giving 9.90 and 7.60 per cent, respectively more bacterial number. The addition of mixed compost also resulted in significantly 21.00 per cent more bacterial population in comparison with local compost (Table 8).

Actinomycetes

The application of all the enriched composts significantly increased actinomycetes population in soil over control and local compost. However, remaining treatments also performed numerically better than control. The maximum actinomycetes population (22.52 10^5 CFU g^{-1} soil) was recorded with addition of pressmud enriched compost. This treatment was also significantly better than local compost, recommended NPK and paper mill bagasse conventional compost by giving 61.1, 39.78 and 36.7 per cent increase, respectively. However, addition of pressmud enriched compost gave 29.20 per cent more actinomycetes population than its conventional compost. The addition of pine needle enriched compost also resulted significantly 38.42 per cent more actinomycetes population than recommended NPK and 23.0 per cent than pine needle conventional compost. The sugarcane trash enriched compost resulted in significantly 19.6 per cent more population than its conventional compost. The treatment with paper mill bagasse enriched compost was numerically better by increasing 18.0 per cent population than conventional paper mill compost.

Fungi

The data illustrated in Table 8 revealed that application of all the treatments, except local compost, recommended NPK, paper mill bagasse and sugarcane trash conventional composts, significantly increased fungal population in soil over control. However, these treatments were numerically better than control. The maximum fungi population (36.92 10^4 CFU g^{-1} soil) was recorded with pressmud enriched compost treatment. Which gave 16.39 and 32.28 per cent, respectively more fungal population than conventional pressmud compost and recommended NPK tratment. The application of pressmud enriched compost resulted significantly 58.72 per cent more number of fungi than local compost. The addition of sugarcane trash enriched compost enhanced significantly 53.0 per cent more fungus population than local compost, this treatment was numerically better than conventional pressmud compost by giving 28.0 per cent higher fungi population. The paper mill bagasse and pine needle enriched composts also significantly increased 27.3 and 13.9 per cent population, respectively than their conventional composts. The performance of mixed enriched compost was numerically better by giving 31.6 per cent more fungal population than local compost. The performance of all the enriched composts was numerically better in comparison to recommended NPK dose.

DISCUSSION

Effect of enrichment on compost quality

The compost prepared by enrichment technique was better than that by conventional technique. The enriched compost contained narrow C:N ratio and more nutrient than conventional compost because of more suitable condition for microbial growth and activity due to increased supply of nutrients through added chemical fertilizers. The inoculation of cellulolytic fungi into composting material also hasten the decomposition rate and released nutrients in compost. Shinde and Rote (1982), Bhriguvanshi (1988), Manna *et al.* (1997) and Sundra (2002) also reported that the addition of inorganic fertilizer and microbial inoculants hasten the decomposition rate, decreased C:N ratio and increased nutrient content of organic wastes. Among the enriched composts pressmud enriched compost had more nutrients than other prepared composts. It might be due to the fact that pressmud had more amount of nutrients and narrow C:N ratio as compared to other organic wastes. Gallardo- Larva and Nogoles (1987) also indicated that nutrient status of composts largely depends on the nutrient content of organic wastes which are composted.

Effect on soybean growth

The application of different treatments numerically increased plant height and trifoliate leaves of soybean than control at all the intervals except plant trifoliate leaves at 30 DAS, which showed significant increase with all the treatments, except sugarcane trash conventional compost.

The increase in all these growth parameters by application of different composts may be the result of improvement in soil fertility and available nutrient concentration. The results are in conformity with the findings of Kashid and Sabale (2003) who reported increase in growth contributing characteristics of pigeonpea due to application of phospho compost. Plant nutrient supply is known to induce cell division, expansion of cell wall, meristmatic activity, photosynthetic efficiency and regulation of water intake into the cells resulting in more growth (Rries *et al.*, 1977). Kumar (2002) also reported that application of enriched pressmud compost significantly increased plant height of rapeseed crop.

Nodulation

The enhancement in nodulation in terms of nodule number and nodule dry weight as obtained by the application of different composts may be due to increase in rhizobial survival and activity in soil because of more available nutrients and carbon. The finding corroborate with the findings of Yadava *et al.* (1992) who reported that application of enriched compost and inoculation of *Rhizobium* significantly increased the nodule number of green gram crop. Similarly, Singh (2000) and Namdeo *et al.* (2003) reported that the application of phospho-compost significantly increased nodulation in soybean crop. Among the composts treatments pressmud enriched compost performed better on nodulation as pressmud enriched compost have higher total NPK and S content and narrow C:N ratio than other composts .

Effect of yield and yield attributes of soybean

The addition of all enriched composts, recommended NPK, pine needle conventional compost and local compost significantly increased grain yield of soybean than control. However, application of treatments gave numerically higher biological yield and test weight than control. The beneficial effects of enriched composts were due to enhanced supply of NPK, S and organic matter through enrichment. The addition of organic matter might have improved the soil physical conditions and resulted in better crop growth. The findings are matching with the results obtained by Singh (2000), Namdeo *et al.* (2003), Sikora and Azad (1993) and Deshmukh (1998) who reported that application of enriched compost significantly increased grain and straw yield of soybean as compared to control. All enriched composts performed better than conventionally prepared composts. Similarly, Kapoor *et al.* (1990) also reported that application of enriched compost gave higher grain yield of wheat than ordinary compost. The increase in grain yield was due to the fact that enriched composts had relatively more total NPK, S and narrow C:N ratio than the their conventionally prepared compost .

Effect on physicochemical properties of soil

The application of different compost treatments decreased electrical conductivity and bulk density of soil. The maximum decreased in electrical conductivity and bulk density was observed with pressmud enriched compost. However, pH was not affected with application of different composts. The reduction in bulk density was due to the supply of organic matter through composts that might have improved physicochemical properties of the soil (Shanmugam *et al.*, 1995). The decrease in electrical conductivity of the soil might be due to presence of neutral salts in pressmud (Kumar, 1991). Similarly, Seth (2002) also reported that application of SPM composts reduced electrical conductivity and bulk density of the soil.

Application of all the treatments numerically increased the organic carbon content of soil than the control. The maximum increase in organic carbon content was observed with pine needle and sugarcane trash conventional compost. It might be due to relatively higher organic carbon content in both these composts than the other composts (Table 7). Similarly, Pal (1995) reported that pine needle amended soil had significantly more organic matter content in soil. Manna *et al.* (2001) also reported that application of phospho-compost significantly increased organic carbon content in soil after the harvest of soybean crop. Similarly, Seth (2002) reported that application of pressmud compost significantly increased organic carbon content in soil after the harvest of rice crop.

The available N content in soil increased to a great extent on incorporation of different composts. Maximum available nitrogen in soil was observed with pressmud enriched compost. This could be attributed by narrow C:N ratio of the pressmud enriched compost. Similar results have also been obtained by Jayamani and Devarajan (1995), Pal (1998) and Manna *et al.* (2001), who reported increased availability of N in soil after the harvest of crop.

The application of all enriched composts, pressmud conventional compost and recommended NPK significantly increased available phosphorus in soil after the harvest of soybean crop. The maximum available P was observed in pressmud enriched compost. The increase in available P status can be attributed to the positive influence of organic manures, i.e., pressmud on labile P in soil by complexing cations like Ca, Mg, Fe and Al preventing them from fixing P into more stable forms and by solubilizing fixed form of P .Another probable reason for increased P availability might be release of native P due to intermediate acids produced during decomposition of organic matter by microbial activities (Sen and Paul, 1957. Similarly, Singh (1997), Manna *et al.* (1997) and Pal and Singh (2002) also reported that application of enriched compost significantly increased available P in soil.

Effect on total nutrient uptake by soybean crop

The application of all enriched compost, except local compost, papermill bagasse and sugarcane trash conventional composts, significantly increased total nitrogen uptake by crop, this might be due to improvement in physicochemical properties of soil along with increase mineralization of nutrients which resulted in more nutrient uptake (Tiwari and Nema, 1999). The maximum nitrogen uptake was recorded with addition of Pressmud enriched compost in soil because of their narrow C: N ratio in comparison to the other composts (Table 7). The results are in agreement of Borde *et al.* (1984) and Rathod *et al.* (2004) who reported that application of enriched compost significantly increased N uptake by crop.

The total P uptake by soybean crop was significantly increased by the application of recommended NPK, all enriched composts and pressmud conventional compost. The maximum P uptake was recorded with Pressmud enriched compost. This might be due to increase in phosphorus availability in soil as a result of application of enriched compost, which may help plant to take more phosphorus from the soil. These finding are in agreement of Borde *et al.* (1984) who reported that application of enriched compost improved P uptake by crop.

Effect on soil microbial biomass

The microbial biomass is positively related with microbial biomass carbon. The results showed more microbial biomass carbon in soil at 50 per cent flowering stage in comparison to the harvesting stage, which might be due the fact that addition of compost in soil microbial number and activity was increased due to more available carbon and nutrients like N, P and S to soil microorganisms which have synthesized more cellular components and provided more energy, later on the nutrients were exhausted by soil microorganisms and crop plant and reduced the microbial biomass in soil. This finding is supported by Wang-Yan *et al.* (1998) who reported that soil microbial biomass increased greatly after application of organic manures at beginning of experiment and thereafter the biomass C decreased. The maximum microbial biomass carbon at both the stages was recorded with pressmud enriched compost. Similarly, Manna *et al.* (2001) and Ghosh *et al.* (2002) have reported that application of enriched compost significantly increased soil microbial biomass C in soil. Recommended NPK dose also increased microbial biomass carbon in soil due increased availability of N, P and to soil microorganisms for their growth.

Effect on soil microbial population

The application of all composts as well as recommended NPK increased microbial population in soil than control. It is an established fact that composts have considerable amount of carbon and nutrients, which support growth and activity of microorganisms in soil.

After addition of all composts and recommended NPK, the bacterial population significantly increased than fungi and actinomycetes as bacteria are first to attack substrate in soil to obtain C, energy and nutrients from easily decomposable organic materials such as, sugars and proteins while fungi and actinomycetes degrade comparatively resistant compounds like cellulose and lignin.

It can be concluded from the present study that the composts prepared from different organic wastes (pine needles, paper mill bagasse, pressmud and sugarcane trash) by enriched technique performed better for soybean crop as well as soil physico-chemical and biological properties than conventionally prepared compost. The maximum beneficial effects were exhibited by pressmud enriched compost.

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J. Farming Systems Research & Development **17** (1&2) : 201-205 (2011)

ALLELOPATHIC EFFECT OF DIFFERENT HEDGEROW SPECIES ON *RABI* SORGHUM IN DIFFERENT ALLEY CROPPING SYSTEMS

S.Y. Wali*, S.B. Devaranavadgi, S.B. Patil, D.N. Kambrekar and M. B. Jambagi

Regional Agricultural Research Station, UAS Campus, BIJAPUR-586 101, Karnataka, India

Abstract

A study was conducted to know the allelopathic effect of hedgerow species on *rabi* sorghum in different alley cropping systems at Regional Agricultural Research Station, Bijapur, University of Agriculture Sciences, Dharwad for two years. The results show that, among hedge row species treatment rubble check (control) recorded significantly higher germination per cent, shoot length, root length and dry weight of sorghum seedlings (86.80%, 11.44 cm, 11.51 cm and 0.38 g, respectively) followed by *Gliricidia sepium*. The *rabi* sorghum genotypes did not shown significant differences. However, interaction effect was found to be significant.

Key words: Allelopathic effect, alley cropping system, hedgerow species, germination, *rabi* sorghum.

Allelopathy refers to biochemical interaction between all types of plants and covers both detrimental and beneficial effects. It is gaining considerable importance in alley cropping systems since it involves integrating of trees with agricultural crops. It is reported that leaf extract of gliricidia promoted radicle and plumule growth of groundnut, rice, blackgram and horsegram and did not show high degree of sensitivity to the extract during germination (Patil, 1984). Similar trends were also observed in safflower by Kalaghatagi *et al.* (1998).

The allelo chemicals produced by the intercropped hedge row species will affect the performance of companion field crops. Therefore it is essential that allelopathic compatability of field crops with hedge row species should be checked. Since it will have significant bearings on the total productivity of an alley cropping system. Preliminary studies on allelopathic effect of different hedge row species on germination (77.99%), seedling root length (9.84 cm) and seedling dry weight (0.38 g) of *rabi* sorghum recorded higher values with gliricidia as hedge row species compared to other hedge row species. This kind of allelopathic effect may be one of the reasons for the variation in the growth and yield of sorghum as influenced by different hedge row species. Keeping this in view, the present investigation was carried out to evaluate the allelopathic effect of hedgerow species on *rabi* sorghum in alley cropping systems.

Materials and Methods

The experiment was conducted at Regional Agricultural Research Station, Bijapur farm of University of Agricultural Sciences, Dharwad, Karnataka state during *rabi* season of 2001-02 and 2002-03. The soil of experimental field was deep black soil (vertisol), having pH 8.5 and EC 0.48 dS m^{-1}, 120 kg ha^{-1} available Nitrogen, 8.5 kg ha^{-1} available P_2O_5, 570 kg ha^{-1} available K_2O and 0.60% organic

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* Author for correspondence, Present Address: Assist. Professor, Dept. of Agronomy, College of Agriculture, Bijapur. Tel. No.08352-267124, E-mail:sywali123@rediffmail.com

carbon. The experiment was laid out in a split plot design with four replications. The fourteen treatment combinations comprised seven hedgerow trees/shrubs species *viz.*, H_1: *Leucaena leucocephala*, H_2: *Gliricidia sepium*, H_3: *Cassia saimea*, H_4: *Albizia lebbeck*, H_5: *Desmenthus virigatus*, H_6: *Dalbergia sissoo* and H_7: Control (rubble check) in main plots and two *rabi* sorghum genotypes *viz.*, V_1: DSV-4 and V_2: M 35-1 in sub plots. The hedgerows of different trees/shrubs species established in the year 2002 were used in this experiment. The paired (60 cm) hedgerows were spaced at 30 cm apart on contour lines and were regularly pruned to a height of 15 cm above ground level till initiation of this experiment. The last pruning was carried out in February 2001. *Rabi* sorghum cultivars were sown on 21 September and 6 October with a spacing of 65 cm x 15 cm during 2001 and 2002, respectively.

The allelopathic effects of hedgerow species and tree species were made by conducting seed germination in the soil samples collected (0-30 cm) from respective treatments (Rao *et al.*, 1994). The observations on germination per cent, shoot length, root length and dry weight of seedlings at 10 days after sowing were recorded for two years and the mean/pooled analysis was taken for interpreting results and data was subjected to statistical analysis as described by Gomez and Gomez (1984). The soil samples (0-30 cm) were collected near the hedgerow and at middle of plot, mixed well and filled in plastic basins (45 cm diameter). Then 100 seeds were sown in each basin and watered every alternate day. The observations were recorded at 10 days after sowing.

RESULTS AND DISCUSSION

The allelopathic effects of different hedge row trees/shrubs species on *rabi* sorghum were found to be significant.

Germination per cent

Significantly higher germination per cent (Table 1) was recorded with control (86.80%) followed by *G. sepium* (77.99%) and the lowest was recorded with *D. sissoo* (71.23%). There was no significant difference the germination of *rabi* sorghum due to the genotypes. Among the different treatment combinations, significantly highest germination was produced by control with DSV-4 (86.48%) and control with M 35-1 (86.28%) which were on par followed by *G. sepium* with M 35-1 (79.10%). The lowest value was recorded by *L. leucocephala* (71.37%) with M 35-1.

Shoot length

The shoot length due to hedgerow species on *rabi* sorghum genotypes was not significantly influenced (Table 1). However, numerically higher shoot length was recorded in control (11.44 cm) followed by *G. sepium* (10.69 cm) and *L. leucocephala* (10.07 cm). The lowest value was recorded in case of *A. lebbeck* (8.96 cm). Between the *rabi* sorghum genotypes numerically higher shoot length was produced by M 35-1 (10.17 cm) compared to DSV-4 (9.96 cm). The sorghum shoot length varied significantly due to different treatment combinations. The highest value was recorded by *G. sepium* with M 35-1 (11.13 cm) followed by control with M 35-1 (11.11 cm) which were on par with each other. The minimum value was recorded in case of *A. lebbeck* with DSV-4 (9.30cm).

Root length

The root length at 10 days was significantly higher in control (11.51 cm) followed by *G. sepium* (9.84 cm) which were on par with each other (Table 2).

Table 1. Allelopathic effects of different hedge row species on germination per cent and shoot length at 10 DAS of *rabi* sorghum

Treatments	Germination % at 10 DAS			Shoot length (cm) at 10 DAS		
	I Year	II Year	Pooled	I Year	II Year	Pooled
Hedgerow species (H)						
H_1 - *Leucaena leucocephala*	72.16	70.80	71.48	10.21	9.93	10.07
H_2 - *Gliricidia sepium*	78.82	77.16	77.99	10.88	10.51	10.69
H_3 - *Cassia saimea*	73.65	71.82	72.24	9.80	9.56	9.68
H_4 - *Albizia lebbeck*	76.82	74.32	75.57	9.10	8.82	8.96
H_5 - *Desmanthus virigatus*	73.31	72.10	71.70	9.90	9.63	9.77
H_6 - *Dalbergia sissoo*	72.30	70.16	71.23	10.01	9.72	9.87
H_7 - Control (Rubble check)	87.47	86.12	86.80	11.60	11.28	11.44
S.Em±	3.12	3.41	2.30	1.18	0.98	0.87
C. D. at 5%	NS	NS	3.81	NS	NS	NS
Varieties (V)						
V_1 - DSV-4	73.22	71.60	72.44	10.12	9.80	9.96
V_2 - M 35-1	74.02	73.45	73.74	10.20	10.13	10.17
S.Em±	1.98	1.36	1.24	0.46	0.39	0.34
C. D. at 5%	NS	NS	NS	NS	NS	NS
Interaction (H x V)						
$H_1 V_1$	73.18	71.10	72.14	10.32	10.06	10.10
$H_1 V_2$	72.40	72.33	71.37	10.43	10.12	10.28
$H_2 V_1$	76.08	77.60	76.84	10.77	10.46	10.60
H_2V_2	78.19	80.00	79.10	11.23	11.02	11.13
H_3V_1	72.81	72.30	75.06	9.86	9.71	9.79
$H_3 V_2$	73.04	75.00	74.02	10.31	10.12	10.22
$H_4 V_1$	75.40	72.00	73.70	9.39	9.21	9.30
$H_4 V_2$	75.80	72.42	74.11	9.51	9.12	9.35
$H_5 V_1$	72.18	72.16	72.17	10.2	19.74	9.98
$H_6 V_1$	73.06	70.08	71.57	10.38	10.34	10.36
$H_6 V_1$	71.87	71‘.26	71.45	9.81	9.67	9.74
$H_6 V_2$	72.10	71.03	71.57	10.13	9.95	10.04
$H_7 V_1$	86.49	86.46	86.48	11.02	10.72	10.82
$H_7 V_2$	87.33	85.23	86.28	11.28	10.94	11.11
S.Em±	3.84	2.48	1.78	1.86	1.99	0.58
C. D. at 5%	8.52	6.84	4.12	NS	NS	1.29
C.V.%	9.50	10.62	10.87	15.53	12.91	11.72

NS: non-significant

Table 2. Allelopathic effects of different hedge row species on root length and dry weight of seedlings at 10 DAS of *rabi* sorghum

Treatments	Root length (cm) at 10 DAS			Dry weight of seedling (g) at 10 DAS		
	I Year	II Year	Pooled	I Year	II Year	Pooled
Hedgerow species (H)						
H_1 - *Leucaena leucocephala*	7.10	6.98	7.04	0.32	0.30	0.31
H_2 - *Gliricidia sepium*	9.92	9.76	9.84	0.39	0.38	0.38
H_3 - *Cassia saimea*	8.30	8.16	8.23	0.33	0.31	0.32
H_4 - *Albizia lebbeck*	7.42	7.30	7.36	0.31	0.29	0.30
H_5 - *Desmanthus virigatus*	8.66	8.50	8.58	0.37	0.36	0.36
H_6 - *Dalbergia sissoo*	7.80	7.68	7.74	0.34	0.33	0.34
H_7 - Control (Rubble check)	11.60	11.42	11.51	0.39	0.36	0.38
S.Em±	0.86	0.85	0.67	0.03	0.03	0.02
C. D. at 5%	1.87	1.80	1.68	0.05	0.07	0.04
Varieties (V)						
V_1 - DSV-4	8.10	7.97	8.03	0.34	0.32	0.33
V_2 - M 35-1	8.21	8.07	8.14	0.35	0.30	0.32
S.Em±	0.19	0.21	0.18	0.008	0.007	0.005
C. D. at 5%	NS	NS	NS	NS	NS	NS
Interaction (H x V)						
$H_1 V_1$	7.06	6.90	6.98	0.31	0.29	0.30
$H_1 V_2$	7.12	6.80	6.96	0.34	0.33	0.34
$H_2 V_1$	8.92	8.71	8.82	0.38	0.37	0.38
H_2V_2	9.10	8.83	8.97	0.42	0.40	0.41
H_3V_1	8.12	7.82	7.97	0.33	0.31	0.32
$H_3 V_2$	8.21	8.03	8.12	0.3	0.34	0.34
$H_4 V_1$	7.96	7.75	7.86	0.30	0.29	0.29
$H_4 V_2$	8.02	7.80	7.91	0.33	0.31	0.32
$H_5 V_1$	8.42	8.10	8.26	0.36	0.34	0.35
$H_5 V_2$	8.50	8.20	8.35	0.48	0.38	0.39
$H_6 V_1$	7.60	7.35	7.48	0.35	0.33	0.34
$H_6 V_2$	7.52	7.32	7.42	0.36	0.34	0.35
$H_7 V_1$	10.83	10.58	10.70	0.37	0.35	0.36
$H_7 V_2$	11.20	10.96	11.08	0.38	0.36	0.37
S.Em±	0.38	0.40	0.23	0.08	0.006	0.040
C. D. at 5%	0.93	0.97	0.51	0.018	0.019	0.010
C.V. %	12.80	12.83	12.80	12.9	11.20	10.91

NS: non-significant

The minimum value was recorded in case of *L. leucocephala* (7.04 cm). The effect due to *rabi* sorghum genotype was not significant. Significant differences were noticed due to the effect of treatment combinations. Maximum value was recorded by control with M 35-1 (11.08 cm) and DSV-4 (10.70 cm) which were on par with each other, followed by *G. sepium* with M 35-1 (8.97 cm) and DSV-4 (8.82 cm) which were on par. The minimum value was recorded by *L. leucocephala* with M 35-1 (6.96 cm) and DSV-4 (6.98 cm).

Dry weight of seedlings

Significantly maximum dry weight of seedling (Table 2) was recorded by *G. sepium* (0.38 g) and control (0.38 g) followed by *D. virigatus* (0.36 g) which were on par with each other. Whereas the minimum value was produced by *A. lebbeck* (0.30 g). There were no significant differences due to the *rabi* sorghum genotypes. The dry matter production was significantly influenced by different treatment combinations. The highest dry weight of seedlings was produced by *G. sepium* with M 35-1 (0.41 g) and *D. virigatus* with M 35-1 (0.39 g) followed by *G. sepium* with DSV-4 (0.38 g). The minimum value was recorded by *A. lebbeck* with DSV-4 (0.29 g).

Contrary to the above findings, Chou and Kuo (1986) found that aqueous extract of *Leucaena leucocephala* seeds, litter and soil showed significant phytotoxic effects on rice and lettuce. Similar trends were also observed by Kaul (1990).

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J. Farming Systems Research & Development **17** (1&2) : 206-209 (2011)

CORRELATION STUDIES FOR OIL YIELD IN MUSTARD (*BRASSICA JUNCEA* L.) UNDER DIFFERENT CROPPING SEQUENCE AND NITROGEN RATES

VINOD KUMAR[1], MUKESH KUMAR[2] AND ARVIND KUMAR[3]

S.V.P. University of Agriculture and Technology, Modipuram, Meerut-250110

ABSTRACT

The Correlation studies for oil yield in mustard (*Brassica juncea* L.) under different cropping sequence and nitrogen rates was conducted during rabi seasons at crop research centre, of G.B. Pant University of Agriculture and Technology, Pantnagar. The experiment was conducted in split plot design with three replications. The main plot treatment consisted of 6 cropping sequences (Maize-Mustard, Soybean-Mustard, Moong-Mustard, Cowpea-Mustard, Fallow-Mustard and Dhaincha-Mustard) and sub plot had five levels of Nitrogen (0, 40, 80, 120 and 160 kg/ha). The soil of experimental field is silty clay loam in texture and neutral in reaction. The soil is medium in total nitrogen and available phosphorus and rich in available potassium and sulphur. It has been observed that cowpea-mustard sequence with the application of 120 kgN/ha has positive correlation between the growth characters, yield attributes, seed and oil yield of mustard crop.

Key words: Correlation, mustard, seed yield, oil yield.

INTRODUCTION

Rapeseed-Mustard, having prominence in northern India, rank second after groundnut and contribute nearly 27% of the total oilseed average in the country. Mustard *(Brassica juncea* L.) is prominently grown as a monocrop and also after cereal or legume crop in sequence. The inclusion of Legumes in rotation has been reported to improve soil fertility. In intensive cropping system, the production of mustard can be sustained by inclusion of legumes and green manuring crop in sequence. Tomar and Tiwari (1990) observed maximum net return form Black Gram-Mustard and Green- Mustard sequences over Fallow-Mustard sequence. Although the beneficial effect of legumes on the succeeding crop has been known to some extent, the information pertaining to the availability of nitrogen to the succeeding non-legumes crops have been scarce. Thus, the effect of legumes vis-à-vis cereals in sequential cropping is of immense practical significance to sustain the production of rapeseed-mustard in the country.

Keeping in view the present study was undertaken to assess the kind and magnitude of correlation and to understand the casual basis of such association through correlation analysis.

MATERIAL AND METHODS

A field experiment was conducted during winter seasons, of 1996-97 and 1997-98 at the Crop Research Centre of the G.B. Pant University of Agriculture & Technology, Pantnagar. The soil of experimental field is silty clay loam in texture and neutral in reaction. The soil is medium in total nitrogen and available phosphorus and rich in available potassium and sulphur. The experiment was laid out in split plot design with three replications. The main plot treatment consisted of 6 cropping

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Present Address- 1&2 S.V.P. Univ. of Agri. and Tech., Meerut. 3 G.B. Pant Univ. of Agri. and Tech., Pantnagar.

sequences (Maize-Mustard, Soybean-Mustard, Moong-Mustard, Cowpea-Mustard, Fallow-Mustard and Dhaincha-Mustard) and sub plot had five levels of Nitrogen (0, 40, 80, 120 and 160 kg/ha). An uniform basal application of 40 kg P_2O_5 and 20 kg K_2O per ha. was made along with 50% N. Remaining quantity of nitrogen was top dressed after first irrigation at 30 days stage, in mustard. Mustard variety Kranti was sown @ 5 kg/ ha at an interval of 25 days starting from 15 days after sowing.

RESULT AND DISCUSSION

Cropping Sequence

The correlation coefficients between different growth and yield contributing characters and the seed yield have been given in (Table 1&2). The dry matter of leaves per plant and dry matter accumulation per plant at 90 DAS had significantly positive correlation with the seed yield. The total number of branches per plant, number of siliquae per plant and seed weight per plant had also significantly positive correlation with the seed yield. Highest positive correlation was recorded between total number of branches per plant and seed yield (0.872 and 0.908), during 1996-97 and 1997-98, respectively, Seed yield also had significant positive correlation with number of siliquae per plant (0.668 and 0.750). Correlation coefficient between seed yield and oil content was also positive during both the year (0.287 and 0.558), respectively.

Nitrogen

Number of siliquae per plant had a significant positive correlation with the seed yield per hectare (0.83 and 0.88). Similar findings was also reported by Singh *et al.*, 1985 in mustard crop with the application of 120 kg N/ha. All these yield attributes had their pronounced effect in increasing the seed yield of

Table 1. Correlation coefficient between different characters during 1996-97

Characters	**Dry matter accumu-lation plant at 90 DAS**	**Dry matter of leaves/ plant 60 DAS**	**Total no. bran-ches plant**	**No. of siliquae/ plant**	**Seed weight/ plant**	**1000-seed weight**	**Oil content (%)**	**Seed yield (q/ha)**
Dry matter accumulation/ plant at 90 DAS	-	0.973	0.884	0.776	0.978	0.073	-0.114	0.842
Dry matter of leaves/ plant 90 DAS			0.893	0.779	0.968	0.102	-0.101	0.860
Total no. of branches/plants				0.921	0.799	0.59	0.163	0.872
No. of siliquae/plant					0.668	0.400	0.331	0.838
Seed weight / plant (g)						0.009	0229	0.787
1000-seed weight							0.440	0.185
Oil content (%)								0.287
Seed yield (q/ha)								

Table 2. Correlation coefficient between different characters during 1997-98

Characters	Dry matter accumulation plant at 90 DAS	Dry matter of leaves/ plant 60 DAS	Total no. branches plant	No. of siliquae/ plant	Seed weight/ plant	1000-seed weight	Oil content (%)	Seed yield (q/ha)
Dry matter accumulation/ plant at 90 DAS	-	0.967	0.852	0.829	0.977	-0.006	0.243	0.805
Dry matter of leaves/ plant 90 DAS			0.873	0.815	0.975	0.026	0.187	0.828
Total no. of branches/ plants				0.958	0.794	0.238	0.488	0.908
No. of siliquae/plant					0.750	0.292	0.538	0.888
Seed weight / plant (g)						0.330	0.137	0.768
1000-seed weight							0.154	0.153
Oil content (%)								0.558
Seed yield (q/ha)								

Significant at 5% level of probability.

mustard at higher rates of nitrogen. Kachroo (1995) also reported that the seed yield of mustard was positive correlation with number of branches, dry matter accumulation per plant, number of siliquae per plant and 1000-seed weight. Kumar and Gangwar (1985) have observed the higher values of yield attributes in toria with the application of 90 kg N/ha.

The number of branches and total seed weight per plant had positive correlation (0.87 and 0.78 during 1996-97 and 0.90 and 0.77 during 1997-98, respectively) with seed yield. Similar findings were also reported by different workers (Sharma, 1986 and Kachroo, 1995).

The relationship between nitrogen rates and seed yield of mustard in different cropping sequences, when pooled over 1996-97 and 1997-98, is also given through following equations :

1. $Y = 12.81 + 0.0534x - 0.000088x^2$ (Maize- Mustard sequence)
2. $Y = 9.59 + 0.0475\,x - 0.00010x^2$ (Soybean- Mustard sequence)
3. $Y = 13.68 + 0.0044x - 0.00005x^2$ (Moong- Mustard sequence)
4. $Y = 13.63 + 0.0803x - 0.0002x^2$ (Cowpea- Mustard sequence)
5. $Y = 13.03 + 0.0495x - 0.0002x^2$ (Fallow-Mustard sequence)
6. $Y = 13.63 + 0.0803x - 0.0002x^2$ (Dhaincha-Mustard sequence)

The dry matter accumulation at 90 DAS and seed yield had positive relationship (R^2 = 0.71 and 0.65 during 1996-97 and 1997-98, respectively). Higher dry matter production at 90 DAS, thus, increase seed yield. The number of siliquae and seed yield had also positive relationship with seed yield (R^2 = 0.75 and 0.78 during 1996=97 and 1997-98, respectively.) Nitrogen being the most important plant nutrient is needed for growth and development of plant and is known to increase the yield of *Brassica* species (Kumar and Gangwar, 1985).

Thus, it has been concluded that the cowpea-mustard sequence with the application of 120 kg N/ha has positive correlation between the growth characters, yield attributes, seed and oil yield and it has been beneficial for sustaining the production of mustard crop.

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J. Farming Systems Research & Development **17** (1&2) : 210-219 (2011)

EFFECT OF ROCKPHOSPHATE, PRESSMUD AND PHOPHORUS SOLUBILIZING BACTERIA ON GROWTH, QUALITY AND PRODUCTIVITY OF PIGEONPEA (C*AJANUS CAJAN*) –WHEAT (T*RITICUM AESTIVUM*) CROPPING SYSTEM

R.G. IDAPUGANTI[1], I.P.S. AHLAWAT [2] AND N.K. JAT[3]

Division of Agronomy, Indian Agricultural Research Institute, New Delhi 110 012

ABSTRACT

A field experiment was carried out at New Delhi during the *kharif* and *rabi* seasons of 2005-06 and 2006-07 on sandy loam soil to assess the effect of different sources and levels of phosphorus on pigeonpea [*Cajanus cajan* (L.) Millsp.]-wheat [*Triticum aestivum* L. emend. Fiori & Paol.] cropping system. The results revealed that application of phosphorus to pigeonpea had significant effect on growth, yield and quality of pigeonpea and wheat. Application of phosphorus to pigeonpea at 34.4 kg ha^{-1} through single super phosphate + phosphorus solubilizing bacteria or pressmud + phosphorus solublizing bacteria recorded higher dry matter, grain yield and protein content of pigeonpea and wheat over control and 17.2 kg P ha^{-1} through rock phosphate + phosphorus solublizing bacteria. Direct application of phosphorus up to 34.4 kg ha^{-1} recorded higher dry matter, protein content and productivity of wheat. Pigeonpea equivalent yield recorded highest when pigeonpea-wheat system received 34.4 kg phosphorus ha^{-1} through pressmud + phosphorus solublizing bacteria and 34.4 kg phosphorus ha^{-1}, respectively. Application of phosphorus to pigeonpea at 34.4 kg ha^{-1} through all the sources (single super phosphate with or without phosphorus solublizing bacteria, pressmud + phosphorus solublizing bacteria, rock phosphate + phosphorus solublizing bacteria) recorded markedly higher phosphorus content in pigeonpea and wheat over control.

Key words: Phosphorus, Pigeonpea, Pressmud, Rock phosphate, Wheat

Pigeonpea [*Cajanus cajan* (L.)Millsp.] is the second most important pulse crop after chickpea in India. Progressive shrinkage of per capita land availability warrants temporal and spatial intensification of cropping. The evolution of short duration and input responsive varieties of pigeonpea has opened up new avenues in this direction. As wheat being important cereal crop next to rice in India, pigeonpea followed by wheat can be grown in quick succession in Indo-Gangetic plains (Singh and Ahlawat, 2007).

In India, most of the soils are either deficient or marginal in phosphorus status. In pigeonpea-wheat cropping system, both the crops require liberal supply of phosphorus for exploiting the yield potential. Adequate phosphorus fertilization is thus essential for economic and sustained crop production. Phosphorus applied to pigeonpea has a residual effect on the succeeding wheat

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[1] Scientist, Division of Agronomy, ICAR Research Complex for NEH Region, Umiam, Shilong-793 103 (email: rgidu@yahoo.co.in)

[2] Ex-Head, Division of Agronomy, Indian Agricultural Research Institute, New Delhi- 110 012 (email: ahlawat47@hotmail.com)

[3] Scientist, Project Directorate for Farming System Research, Modipurum, Meerut, U.P. (email: nandagro09@gmail.com)

as use efficiency of phosphorus is only 20 per cent or less (Vance, 2001). P deficient soils require heavy dose of phosphatic fertilizers, which are imported and expensive too. Therefore, there is a need to find out eco- friendly, feasible and cheaper options of this nutrient to meet the needs of phosphorus in these crops.

Availability of cheaper and local sources of phosphorus has opened up new approaches for phosphorus fertilization in this cropping system. There are many deposits of rock phosphate and in all the sugar industries pressmud is available in the country. The locally available sources of phosphorus can be cheaper and eco-friendly besides solving the problem of disposing of by-products like pressmud. These sources of P have low solubility and the use of phosphorus solubilizing bacteria enhances the availability of native as well as applied P to the crop (Banerjee, 2005). Since, bacteria belonging to the genera *Pseudomonas* and *Bacillus* possess the ability to bring insoluble phosphates in soil into soluble forms by secreting organic acids such as formic, acetic, propionic, lactic, glycolic, fumaric and succinic acid and bring about the dissolution of bound forms of phosphate by lowering the pH of soil. Hence, interest in use of these materials as alternative phosphatic fertilizers has increased and thought to test these locally available P sources along with commonly used source like single superphosphate in pigeonpea and their residual effect along with directly applied P in wheat crop.

Materials and Methods

The field experiment was carried out at the Research Farm of Division of Agronomy, Indian Agricultural Research Institute, New Delhi during rainy and winter seasons of 2005-06 and 2006-07 at a new site in each year. The soil was sandy loam with pH 7.8, 8.1(1:2.5 soil to water), organic carbon 0.36, 0.38%, available nitrogen (N) 160.6, 164.8 kg/ha and available phosphorus (P) 12.9, 13.3 kg/ha at the start of the experiment in 0-30 cm soil layer during 2005-06 and 2006-07, respectively. The total rainfall received during the experimental period was 578.3 mm in 2005-06 and 629.5 mm in 2006-07. There were nine P treatments through different combination of sources viz. single super phosphate (SSP), rock phosphate (RP), pressmud (PM) and levels (0, 17.2 and 34.4 kg/ha) of P to pigeonpea laid out in randomized block design. During *rabi*, split-plot design was adopted with P applied to pigeonpea in the main plots and P applied directly to succeeding wheat in the sub-plots. The treatments were replicated thrice.

The recommended dose of N @ 25 kg ha^{-1} to pigeonpea was applied as basal dose, while in wheat 120 kg N ha^{-1} was applied in 3 equal splits (one third each at sowing, crown root initiation and at 50 days after sowing). N was given to both the crops through urea. P was applied as per treatment through SSP 3-5 cm below the seed with the help of metallic tube attached to plough. RP and PM were applied broadcasted and mixed with the soil 15 days before sowing. The amount of sulphur supplied through SSP was balanced in all the plots. Phosphate solubilizing bacterial culture ‘Microphos’ containing inoculum of *Pseudomonas striata* was used to inoculate pigeonpea seeds according to treatments. Pigeonpea variety ‘Pusa 992’ was sown on 14 June and 19 June in 60 cm x 20 cm geometry and harvested on 25 November and 20 November in 2005 and 2006, respectively. Wheat variety ‘HD 2824’ was sown after pigeonpea on 05 December and 02 December during each year, respectively.

Other management practices were adopted as per recommendations of the crops under irrigated conditions.

The plant samples of both pigeonpea and wheat collected at harvest were dried in an electric oven at 65 C for 48 hours and ground to pass through a 0.5 mm mesh sieve and analyzed for N and P. N in grain of pigeonpea and wheat was estimated by Kjeldahl's method (Jackson, 1973) and P by Vanadomolybdo-phosphoric yellow colour method (Jackson, 1973). Protein content in grain was obtained by multiplying the N content by 6.25 in case of pigeonpea and by 5.75 in case of wheat (A.O.A.C., 1995). The productivity of the system was measured by computing pigeonpea equivalent yield on the basis of market price of both the crops.

RESULTS AND DISCUSSION

Effect of P on pigeonpea

A perusal of data presented in Fig. 1 and Table 1 indicates that significant improvement in growth and yield of pigeonpea was recorded by P application. Application of P through SSP with or without PSB or PM + PSB at 34.4 kg P$_{-}$ ha^{-1} being on par recorded significantly more dry matter accumulation plant^{-1} at harvest over control, 17.2 kg P$_{-}$ ha^{-1} through SSP alone or RP + PSB, and 34.4 kg P$_{-}$ ha^{-1} through RP + PSB. P at 17.2 kg ha^{-1} through SSP + PSB or PM + PSB recorded similar dry matter accumulation plant^{-1} at harvest as of 34.4 kg P$_{-}$ ha^{-1}through SSP + PSB or PM + PSB. The overall improvement in crop growth of pigeonpea with P application seems to be on account of its pivotal role in early formation of roots, their proliferation and increased microbial activities in root nodules. This might have improved effective utilization of soil nutrients by crop and greater biological nitrogen fixation through enhancement in nitgrogenase activity (Tisdale *et al.*, 1995). During 2005, all the sources of P at both the rates (17.2 and 34.4 kg P$_{-}$ ha^{-1}) recorded statistically similar seed

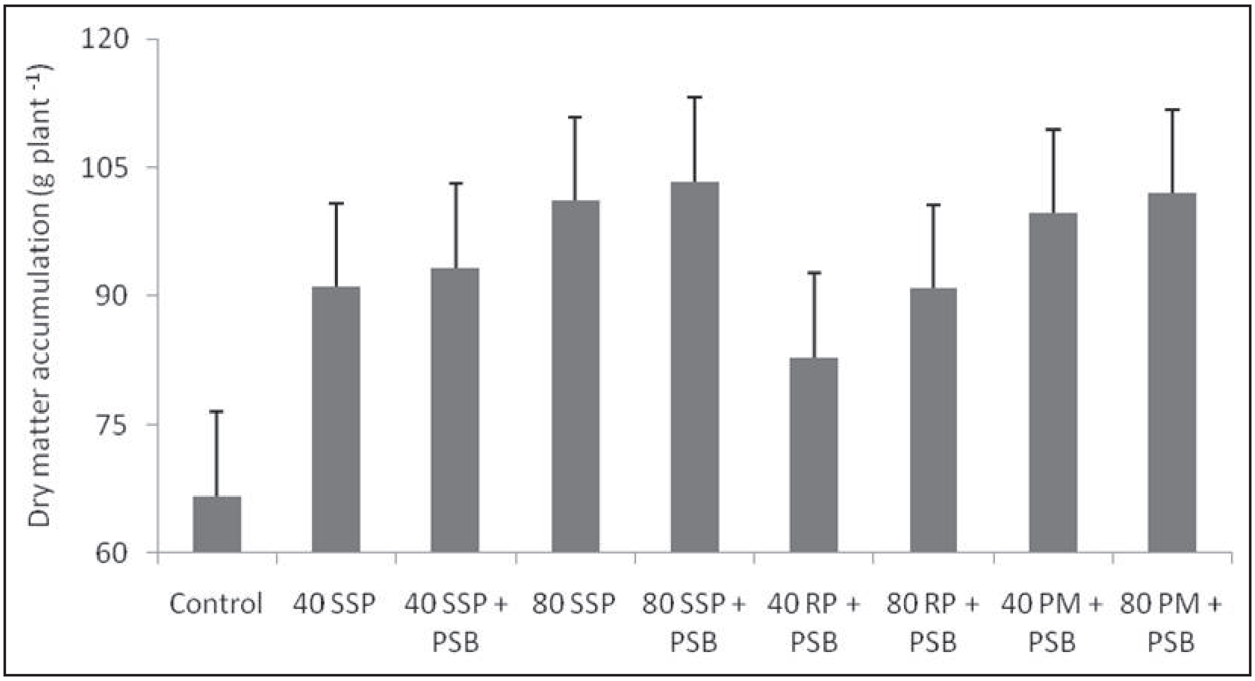

Fig. 1. Effect of P on dry matter accumulation of pigeonpea

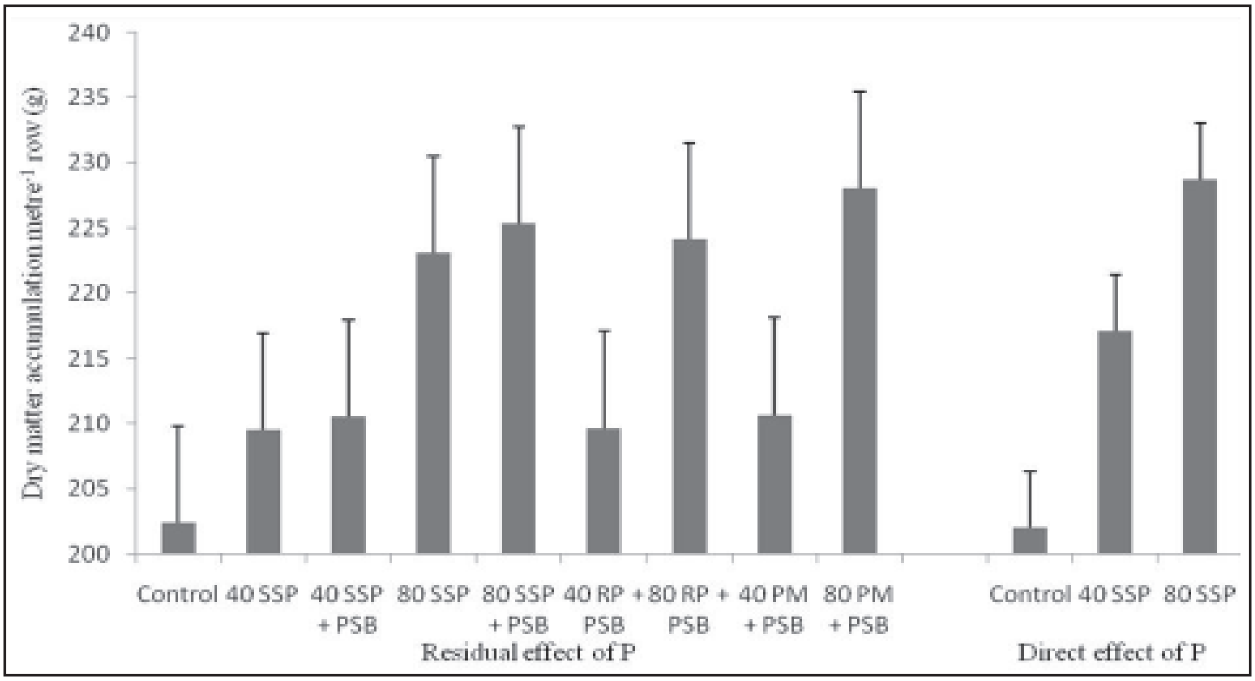

Fig. 2. Direct and residual effect of P on dry matter accumulation of wheat

yield, but in 2006, application of P through SSP + PSB or through PM + PSB at 34.4 kg P ha^{-1}, being on par, recorded significantly more seed yield over control, 17.2 kg P ha^{-1} through SSP alone or RP + PSB and 34.4 kg P ha^{-1} through RP + PSB. P at 17.2 kg ha^{-1} through SSP + PSB or PM + PSB registered higher grain yield over control and 17.2 kg P ha^{-1} through RP + PSB. However, no marked effect of P application was recorded on harvest index of pigeonpea during both the years of investigation. The increase in grain yield of pigeonpea by P up to 34.4 kg P ha^{-1} was pronounced because of improved growth and subsequent increase in yield attributes (Singh and Ahlawat, 2006).

Residual effect of P on wheat

The residual effect of P applied to pigeonpea at 34.4 kg P ha^{-1} enhanced significantly the dry matter accumulation recorded statistically similar dry matter accumulation of wheat at harvest but found significantly superior over control and 17.2 kg P ha^{-1} through SSP with or without PSB or PM + PSB or PM + PSB. Application of 34.4 kg P ha^{-1} through PM + PSB to pigeonpea reported highest dry matter accumulation of wheat at harvest. This could be ascribed to residual effect of P at 34.4 kg ha^{-1} applied to preceding crop that might have modified and improved the overall nutritional environment of the soil conducive for the growth and development of wheat crop (Shivran *et al.*, 2000).

Irrespective of sources, P dose at 17.2 kg ha^{-1} applied to preceding pigeonpea failed to record increase in grain yield of wheat over control. While application of 34.4 kg P ha^{-1} through SSP + PSB or PM + PSB to pigeonpea, being at par, recorded significant improvement in grain yield of wheat over control and 17.2 kg P ha^{-1} through SSP with or without PSB or RP + PSB or PM + PSB

Table 1. Direct and residual effect of P on grain yield and harvest index of pigeonpea, wheat and pigeonpea equivalent yield.

Treatment(kg P ha^{-1})	Pigeonpea				Wheat				Pigeonpea equivalent yield (tonnes ha^{-1})	
	Grain yield (tonnes ha^{-1})		Harvest Index(%)		Grain yiel (tonnes ha^{-1})		Harvest Index(%)			
	2005	**2006**	**2005**	**2006**	**2005-06**	**2006-07**	**2005-06**	**2006-07**	**2005-06**	**2006-07**
P to pigeonpea										
Control	1.25	1.08	19.28	18.88	4.13	4.16	40.64	40.90	3.46	3.59
17.2 through SSP	1.51	1.32	20.09	19.10	4.20	4.32	40.82	41.33	3.76	3.93
17.2 through SSP + PSB	1.55	1.36	20.13	19.22	4.23	4.34	40.90	41.27	3.81	3.98
34.4 through SSP	1.56	1.40	19.60	19.26	4.38	4.51	41.06	41.35	3.90	4.12
34.4 through SSP + PSB	1.57	1.41	19.13	18.77	4.42	4.55	41.43	41.39	3.94	4.15
17.2 through RP + PSB	1.48	1.25	19.76	18.87	4.26	4.25	40.69	41.05	3.76	3.81
34.4 through RP + PSB	1.51	1.33	19.57	19.06	4.47	4.38	41.64	40.94	3.91	3.97
17.2 through PM + PSB	1.55	1.39	20.10	19.27	4.22	4.33	40.35	41.23	3.82	4.00
34.4 through PM + PSB	1.56	1.41	19.62	18.80	4.47	4.58	41.63	41.60	3.96	4.17
SEm ±	0.06	0.03	0.28	0.59	0.04	0.06	0.53	0.67	0.06	0.04
CD (P=0.05)	0.17	0.08	NS	NS	0.13	0.19	NS	NS	0.19	0.13
P to wheat										
0					4.06	4.15	40.06	40.51	3.68	3.83
17.2					4.39	4.42	41.39	41.36	3.86	3.99
34.4					4.48	4.57	41.60	41.82	3.90	4.08
SEm ±					0.03	0.03	0.23	0.38	0.02	0.02
CD (P=0.05)					0.08	0.10	0.65	0.75	0.04	0.05

SSP = Single Superphosphate; RP = Rockphosphate; PM = Pressmud

during both the years. However, residual effect of P did not cause perceptible variation in harvest index of wheat during both the years of experimentation. The increased vigour and growth in terms of plant height and tillering owing to residual P led to better development of yield attributes, which resulted in increased yield of wheat. Such responses in above crop parameters clearly indicated marked residual effect of P on wheat (Shivran *et al.*, 2000).

Direct effect of P on wheat

Direct application of P at 17.2 and 34.4 kg P ha^{-1} recorded higher dry matter accumulation at harvest and grain yield of wheat over control (Table 1). Direct application of P to wheat at 17.2 and 34.4 kg ha^{-1}, being on par, recorded significantly higher harvest index over control to wheat during both the years. Graded application of P to wheat both at 17.2 and 34.4 kg P ha^{-1} might have improved yield attributes and yields over control. This might be possibly due to continued and balanced supply of nutrients enhancing their availability for their active involvement in shoot and root growth, which finally translated into higher yield of wheat (Singh and Rai, 2002).

Pigeonpea equivalent yield (PEY)

P application to pigeonpea, irrespective of rates and sources, markedly influenced the pigeonpea equivalent yield (Table 1). Pigeonpea receiving 34.4 kg P ha^{-1} through any sources recorded significantly higher pigeonpea equivalent yield (PEY) over control during both the years. In first year, 34.4 kg P ha^{-1} through PM + PSB registered higher PEY over 17.2 kg P ha^{-1} through SSP alone or RP + PSB. Application of P to pigeonpea at 34.4 kg ha^{-1} through SSP + PSB or PM + PSB also significantly enhanced PEY over 17.2 kg P ha^{-1} through SSP with or without PSB or RP + PSB or PM + PSB during second year. The percent increase in PEY with 34.4 kg P ha^{-1} through SSP + PSB or PM + PSB over control were 13.68 and 14.20 in 2005-06 and 15.65 and 16.15 in 2006-07, respectively. This might be attributed to increase in economic yields of both the component crops due to direct and residual effects of P. Similar results were also reported by (Singh and Ahlawat, 2006). Direct application of P to wheat up to 34.4 kg P ha^{-1} recorded significantly higher PEY in both the seasons. The percent increase in PEY with 17.2 and 34.4 kg P ha^{-1} over control was 4.70 and 6.05 in 2005-06 and 4.28 and 6.68 in 2006-07, respectively. It indicates the high P requirement of the cropping system and in the present study both pigeonpea and wheat need got ample supply of P for higher productivity. These results are in close conformity with those of Kantwa *et al.* (2006).

N and protein content; and protein yield

Irrespective of sources and levels of P, except 17.2 kg P ha^{-1} through RP + PSB, N concentration and protein content in grain in of both pigeonpea and wheat influenced significantly during both the years (Table 2). In 2005, 34.4 kg P ha^{-1} through SSP with or without PSB and 17.2 and 34.4 kg P ha^{-1} through PM + PSB, being on par, recorded significantly higher N concentration in grain over control and 17.2 kg P ha^{-1} through SSP alone or RP + PSB. While during 2006, P at 34.4 kg P ha^{-1} through SSP + PSB or PM + PSB, being on par, improved N concentration and protein content in pigeonpea grain over control, 17.2 kg P ha^{-1} through SSP alone and 17.2 and 34.4 kg P ha^{-1} through RP + PSB. During 2005, P applied to pigeonpea at 34.4 kg

Table 2. Effect of sources and levels of P on N and protein content in grain and protein yield of pigeonpea and wheat.

Treatment(kg P ha^{-1})	Pigeonpea						Wheat					
	N content (%)		Protein content (%)		Protein yield (kg ha^{-1})		N content (%)		Protein content (%)		Protein yield (kg ha^{-1})	
	2005	**2006**	**2005**	**2006**	**2005**	**2006**	**2005-06**	**2006-07**	**2005-06**	**2006-07**	**2005-06**	**2006-07**
P to pigeonpea												
Control	2.74	2.76	17.15	17.23	214.3	186.6	1.63	1.64	9.38	9.42	389.2	394.2
17.2 through SSP	2.99	3.04	18.71	19.02	283.4	251.6	1.67	1.69	9.59	9.72	404.2	421.2
17.2 through SSP+PSB	3.07	3.11	19.19	19.46	297.6	265.1	1.68	1.71	9.67	9.81	409.7	426.3
34.4 through SSP	3.19	3.23	19.96	20.02	311.8	280.3	1.81	1.83	10.37	10.34	454.9	467.2
34.4 through SSP+PSB	3.21	3.25	20.21	20.31	314.8	286.8	1.81	1.82	10.41	10.44	460.9	475.4
17.2 through RP+ PSB	2.86	2.81	17.88	17.58	264.7	219.8	1.73	1.69	9.97	9.74	425.6	415.6
34.4 through RP+ PSB	3.06	3.05	19.13	19.04	289.3	253.1	1.82	1.78	10.44	10.24	467.5	449.6
17.2 through PM+ PSB	3.19	3.21	19.92	20.08	309.4	278.7	1.71	1.69	9.84	9.73	417.6	422.4
34.4 through PM+ PSB	3.22	3.26	20.13	20.35	314.1	287.1	1.81	1.84	10.42	10.58	466.6	485.5
SEm ±	0.06	0.07	0.34	0.44	13.2	7.5	0.03	0.03	0.28	0.15	9.3	11.5
CD (P=0.05)	0.16	0.2	1.02	1.21	39.7	22.6	0.11	0.08	0.59	0.44	28.2	34.4
P to wheat												
0							1.59	1.61	9.15	9.24	372.4	384.6
17.2							1.78	1.76	10.21	10.15	448.3	448.9
34.4							1.86	1.85	10.67	10.62	477.8	485.7
SEm ±							0.016	0.017	0.09	0.1	4.91	4.95
CD (P=0.05)							0.05	0.05	0.27	0.28	14.2	14.1

SSP = Single Superphosphate; RP = Rockphosphate; PM = Pressmud

P$_-$ ha^{-1} through SSP with or without PSB or PM + PSB or RP + PSB being on par with 17.2 kg P$_-$ ha^{-1} through SSP with or without PSB or PM + PSB significantly yielded more protein in seed over control and 17.2 kg P$_-$ ha^{-1} through RP + PSB. In next season (2006), pigeonpea fertilized with 34.4 kg P$_-$ ha^{-1} through SSP with or without PSB or PM + PSB being on par with 17.2 kg P$_-$ ha^{-1} through PM + PSB significantly improved protein yield over control and 17.2 kg P$_-$ ha^{-1} through RP + PSB. This could be attributed to the fact that added P increased N and protein content in grain and stover by providing balanced nutritional environment inside the plant and higher photosynthetic efficiency (Jat and Ahlawat, 2001).

P applied to preceding pigeonpea had significant residual effect on N

Table 3. Effect of sources and levels of P on P content (%) of pigeonpea and wheat

Treatment(kg P ha^{-1})	**Pigeonpea**				**Wheat**			
	Grain		**Stover**		**Grain**		**Stover**	
	2005	**2006**	**2005**	**2006**	**2005-06**	**2006-07**	**2005-06**	**2006-07**
P to pigeonpea								
Control	0.25	0.26	0.07	0.08	0.22	0.22	0.054	0.062
17.2 through SSP	0.30	0.32	0.11	0.11	0.24	0.24	0.059	0.066
17.2 through SSP + PSB	0.32	0.33	0.11	0.12	0.24	0.24	0.060	0.067
34.4 through SSP	0.34	0.35	0.12	0.13	0.26	0.26	0.068	0.073
34.4 through SSP + PSB	0.35	0.35	0.12	0.13	0.26	0.26	0.068	0.074
17.2 through RP + PSB	0.29	0.30	0.10	0.10	0.24	0.24	0.060	0.066
34.4 through RP + PSB	0.33	0.34	0.11	0.11	0.26	0.26	0.069	0.074
17.2 through PM + PSB	0.32	0.33	0.12	0.13	0.24	0.24	0.060	0.067
34.4 through PM + PSB	0.35	0.35	0.12	0.13	0.26	0.27	0.070	0.075
SEm ±	0.016	0.015	0.006	0.004	0.002	0.003	0.002	0.002
CD (P=0.05)	0.05	0.04	0.08	0.02	0.006	0.010	0.007	0.007
P to wheat								
0					0.24	0.24	0.058	0.064
17.2					0.25	0.25	0.063	0.069
34.4					0.26	0.26	0.069	0.074
SEm ±					0.002	0.002	0.001	0.001
CD (P=0.05)					0.005	0.005	0.002	0.003

SSP = Single Superphosphate; RP = Rockphosphate; PM = Pressmud

concentration in grain and protein content of wheat during both the years of investigation. In 2005-06, application of 34.4 kg P ha^{-1} through SSP with or without PSB or RP + PSB or PM + PSB to pigeonpea, being on par, significantly enhanced N concentration in wheat grain over control and 17.2 kg P ha^{-1} through SSP with or without PSB. In 2006-07, pigeonpea fertilized with 34.4 kg P ha^{-1} through SSP with or without PSB or PM + PSB recorded higher N concentration in grain and protein content in wheat over control and 17.2 kg P ha^{-1} through SSP with or without PSB or RP + PSB or PM + PSB to pigeonpea. However, application of 17.2 kg P ha^{-1} irrespective of its sources could not registered significant improvement in N concentration and protein content in wheat grain over control during both the years. P applied to pigeonpea at 34.4 kg P ha^{-1} through SSP with or without PSB or PM + PSB being statistically similar with 34.4 kg P ha^{-1} through RP + PSB improved protein yield in wheat grain over control and 17.2 kg P ha^{-1} through all sources in both the seasons. In 2005-06, 34.4 kg P ha^{-1} through RP + PSB also found superior over control and 17.2 kg P ha^{-1} through all sources. As major portion of the P applied to pigeonpea was left behind for use by the succeeding crop, it created a balanced nutritional environment inside the plant leading to higher photosynthetic efficiency favouring plant growth and crop yield. Thus, the higher uptake of N by plants resulted in higher protein content and yield. These results are in line with those of Shivran and Ahlawat (2000). Wheat directly fertilized with P up to 34.4 kg ha^{-1} also significantly enhanced N content, protein content and protein yield in grain over control. This could be attributed to higher N concentration in grain by P fertilization. P being constituent of nucleic acid and phospho-proteins is known to play a key role in synthesis of proteins. Similar results were also observed by Singh (2005).

P content

Application of different sources and levels of P significantly increased concentration of P in grain and stover of pigeonpea except 17.2 kg P ha^{-1} through RP + PSB in grain during both the years. P application at 34.4 kg ha^{-1} applied through SSP + PSB or PM + PSB, being on par, recorded the highest P concentration in grain and stover during both the years. Application of 17.2 kg P ha^{-1} through SSP with or without PSB or PM + PSB recorded similar P concentration in grain to that of 34.4 kg P ha^{-1} through SSP with or without PSB or PM + PSB or RP + PSB during both the years. Application of P to pigeonpea also had favourable residual effect on P concentration in wheat grain and straw during both the years of study. Application of P to pigeonpea at 34.4 kg P ha^{-1} through any sources, being on par, recorded markedly higher P concentration in wheat grain and straw over control and 17.2 kg P ha^{-1} through all the sources during both the years of experimentation. Application of 17.2 kg P ha^{-1} through all sources to pigeonpea also recorded higher P concentration in wheat grain and straw over control in both the seasons. Significantly higher P concentration in wheat grain was observed up to 34.4 kg P ha^{-1} applied to wheat. P at 34.4 kg ha^{-1} and 17.2 kg ha^{-1} applied to wheat being statistically different recorded higher P concentration in wheat grain and straw over control. This could be attributed to the fact that added P increased P content in grain and stover by providing balanced nutritional environment inside the plant (Jat and Ahlawat, 2001).

Based on the findings of present investigation, it may be concluded that RP and PM along with the PSB can be effectively used as source of P in pigeonpea-wheat cropping system in P deficient soils of Indo- Gangetic plains. This may solve the disposal problem of PM from sugarcane industries and there are many RP mines with good reserves available in the country of course of low grade which are more environment friendly to the chemical fertilizers. This will reduce the dependence on import of costly P fertilizers like SSP, DAP etc

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J. Farming Systems Research & Development **17** (1&2) : 220-225 (2011)

IDENTIFICATION OF PROMISING SOM (*PERSEA BOMBYCINA* KOST.) BASED INTERCROPPING SYSTEM FOR INCREASING PRODUCTIVITY AND SUSTAINABILITY FOR ASSAM

U. Hazarika[1], S.K. Barthakur [2] , R. Chakravarty[3] and K. Pathak[4]

[1&3]Central Muga Eri Research & Training Institute, Lahdoigarh, Jorhat, Assam and [2]Department of Botany, Gauhati University, Guwahati, Assam
[4] Directorate of Research, Assam Agricultural University, Jorhat
**For correspondence (e-mail: dr.urmicsb@yahoo.co.in)*

Abstract

Experiment was conducted during 2007-08 to 2009-10 at Lahdoigarh, Jorhat to identify the promising Som (*Persea bombycina* Kost.) based intercropping system which can sustain and be well suited under Assam agro climatic conditions. The intercropping systems studied were Som (*Persea bombycina* Kost.) + Ginger (*Zingiber officinale* Rosc.), Som (*Persea bombycina* Kost.) + Turmeric (*Curcuma longa* L.), Som (*Persea bombycina* Kost.) + Garlic (*Allium sativum* L.), Som (*Persea bombycina* Kost.) + Stevia (*Stevia rebaudiana* (Bertoni) Hemsl.), Som (*Persea bombycina* Kost.) + Patchouli (*Pogostemon cablin* Benth.), Som (*Persea bombycina* Kost.) + Brahmi (*Bacopa monnieri* (L.) Wetts.), Som (*Persea bombycina* Kost.) + Colocasia (*Colocasia esculenta* Schott), Som (*Persea bombycina* Kost.) + Potato (*Solanum tuberosum* L.) and Som (*Persea bombycina* Kost.) + Onion (*Allium cepa* L.). The total productivity of a system in terms of Muga cocoon equivalent yield (117.1'000 numbers /ha/year) was recorded maximum in Som + Stevia than other intercropping systems. Som + Stevia was also found more economically viable in terms of net returns (‘ 41,110 /ha/yr), profitability (‘112.6/ha/day), REE (87.80 %), employment generation efficiency (89.59%) and sustainability with respect to net return (165.11) which was followed by Som + Patchouli. On the other hand, Som + Patchouli recorded the highest benefit cost ratio (1.67) than all other systems which was identified to be superior and more economically viable. Som + Patchouli also registered higher net returns (‘38,710 /ha/yr), profitability (‘106.1 /ha/day), REE (76.84 %).**)**, employment generation efficiency (76.16%) and sustainability with respect to net return (165.17) over the years owing to less fluctuation in net returns. The higher cost involved in Stevia cuttings and other intercultural operations increased the cost of cultivation of Som + Stevia system. Thus, Som + Stevia was in second rank in order of economic merit followed by Som + Patchouli.

Key words: Economic viability, Employment generation efficiency, Productivity and Sustainability.

Assam, the easternmost state of the Indian Union, has the unique distinction for producing Muga silk with an annual production of around 101 metric tonnes (2008-09) of Muga silk yarn. Muga silk is obtained from semi domesticated silk worm called *Antheraea assamensis* Helfer of which Som (*Persea bombycina* Kost.) and Soalu (*Litsaea polyantha* Juss.) are the primary food plants. The area under the Muga food plants, Som (*Persea bombycina* Kost.) and Soalu (*Litsaea polyantha* Juss.). in Assam is around 7305 hectares (*Economic Survey of Assam 2009-10* which is about 26-per cent of total cropped areas of Assam.

Now-a-days, Muga silk production has been fluctuating due to inadequacy in timely supply of quality seed and several other inherent constraints. With particular reference to seed, Assam alone presently needs one crore disease free layings (dfls) of Muga. Consequent upon the short supply of quality seed in time, the Muga rearers cannot utilize their plantation for rearing to their fullest potential even during the favorable commercial crops. Further, Muga silkworm rearing is conducted outdoor for which silkworms are exposed to fluctuating environmental conditions with profound impact on production and productivity during different seasons. Moreover, crop loss due to pebrine is a perpetual problem in Muga sector. Hence, the possibility of crop failure in Muga culture cannot be ignored. Moreover, most of the world's production in Muga comes from smallholdings. Because of the limited size of the holdings and limited rearing capacity, farmers get limited limited returns from the Muga culture which is not sufficient for most of the families to survive only on the income of Muga culture. This has made muga farmers to look for supporting cropping systems like crop intensification in space or intercropping introducing some new profitable crops as intercrops in between Som plantation which can sustain and be well suited under Assam agro climatic conditions. This will not only enhance the socio-economic conditions of the farmers by providing employment for longer duration and also enable them to exploit the upcoming marketing and processing infrastructure in this area. Keeping in view above facts, present investigation was carried out to evaluate production potential and economic viability of different Som based intercropping systems.

MATERIALS AND METHODS

The study was initiated to identify the promising need based intercropping system with Som for crop diversification and intensification at the research farm of Central Muga Eri Research & Training Institute, Jorhat, Assam during 2007-08 to 2009-10 (three years). The soil was sandy loam in texture and acidic in reaction (pH 5.03). It was medium in organic carbon (0.58%), low in available nitrogen (138 kg/ha), low in available phosphorus (6.87 kg/ha) and low in available potassium (91.3 kg/ha). The experiment was laid out in RBD with 3 replications. The treatments consisted of nine intercropping systems *viz.*, Som + Ginger, Som + Turmeric, Som+ Colocasia, Som + Patchouli, Som + Stevia, Som + Brahmi , Som + Colocasia > Potato (Colocasia followed by Potato), Som + Colocasia > Onion (Colocasia followed by Onion), Som + Colocasia > Garlic (Colocasia followed by Garlic) which were compared with Som sole cropping (Control). An area of 5040 m^2 under existing 13 years old Som plantation of 3m x 3m spacing was selected for the study. Three months before raising of intercrops, selected plantation was pruned at a height of 3 m (10 ft) above the ground level. For each treatment, replication wise individual plot of 144 m^2 size was prepared by harrowing and leveling the selected area. In each individual plot, three beds of 16.2 sq. m. size (1.8 m breadth and 9.0 m length) leaving 60 cm from each side of the Som plants were prepared and raised up to a height of 30 cm for plantation of intercrops. Recommended package of practices were followed for maintenance of both Som and intercrops. Nitrogen, phosphorus and potassium were supplied through urea, single super phosphate and muriate of potash as per recommended doses of the crops. The total rainfall received was 1026.1 mm, 611.7 mm and 1340.9 mm (126, 125 & 130 rainy days) during 2007-08, 2008-09 and 2009-10 respectively.

Leaf yield of Som was recorded before starting of two commercial rearings of

Muga silkworm during April-May and October-November per year which was converted to Muga cocoon equivalent yield based on silkworm rearing capacity of Som plantation in terms of disease free layings (dfls) and potential cocoon yield per dfl. The yield obtained from different intercrops were also converted to Muga cocoon equivalent yield by multiplying yield with prevailing farm gate price of produce and divided by price of Muga cocoons. The prevailing farm gate prices of produce were also used to work out the economics of different systems. The production efficiency (PE) was obtained dividing the total productivity of a system (in terms of Muga cocoon equivalent yield) by total duration of that system (Tomar & Tiwari, 1990). Total duration of the system includes period required for field preparation also.

The profitability of the systems was calculated by dividing the net returns (‘/ ha) in a system by 365 days. The relative productivity efficiency (RPE) and relative economic efficiency (REE) were calculated by using following formula (Urkurkar *et al*, 2006 and Urkurkar *et al*, 2008).

RPE (%) = (Total productivity of a system–Productivity of Som sole cropping)/ Productivity of Som sole cropping x 100

REE (%) = (Total net return of a system–Net return from Som sole cropping)/ Net return of Som sole cropping x 100

The sustainable yield index (SYI) and sustainable return index (SRI) were calculated by using following formula given by Singh *et al.* (1990).

SYI = (Total productivity of a system –Standard deviation) / Observed maximum productivity in the experiment over the years

SRI = (Total net return of a system – Standard deviation) / Observed maximum net return in the experiment over the years

Employment generation efficiency was determined dividing the total mandays employment for the system by 365 days and expressed in percentage.

RESULTS AND DISCUSSION

System productivity

The pooled data over 3 years revealed that the total productivity in terms of Muga cocoon equivalent yield was significantly higher in Som + Stevia intercropping system (117.1’000 numbers /ha) than other systems (Table 1). It was statistically at par with Som + Colocasia > Garlic (114.7’000 numbers /ha). Again, Som + Colocasia > Garlic was at par with Som + Colocasia > Potato (111.7’000 numbers /ha) and Som + Colocasia > Potato was at par with Som + Colocasia > Onion (109.3’000 numbers /ha). The relative productivity efficiency (RPE) also followed the similar trend. The production efficiency of different intercropping systems showed maximum efficiency in Som + Colocasia > Potato (304 numbers /ha/day) followed by Som + Patchouli (255 numbers /ha/day) systems.

Monetary returns

Different intercropping systems had different growth characters due to which the individual crop productivity does not give any comparable indication. Therefore, considering the prevailing market prices of inputs and farm gate prices of different produce, the net return, profitability and relative economic efficiency (REE) were worked out separately to have a proper interpretation of results. The maximum net returns (‘41,110 /ha/yr), profitability (‘ 112.6 /ha/day) and REE (87.8 %) were

Table 1. Productivity, relative productivity efficiency and production efficiency of different Som based intercropping systems (Pooled data of 3 years)

Treatments	Actual yield Muga cocoon ('000 nos./ha)	Actual yield Inter-crop (t/ha)	Total productivity in terms of Muga cocoon equivalent yield ('000 nos./ha)	RPE (%)	Duration of cropping systems days	Production efficiency (numbers/ (ha/day)
Som + Ginger	66.1	4.68	103.5	57.29	463	224
Som + Turmeric	66.8	5.64	95	44.38	467	203
Som + Colocasia	67.9	4.57	99.9	51.82	489	204
Som + Patchouli	66.5	1.49	96.3	46.35	378	255
Som + Stevia	65.1	0.52	117.1	77.96	498	235
Som + Brahmi	65.1	1.01	85.3	29.64	367	232
Som +Colocasia > Potato	67.2	6.35	111.7	69.76	367	304
Som +Colocasia > Onion	65.1	6.10	109.3	66.11	469	233
Som + Colocasia > Garlic	64.7	4.66	114.7	74.32	458	250
Som sole cropping	65.8	-	65.8	-	367	179
CD at 5%	1.16	0.18	3.21	-	-	-

obtained under Som + Stevia intercropping system which was followed by Som + Patchouli registering higher net returns (‘ 38,710 /ha/yr), profitability (‘ 106.1 /ha/day) and REE (76.8 %) than rest of the systems. (Table 2).

Sustainability

Sustainability with respect to total productivity reflects the fluctuation in yield over the years. Based on over the years analysis, sustainability of the system with respect to total productivity was found highest with Som + Stevia system (0.54) which was closely followed by Som + Colocasia > Garlic, Som + Colocasia > Potato and Som + Colocasia > Onion systems showing sustainability of 0.52, 0.49 and 0.47 respectively revealing the consistency of producing higher yields over the years and found to be more compatible than other systems. However, sustainability was the lowest (0.27) in Som + Brahmi showing less stability in order of merit and limited adoptability of the system in Assam.

Sustainability with respect to total net return was negative in all the systems. However, Som + Stevia (165.11), Som + Patchouli (165.17) and Som + Colocasia > Potato (165.19) showed more sustainability than other systems (Table 2).

Employment generation

Crop diversification through crop intensification will not only enhance the productivity and profitability of the farmers but also generates employment to the farming community for longer periods which will help in minimizing the problem of migration during lean periods after harvesting of Muga cocoons and even during the time of Muga crop failure. Employment generation efficiency of any diversified system is a direct

Table 2. Production and stability analysis of different Som based intercropping systems (Pooled data of 3 years)

Treatments	Total Net returns (‘/ha/yr)	Profitability (‘./ha/day)	REE (%)	Sustainable yield index	Sustainable return index	Mandays employment (days)	Employment generation efficiency (%)	Benefit cost ratio
Som + Ginger	34870	95.53	59.3	0.42	(-)165.26	257	70.41	1.51
Som + Turmeric	31805	87.14	45.29	0.35	(-)165.34	252	69.04	1.50
Som + Colocasia	34370	94.16	57.01	0.39	(-)165.28	257	70.41	1.52
Som + Patchouli	38710	106.1	76.84	0.36	(-) 165.17	278	76.16	1.67
Som + Stevia	41110	112.6	87.80	0.54	(-) 165.11	327	89.59	1.54
Som + Brahmi	28145	77.11	28.57	0.27	(-)165.43	243	66.58	1.49
Som +Colocasia > Potato	37760	103.5	72.5	0.49	(-) 165.19	250	68.49	1.51
Som +Colocasia > Onion	34630	94.88	58.2	0.47	(-)165.27	250	68.49	1.46
Som + Colocasia > Garlic	33450	91.64	52.81	0.52	(-)165.30	243	66.58	1.41
Som sole cropping	21890	59.97	-	0.10	(-)165.58	210	57.53	1.50
CD at 5%	3233	-	-	-	-	-	-	0.51

measure of it's preferability in any area. Som + Stevia and Som + Patchouli systems were found to be most preferable in terms of providing employment coupled with better economic returns. These systems employed maximum number of man-days in a year and showed highest employment generation efficiency (89.59 % and 76.16 % respectively) as compared with other systems (Table 2).

Economic viability

The maximum net returns, profitability, REE , sustainability with respect to total net return and employment generation efficiency were obtained under Som + Stevia intercropping system and it was followed by Som + Patchouli system. But amongst all the systems, Som + Patchouli was identified to be superior and more economically viable in terms of BCR (1.67) and ranked first in order of economic merit. The higher cost involved in Stevia cuttings and other intercultural operations increased the cost of cultivation of Som + Stevia system. Thus, Som + Stevia was in second rank in order of economic merit followed by Som + Patchouli (Table 2). Som + Colocasia > Garlic, Som + Colocasia > Onion and Som + Brahmi systems registered lower BCR than Som sole cropping indicating non-viability of the systems over Som sole cropping.

CONCLUSION

All the tested Som based intercropping systems were more efficient than Som sole crop with respect to total productivity in terms of cocoon equivalent yield, production efficiency, net returns, profitability, sustainability and employment generation efficiency. However, from BCR point of view, Som + Patchouli were found to be superior over all the systems which was followed by Som + Stevia. On the other hand, Som + Colocasia > Garlic, Som + Colocasia > Onion and Som + Brahmi systems were found economically non-viable over Som sole cropping.

Hence, it can be concluded that existing Som sole cropping system can effectively be diversified with the inclusion of various crops like Ginger, Turmeric, Colocasia, Stevia, Patchouli, Colocasia, followed by Potato to fetch higher economic returns from a plantation of Muga host plant, Som. However, amongst all the systems, Som + Patchouli has been identified as the most promising Som based intercropping system for agro climatic condition of Assam.

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J. Farming Systems Research & Development **17** (1&2) : 226-229 (2011)

EFFECT OF IRRIGATION SCHEDULING ON NPK CONCENTRATION, UPTAKE AND YIELD OF ZERO TILLED WHEAT (*TRITICUM AESTIVUM* L.)

Harveer Singh[1], V.P. Singh[2], H.K. Sachan[3], Deeksha Krishna[4] and Sandeep Singh Yadav[5]

[1]Research Scholar, SVPUAT, Meerut, [2]Professor Agronomy, GBPUAT, Pantnagar, [3]Assistant Professor Agronomy SGRR PG College, Dehradun, [4]Scientist Soil Science, IRRI India Office, New Delhi and [5]Field Officer Spices Board, Mudegre, Karnatka.

A field study during rabi 2004-05 was conducted on wheat (*Triticum aestivum* L.) crop variety PBW-343 to study the effect of irrigation scheduling on wheat NPK concentration, uptake and yield sown with the help of Pantnagar zero ferti seed drill on November 27, 2004 in Crop Research Centre (CRC), GBPUA&T.,Pantnagar, U.S.Nagar,Uttarakhand located at 29^{0}N latitude, 79.29^{0}E longitude and an altitude of 243.84 m above the mean sea level in the *Tarai* belt of Shiwalik range of the Himalayan foot hills characterized by a sub-tropical and sub humid climate. The experimental plot had silty clay loam soil, in texture and classified as mollisol. Soil of the experimental plot was rich in organic carbon, low in available nitrogen and medium in available phosphorus and potash and neutral in reaction. For the last several years rice - wheat cropping system was followed in the experimental field. Four treatments (different irrigation schedules (Irrigation at 0.3 IW/CPE ratio(I_1), Irrigation at 0.6 IW/CPE ratio(I_2), Irrigation at 0.9 IW/CPE ratio (I_3) and Irrigation at 1.2 IW/CPE ratio (I_4)) based on pan evaporation (mm/day) were replicated six times in a Randomized block design.The crop was fertilized at the rate of 150 kg N, 60 kg P_2O_5 and 40 kg K_2O per hectare through urea, single super phosphate (SSP) and muriate of potash (MOP) respectively. Isoproturon @ 1.0 kg/ha was applied at 30-35 days after sowing for the control of weeds. At maturity, net plot area (8.4m^2) was harvested manually and threshed with the help of Pullman thresher. The nitrogen, phosphorus and potash concentration (%) and uptake (kg/ha) in grain as well as straw at maturity were determined by modified micro kjeldahl method (Jackson 1973), molybdo vanado phosphoric acid method (Jackson 1973) with the help of spectrophotometer and flame photometer respectively. Nitrogen uptake (kg/ha) was calculated as follows:

$$\text{Total nitrogen uptake (kg/ha)} = \text{N uptake by straw (kg/ha)} + \text{N uptake by grain (kg/ha)}$$

Where,

$$\text{Nitrogen uptake by grain (kg/ha)} = \frac{\text{Nitgrogen concentration in grain (\%)} \times \text{grian yield (kg/ha)}}{100}$$

$$\text{Nitrogen uptake by straw (kg/ha)} = \frac{\text{Nitrogen concentration in straw (\%)} \times \text{straw yeild (kg/ha)}}{100}$$

Same procedure was adopted both for phosphorus and potassium.

Effect on NPK concentration

Nitrogen concentration in grain and straw

The maximum concentration of nitrogen in grain and straw was due to treatment IW:CPE 0.3, which was significantly higher than other IW/CPE ratio (0.6, 0.9 and 1.2) (Table-1). The N concentration in grain due to IW:CPE 1.2 and 0.9 being at par among them salves and significantly lower than due to IW/CPE 0.6. Due to IW/CPE 0.6 and 0.9, the nitrogen concentration in straw was at par among them salves insignificantly higher than IW/CPE 1.2.

Table 1. N, P and K concentration of grain and straw as influenced by different irrigation schedules

Treatment	Nitrogen (%)		Phosphorus (%)		Potassium (%)	
	Grain	Straw	Grain	Straw	Grain	Straw
IW:CPE = 0.3	1.799	0.523	0.342	0.073	0.336	1.251
IW:CPE = 0.6	1.755	0.510	0.351	0.080	0.346	1.314
IW:CPE = 0.9	1.711	0.504	0.363	0.085	0.355	1.405
IW:CPE = 1.2	1.706	0.493	0.373	0.096	0.363	1.49
S.Em±	0.011	0.003	0.002	0.002	0.002	0.007
C.D. at 5%	0.032	0.008	0.007	0.006	0.007	0.021

Phosphorus concentration in grain and straw

The maximum concentration of P in grain and straw was due to IW/CPE 1.2, which was significantly higher than IW/CPE 0.9, 0.6 and 0.3. The P concentration in grain due to IW/CPE 0.9 and 0.6 being significant to each other and also both had significantly higher value of P concentration than IW/CPE 0.3 (Table-1). The P concentration in straw due to IW:CPE 0.6 and 0.9 being at par with each other and significantly higher than IW/CPE ratio of 0.3.

Potassium concentration in grain and straw

The maximum concentration of K in grain and straw was due to IW/CPE 1.2, which was significantly higher than IW/CPE 0.9, 0.6 and 0.3 (Table-1). The K concentration in grain and straw due to IW:CPE 0.9 and 0.6 being significant to each other and also both had significantly higher value of K concentration than IW/CPE 0.3.

Effect on NPK uptake

N uptake of grain and straw

The maximum uptake of N of grain and straw was due to IW/CPE 1.2, which was significantly higher than other ratio (IW/CPE 0.3, 0.6 and 0.9). The N uptake of grain due to IW/CPE 0.6, 0.3 and 0.9 were at par among themselves (Table-2). The N uptake of straw due to IW:CPE 0.6 and 0.9 being at par among them selves and significantly higher than IW/CPE0.3. The total uptake of N by plant was significantly higher due to IW/CPE 1.2. Total uptake of N by plant due to IW: CPE 0.3 and 0.6 being at par among them selves and significantly lower than IW/CPE 0.9.

P uptake of grain and straw

Highest P uptake due to IW/CPE 1.2, which was significantly higher than other treatments (IW:CPE 0.3, 0.6 and 0.9) (Table-2). The P uptake by grain and straw due to IW/CPE 0.9 was at par with IW:CPE 0.6 and significantly higher than IW:CPE 0.3. The total uptake was significantly high due to IW:CPE 1.2 than other treatments (IW/CPE 0.6, 0.9 and 0.3). The total uptake by plant at IW/CPE 0.6 and 0.9 were at par with each and significantly higher than IW/CPE 0.3.

K uptake of grain and straw

The maximum uptake of K of grain and straw was due to IW/CPE 1.2, which

Table 2. N, P and K uptake by Grain, Straw and Total as influenced by different irrigation schedules.

Treatment	Nitrogen (kg ha^{-1})			Phosphorus (kg ha^{-1})			Potassium (kg ha^{-1})		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
IW:CPE = 0.3	57.2	26.3	83.61	11.40	3.7	15.19	11.1	73.4	84.57
IW:CPE = 0.6	59.9	29.0	88.36	12.09	4.6	16.75	11.7	79.2	90.97
IW:CPE = 0.9	60.7	30.3	91.12	12.53	5.0	17.54	12.2	82.5	94.85
IW:CPE = 1.2	71.8	32.1	103.9	4.94	5.8	20.80	14.5	86.9	101.55
S.Em±	1.12	0.46	1.03	0.26	0.16	0.29	0.23	1.28	1.25
C.D. at 5%	3.37	1.4	3.12	0.80	0.50	0.87	0.71	3.87	3.76

was significantly higher than other ratio (IW/CPE 0.3, 0.6 and 0.9) (Table-2). The K uptake of grain and straw due to IW:CPE 0.6 and 0.9 being at par among them selves and significantly higher than IW/CPE 0.3. The total uptake was maximum at IW/CPE 1.2, which was significantly higher than rest of IW/CPE ratio. The total uptake due to IW/CPE 0.6 and 0.9 were significantly among them selves and also significant over IW/CPE 0.3.

Effect on yield

Although, all yield attributes are decided by genetic makeup of that particular crop and variety, but the agronomic manipulation also affect them to a great extent. The reproductive growth depends on vegetative growth of plant, more vegetative growth increase number of leaves and supply photosynthates for the formation of spike, grains in spike and other yield attributes. In present study, it was observed that significant increase in grain yield was recorded due to increased IW: CPE ratios. The highest yield (40.1 q ha^{-1}) was obtained when irrigation water supply at IW: CPE ratio of 1.2 (Table-3). Increase in grain yield was due to increase in yield attributes and more so due to significant increase in number of spike per m^2, number of grains per spike, fertile spikelets per spike, spike length, 1000-grain weight and grain to straw ratio. Patel and Upadhyay, (1993) reported that the higher grain yield IW:CPE ratio 1.2, was the result of improved yield attributes, viz. effective tiller per meter row length, spikelets per spike, number of grains per spike, grain weight per spike and 1000-grain weight. Similar findings have also been reported by Khola *et al.* (1989), Sharma *et al.* (1990) and Gupta *et al.* (1990). The highest straw yield was

Table 3. Effect of different irrigation schedules on grain yield, straw yield, Biological yield of wheat

Treatments	Grain (q ha^{-1})	Straw (q ha^{-1})
IW: CPE = 0.3	32.6	50.0
IW:CPE = 0.6	33.4	53.6
IW: CPE = 0.9	34.1	55.5
IW: CPE = 1.2	40.1	58.3
S.Em±	0.62	0.87
C.D. at 5%	1.89	2.63

observed at IW: CPE 1.2, which was significantly higher than IW:CPE 0.9, 0.6 and 0.3. The straw yield with IW: CPE 0.9 and 0.6 being at par among themselves and significantly higher than that of IW:CPE 0.3.The biological yield (98.4 q ha^{-1}) and harvest index (43.4%) was also maximum at IW:CPE ratio 1.2 followed by 0.9, similar results were also confirmed by Patel and Upadhayay (1993).

From the above study, it may be concluded that, application of irrigation water at IW:CPE 1.2 proved to be optimum for exploiting the full production potential of wheat cv. PBW-343 grown in zero tillage (after harvest of rice crop) under shallow water table condition of the *Tarai* region of Uttaranchal. However, these finding are single crop based which in future needs to be confirmed on system basis.

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J. Farming Systems Research & Development **17** (1&2) : 230-233 (2011)

EFFECT OF MICRO-NUTRIENTS ON GROWTH, FLOWERING AND YIELD OF OKRA (*ABELMOSCHUS ESCULENTUS* L. MOENCH) CV. PARBHANI KRANTI.

Jitendra Kumar, Fateh Singh and Krishan Pal

Department of Horticulture, University Teaching Departments, Chaudhary Charan Singh University Campus, Meerut-250005, Uttar Pradesh.

Among the vegetables okra (*Abelmoschus esculentus* L.) belongs to malvaceae family, finds a prominent place and available in the market for a major part of the year. In the northern plains of India, it is grown mainly in two season i.e. kharif or rainy season and zaid or summer season but kharif is the main season for the cultivation. Application of adequate amount of fertilizers is one of the pre-requisite for exploiting the genetic potential of any crop. Role of (Hazara *et al.*, 1987) micronutrients viz.-zinc, boron and molybdenum have already been established by many plant researchers (Frolov and Frolova, 1983). The inadequately use and unbalanced fertilization may lead to poor yield and deficiency in produce for nutrient in question. In this aspect the present investigation was therefore, planned to study the response of micronutrients on growth, flowering and yield of okra (*Abelmoschus esculentus* L. Moench) cv. Parbhani Kranti.

The present investigation was carried out during summer season 2007 with commercial cultivar 'Parbhani Kranti' of okra at the Research Farm, Department of Horticulture, C.C.S. University Campus, Meerut. The experiment was laid out in randomized block design with two levels of zinc (100 ppm) (Z_1) and 150 ppm) (Z_2), two levels of boron (100 ppm (B_1) and 150 ppm) (B_2), their interaction (zinc x boron) (Z_0B_0) and one is control. There were total nine treatment combinations and all treatments randomly replicated three times among the plots at 30 x 30 cm spacing. The stock solution of each micro-nutrient viz. zinc and boron according to the concentration were made separately by dissolving zinc sulphate and borax. The chemicals were first dissolved in small amount of warm water and later on diluted to make the required concentration of solution and sprayed on experimental crop according to treatments. All cultural operations were performed during the experimentation period.

Effect of zinc and boron

It is evident from Table-1 that individual application of zinc and boron at different levels viz. 100 and 150 ppm show the significant effect in comparison to control (spray of distilled water) on various parameters of growth, flowering and yield. The results may be ascribe that zinc is necessary for the formation of tryptophane which is a precursor of IAA, promotes the plant growth and also helps in inflorescences development and boron play an important role in calcium uptake and translocation of photosynthetic substances from leaves to the growing part of the plant Abdollah *et al.*, (1984). Application of zinc @ 150 ppm gave the better performance in comparison to zinc @ 100 ppm in respect to plant height (70.15 cm), leaves per plant (20.20), days taken to appearance of first flower (43 days), days taken to appearance of first pod (47 days), length of pod (12.41 cm), diameter of pod (1.93 cm), fresh weight per pod (7.08 gm),

Table 1. Effect of Zinc and Boron on growth, flowering and yield of okra.

Treatments	Height of Plant (cm)	Number of leaves/ plant	Days taken for appear-ance of first flower	Days taken for appear-ance of first pod	No. of pods/ plants	Length of pod (cm)	Diameter of pod (cm)	Fresh weight /pod (g)	Weight of pods/ plant (g)	Weight of seeds/ pod (g)	No. of seeds/ pod	Yield of pods (q/ha)
Control C_O	57.63	16.20	45.00	50.00	9.60	11.36	1.70	6.55	63.80	1.44	32.07	71.49
Zinc application rates												
100 ppm Z_1	67.08	17.87	44.00	49.00	11.00	11.63	1.87	6.65	71.77	1.76	36.80	80.76
150 ppm Z_2	70.15	20.20	43.00	47.00	10.87	12.41	1.93	7.08	77.54	1.92	37.53	87.60
Boron application rates												
100 ppm B_1	65.23	18.73	43.40	47.80	10.4	12.20	1.86	6.64	71.78	1.76	36.47	81.44
150 ppm B_2	69.75	20.00	42.90	48.00	11.00	12.27	1.93	6.91	73.94	1.82	37.47	82.48
SEm±	0.322	0.232	0.112	0.088	0.163	0.106	0.016	0.087	0.327	0.030	0.276	0.253
CD at 5%	0.965	0.695	0.336	0.265	0.488	0.318	0.049	0.260	0.980	0.089	0.829	0.759

Table 2. Interaction effect of Zinc and Boron on growth, flowering and yield of okra.

Treatments	Plant height (cm)	Number of leaves/ plant	Days taken for appearance of first flower	Days taken for appearance of first pod	No. of pods/ plants	Length of pod (cm)	Diameter of pod (cm)	Fresh weight /pod (g)	Weight of pods/ plant (g)	Weight of seeds/ pod (g)	No. of seeds/ pod	Yield of pods (q/ha)
Control (Z_OB_O)	57.63	16.20	45.00	50.00	9.60	11.36	1.70	6.55	63.80	1.44	32.07	71.49
Z_1B_1	69.92	19.00	42.40	46.40	11.20	12.20	1.90	6.90	72.33	1.82	37.40	83.00
Z_1B_2	72.50	20.57	41.80	45.53	11.53	12.80	2.05	6.94	74.07	1.84	38.07	85.00
Z_2B_1	76.56	20.53	41.47	45.60	12.00	12.82	1.96	7.45	77.98	1.98	38.27	87.70
Z_2B_2	80.50	22.00	41.00	45.20	12.80	14.06	2.01	7.68	82.85	2.04	41.07	91.86
SEm±	0.322	0.232	0.112	0.088	0.163	0.106	0.016	0.087	0.327	0.030	0.276	0.253
CD at 5%	0.965	0.695	0.336	0.265	0.488	0.318	0.049	0.260	0.980	0.089	0.829	0.759

weight of pod per plant (77.54 gm), weight of seeds per pod (1.92 gm), no. of seeds per pod (27.53) and yield of pod (87.60 q/ha) except to more no. of pods/ plant (11 pods) was recorded under the treatment Z_1, where zinc was applied @ 100 ppm. As well as application of boron at higher concentration i.e. 150 ppm gave the better result in respect to plant height (69.75 cm), no. of leaves per plant (20.00), days taken for appearance of first flower (42.90), no. of pods per plant (11.00), length of pod (12.27 cm), diameter of pod (1.93 cm), fresh weight per pod (6.91 gm), weight of pods per plant (73.94 gm), weight of seeds per pod (1.82 gm), no. of seeds per pod (37. 47) and yield of pods (82.48 q/ha), while early appearance of first pod (47.8 days) was recorded at lower concentration i.e. @ 100 ppm of boron. Comparative study of zinc and boron application at higher concentration i.e. 150 ppm revealed that application of zinc show the better effect in most of the parameters. Zinc being precursor of Auxin (IAA), promotes the plant height, early flowering, cell elongation etc. and ultimately reflected on yield Singh and Moruya (1979).

Interaction effect of zinc and boron

Combined application of zinc and boron at higher concentration under the treatment Z_2B_2 (150 ppm zinc and boron application, gave better effect in respect to plant height (80.50 cm), no. of leaves per plant (22.00), days taken to appearance of first flower (41.00 days), days taken to appearance of first pod (45.20 days), no. of pods per plant (12.80), length of pods (14.06 cm), diameter of pods (2.01 cm), fresh weight per pod (7.68 gm), weight of pods per plant (82.85 gm), weight of seeds per pod (2.04 gm), no. of seeds per pod (41.07) and yield of pods (91.86 q/ha) in comparison to other treatment i.e. individual application of zinc and boron as well as combined application of zinc and boron. Beneficial effect of combined application of zinc and boron on growth, flowering and yield attributes in okra is due that zinc is necessary for the formation of tryptophate which is precursor of IAA, promotes the plant growth, carbohydrates metabolism and boron actively engaged in calcium uptake and translocation of photosynthetic substances from leaves to the growing part of plant, role as activator in different enzymes, acting as early flower inducers. Findings are in aggrements with the earlier report by Verma *et al.*, 1973.

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