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Effect of preceding crops and nutrient management on productivity of wheat (*Triticum aestivum*)–based cropping system in arid region

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ABSTRACT

A field experiment was conducted during 2003–04 and 2004–05 at Jodhpur to study the effect of preceding crops, viz. pearlmillet [*Pennisetum glaucum* (L.) R. Br. emend. Stuntz.], greengram (*Phaseolus radiatus* L.) and clusterbean [C*yamopsis tetragonoloba* (L.) Taub.] and nutrient management practices on the production potential of wheat (*Triticum aestivum* L. emend. Fiori & Paol.)–based cropping systems in arid region of Rajasthan. Growing of clusterbean and greengram as the preceding crop resulted in significantly higher grain yield of wheat and the N and P uptake than the preceding pearlmillet. Among the rainy season (*kharif*) crops, greengram gave the maximum wheat grain-equivalent yield (WGEY) and net returns, but N uptake was significantly highest with clusterbean. However, highest WGEY (5.58 t/ha) was recorded with greengram-wheat, being 10 and 31.3% higher than that of the clusterbean–wheat and pearlmillet–wheat crop sequences respectively. Net returns and benefit : cost ratio were also maximum with greengram–wheat, but maximum gain in available N and P status was noted with clusterbean-wheat sequence. Integrated use of FYM @ 7.5 t/ha + 50% RDF (50 kg N + 13.25 kg P/ha) + biofertilizer (*Azotobacter* + PSB) recorded significantly highest grain yield of wheat, which was 33.2% higher than in the control. Yield and nutrient uptake by *kharif* crops also increased markedly due to residual effect of FYM applied either alone or in combination. The highest WGEY, net returns and benefit: cost ratio of crop sequences were recorded with combined application of FYM @ 7.5 t/ha + 50% RDF + biofertilizer. The maximum gain in available N and P status was observed with the application of FYM @ 15 t/ha, followed by FYM @ 7.5 t/ha + 50% RDF + biofertilizer. Thus wheat grown after legumes (greengram or clusterbean) with combined application of FYM @ 7.5 t/ha + 50% RDF + biofertilizer gave maximum WGEY and monetary benefit.

***Key words*:** Preceding crops, Nutrient management, Wheat, Cropping sequence, Sustainable yield

In arid region of Rajasthan, wheat (*Triticum aestivum* L. emend. Fiori & Paol.) cultivation is gaining much popularity owing to increase in irrigation facilities. The area under wheat cultivation has increased from 0.6 million ha in 1975-76 to 2 million ha in 2004–05. However, it's average productivity (2.69 t/ha) is still lower than its potential in the region. Besides, intensive cropping has emerged as an important factor of low productivity of wheat in the region. Since most of these soils are deficient in organic matter, available N and P (Tripathi and Praveen Kumar, 2000). Further cultivation of nutrient exhaustive crops in the sequence without adequate nutrient management led to deterioration in soil health as well as productivity. Under such a condition, proper selection of suitable crops in the sequence and supply of balanced nutrients through appropriate sources can not only meet the nutrient requirement of the crops but also aid in sustaining the soil fertility. Inclusion of legumes play vital role in improving soil fertility through addition of biologically fixed nitrogen (Ali *et al.*, 2002). Studies conducted in the arid region showed that clusterbean [*Cyamopsis tetragonoloba* (L.) Taub.]–pearlmillet [*Pennisetum glaucum* (L.) Br. emend. Stuntz.], rotation was superior to continuous pearlmillet cropping because of maintenance of higher organic matter in the soil (Saxena *et al.*, 1997). Further, integration of farm yard manure (FYM) along with chemical nitrogen significantly increased the yield of wheat as well as of succeeding greengram (Yadav *et al*., 2003). Hence the present investigation was made to find out the effect of preceding crops and nutrient management on the productivity of wheat based cropping system.

MATERIALS AND METHODS

A field experiment was conducted during 2003-04 and 2004-05 under on farm research programme of Central Arid Zone Research Institute at Satheen village of Jodhpur district (Rajasthan). The soil was sandy loam with pH 7.9, low in organic C (0.28%) and available N (124 kg/ha),

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medium in available P (11.5 kg/ha) and adequate in available K (242 kg/ha). The study consisted of three preceding crops [pearlmillet, greengram (*Phaseolus radiatus*) and clusterbean] and four nutrient- management treatments, viz. the control, FYM @ 15 t/ha, 100% RDF (100 kg N + 26.5 kg P/ha) and FYM @ 7.5 t/ha+ 50% RDF (50 kg N+ 13.25 kg P/ha) + biofertilizer (*Azotobacter* + PSB)]. A split plot design was followed with three replications. The preceding crops were allotted in main plots and the nutrient management treatments in subplots.

During the rainy season (*kharif*), pearlmillet 'HHB 67', greengram 'K 851' and clusterbean 'RGC 936' were sown in rows 45 cm apart on 11 July 2003 and 9 July 2004 under rainfed condition, and harvested at the physiological maturity. Recommended dose of fertilizer, i.e. 40 kg N + 17.5 kg P/ha in pearlmillet and 20 kg N + 17.5 kg P/ha in clusterbean and greengram were applied through urea and single superphosphate. Half the N and full quantity of phosphorus in pearlmillet and full N and phosphorus in clusterbean and greengram were applied at the time of sowing. The remaining N was top dressed at tillering stage of pearlmillet. Wheat 'Raj 3077' was sown in rows 22.5 cm apart on 24 and 20 November during *rabi* season using seed rate of 100 kg/ha under irrigated condition at the same location. The crop was harvested on 6 March 2004 and 1 March 2005. The gross plot size was 24.75 m^2 (4.5 x 5.5 m). Properly decomposed FYM, containing 0.51% N, 0.26% P, and 0.60% K with 30 : 1 C : N ratio, was applied at 15 days before sowing wheat, whereas half the N and full dose of P as per treatments were applied through urea and single super phosphate at the time of sowing. The remaining N was top dressed in two equal splits, i.e. at crown-root and panicle initiation stages of the crop. The wheat seed was inoculated with biofertilizers (*Azotobacter* and phosphate solubilizing bacteria) and was sown as per treatment. Other packages of practices were followed as per recommended practices for all the crops. Wheat-grain equivalent yield and economics were calculated considering the prevailing market prices of inputs and outputs. N and P contents were determined in seed and straw of all the rainy season (*kharif*) crops and wheat. Nutrient uptake (N and P) was estimated by multiplying the nutrient content with respective yields. Soil was analysed at the initial stage and after completion of the study to monitor the changes in nutrient status due to different treatments. Total rainfall received during the study was 418 and 222 mm in the respective years.

RESULTS AND DISCUSSION

Growth and yield of wheat

The preceding crops significantly influenced the growth and yield attributes of wheat except test weight during both the years (Table 1)**.** Raising of wheat after clusterbean recorded the highest plant height, effective tillers/m^2 and grains/spike, which were comparable to those obtained after greengram. However, wheat raised after pearlmillet has significantly lower plant height, effective tillers/m^2 and grains/spike compared with the preceding clusterbean and greengram. Wheat raised after either greengram or clusterbean gave significantly higher grain yield than the preceding pearlmillet during both the years. Wheat preceded by greengram (2003-04) and clusterbean (2004**–**05) gave the highest grain yield. On an average, mean grain yield of wheat was 12.20 and 10.45% higher due to the preceding clusterbean and greengram respectively than that of preceding pearlmillet. Growing of clusterbean and greengram as the preceding crops improved physical, chemical and microbiological properties of the soil compared with that preceding pearlmillet, which in turn improved the yield-attributing parameters and yield of the succeeding wheat. Singh *et al*. (2003) also reported the beneficial effect of including legumes in sequence on soil health and yield of the succeeding crop compared with that of the cereal-cereal crop sequence.

All the nutrient-management treatments significantly influenced the growth, yield attributes (except test weight) and yield of wheat compared with control. Among the nutrient-management treatments, application of FYM @ 7.5 t/ha + 50% RDF + biofertilizers recorded the highest plant height, effective tillers/m^2, grains/spike and 1000-seed weight during both the years. The highest grain yield of wheat was also recorded with the combined application of FYM @ 7.5 t/ha + 50% RDF + biofertilizers, being 7.81, 13.49 and 38% higher during 2003-04, and 3.14, 11.41 and 24.91% during 2004-05 over 100% RDF and FYM @ 15 t/ha and the control respectively; and its mean increase was 5.37, 12.42 and 33.21% respectively. This could be attributed to the supply of most of the required macro- and micro-nutrients in adequate amount for a long time due to slow release of nutrients by the FYM, besides increasing the soil micro-flora activities and improving the physical properties of the soil. Further, addition of N and P through organic fertilizer played vital role to meet the immediate nutrient requirement of the crop, whereas production of amino acids, vitamins and growth-promoting substances by *Azotobactor* and PSB resulted in improvement of growth and productivity of the crop (Singh, 2006; Gawai and Pawar, 2006).

Yield of rainy season crops

In general the yield of all the *kharif* crops was better during 2003 owing to higher rainfall (88.29%) than during 2004 (Table 2). The mean seed yield of *kharif* crops converted into WGEY revealed that greengram gave signifi-

Table 1. Yield attributes and yields (t/ha) of wheat, rainy season crops and crop sequences as influenced by preceding crops and nutrient management practices

Treatment	Plant height (cm)	Effective tillers/m^2	Grains/ spike	Test weight (g)	Grain yield of wheat		Seed yield of *kharif* crops		WGEY of *kharif* crop	WGEY of sequence	
					2003	2004	2003	2004		2003	2004
Preceding crops											
Pearlmillet	77.3	275.5	27.2	38.3	2.79	3.12	0.87	0.66	0.83	4.16	4.33
Greengram	80.1	296.3	35.6	38.9	3.15	3.39	0.65	0.50	1.81	5.70	5.47
Clusterbean	81.6	317.3	37.7	39.0	3.01	3.42	0.69	0.35	1.24	5.31	4.83
SEm±	0.6	3.1	1.1	1.3	0.05	0.06	0.03	0.03	0.18	0.18	0.17
CD (P=0.05)	2.3	12.1	4.2	NS	0.18	0.25	0.10	0.13	0.40	0.70	0.65
Nutrient management											
Control	70.4	246.3	30.2	36.9	2.50	2.89	0.72	0.40	1.14	4.40	4.19
FYM @ 15 t /ha	82.1	300.3	34.1	39.1	3.04	3.24	0.76	0.62	1.42	5.03	5.02
RDF	82.9	311.3	35.9	39.4	3.20	3.50	0.71	0.47	1.28	5.23	5.06
FYM @ 7.5 t/ha + 50% RDF + biofert.	83.2	327.0	36.2	39.6	3.45	3.61	0.75	0.52	1.35	5.55	5.26
SEm±	1.9	5.8	1.1	1.5	0.17	0.16	0.02	0.02	0.18	0.21	0.19
CD (P=0.05)	5.7	17.5	3.3	NS	0.51	0.48	0.05	0.06	0.32	0.63	0.57

cantly higher equivalent yield than clusterbean and pearlmillet, being respectively 46 and 118%. This was mainly owing to higher market price of greengram seed than of clusterbean and pearlmillet.

Application of FYM in wheat showed significant residual effect on the yield of *kharif* crops. However, application of FYM @ 15 t/ha in wheat recorded the highest WGEY of *kharif* crops, followed by FYM @ 7.5 t/ha + 50% RDF + biofertilizers. The mean WGEY of *kharif* crops increased by 24.56 and 18.42% due to residual effect of FYM @ 15 t/ha and FYM @ 7.5 t/ha + 50% RDF+ biofertilizers respectively over the control. Ismail *et al*. (1998) also reported increase in the yield of the succeeding crop due to residual effect of FYM.

Sequence productivity

Data on the sequence productivity indicated that WGEY was significantly influenced by the preceding crops and nutrient-management treatments (Table 1). The sequence involving greengram gave the highest WGEY which being on a par with that of clusterbean-wheat recorded significantly higher than pearlmillet–wheat sequence during both the years. Clusterbean-wheat sequence also had significant effect on WGEY than pearlmillet–wheat sequence during 2003-04, but it remained at par during 2004–05. On mean basis, greengram-wheat and clusterbean-wheat significantly increased the WGEY by 31.29 and 19.29%, respectively over pearlmillet–wheat sequence. In fact the crop sequence involving legumes played an important role in restoring the soil fertility in terms of N and other biological parameters due to atmospheric N fixation through symbiotic process, which in turn improved the yield of the succeeding crop compared with that of the cereal-cereal crop sequence (Ramesh and Reddy, 2004). Further, better price of greengram and clusterbean seed than of pearlmillet also played a vital role in improving the WGEY. The results reveal the importance of inclusion of legumes in the cropping sequence.

Maximum WGEY of crop sequences was recorded with the combined application of FYM @ 7.5 t/ha + 50% RDF + biofertilizers, followed by 100% RDF and FYM @ 15 t/ha, which being on a par recorded significantly higher than the control during both the years (Table 1). However, the increase in mean WGEY due to combined application of FYM @ 7.5 t/ha + 50% RDF+ biofertilizers was 5.06, 7.57 and 25.58% compared with that of 100% RDF, FYM @15 t/ha and the control respectively. It might be attributed to the combined effect of organic, inorganic and biofertilizers, which not only supplied the required nutrients in adequate amount, but also improved the physico-chemical properties of the soil, leading to improved total productivity of the sequence.

Nutrient uptake

After 2 years of the study it was observed that nutrient uptake was significantly influenced by the preceding crops (Table 3). Clusterbean and greengram recorded significantly higher N uptake, which was 37.8 and 26.7%, respectively higher than of pearlmillet. But P uptake was not significantly influenced by the preceding crops. However, pearlmillet gave the maximum P uptake and greengram the lowest. Apparently the maximum N uptake was due to increased better utilization of resources and higher N content in clusterbean and greengram compared than in pearlmillet, whereas the maximum P uptake was due to the higher biological yield of pearlmillet than of clusterbean and greengram. The nutrient management treatments applied to wheat significantly influenced the N uptake by *kharif* crops. Maximum N and P uptake by the *kharif* crops was recorded with the application of FYM @ 15 t/ha in wheat. Application of FYM @ 7.5 t/ha + 50% RDF + biofertilizer and 100% RDF in wheat also showed marked increase of N and P uptake over the control. Actually the residual effect of FYM improved the soil fertility, which in turn increased the biological yield of *kharif* crops and thereby N and P uptake.

The highest N uptake by wheat was recorded when it was grown after cluster bean followed by greengram, which, being at par, recorded significantly higher than the preceding pearlmillet, but P uptake remained unaffected. Improvement in the available N status of the soil due to the preceding cluster bean and greengram might have improved the N uptake by wheat. Integrated application of FYM @ 7.5 t/ha + 50% RDF + biofertilizer resulted in significantly highest N and P uptake, followed by that of 100% RDF and FYM @ 15 t/ha over the control. The increase in N and P uptake could be mainly attributed to the production of higher yield of wheat due to favourable effect of different nutrient-management treatments.

Nutrient balance

Inclusion of legumes (clusterbean and greengram) in the crop- sequence significantly influenced the available N and P status in the soil compared with that of pearlmillet (Table 3). Maximum available N and P were recorded when clusterbean was included in the sequence, followed by greengram. However, clusterbean-wheat and greengram–wheat sequences increased the available N by 14.17 and 12.5% and available P by 9.8 and 7.4% respectively over the pearlmillet–wheat sequence. Inclusion of legumes (clusterbean and greengram) in the sequence increased the available N and P status leading to improved soil health (Ali *et a*l, 2002).

The nutrient management treatments including FYM either alone or in combination contributed to significant increase in the available N and P status (Table 3) compared with the remaining treatments. Application of FYM @ 15 t/ha resulted in maximum improvement in the available N and P status (21.37 and 23.68% respectively), followed by that of FYM @ 7.5 t/ha + 50% RDF+ biofertilizers (17.09 and 19.3%, respectively) compared with the control. This was owing to the improvement of soil health due to addition of nutrients and increased availability of native nutrients with FYM application.

Economics

The net returns and benefit : cost ratio was significantly affected by the preceding crops and nutrient- management treatments (Table 2). Among the kharif crops, greengram

Table 2. Effect of preceding crops and nutrient management on the economics (x 10^3 Rs/ha).

Treatment	*Kharif* crops			Wheat			Total economic returns		
	Cost of cultivation	Net returns	B : C ratio	Cost of cultivation	Net returns	B : C ratio	Cost of cultivation	Net returns	B : C ratio
Preceding crops									
Pearlmillet	7.51	0.29	1.04	17.79	12.59	1.71	25.07	12.89	0.51
Greengram	7.05	9.09	2.29	17.79	16.32	1.92	24.84	25.41	1.02
Cluster bean	7.05	3.95	1.56	17.79	16.83	1.95	24.84	20.78	0.84
SEm±		0.38	0.06		0.53	0.05		0.71	0.06
CD (P=0.05)		1.50	0.23		2.10	0.21		2.79	0.25
Nutrient management									
Control	7.20	3.06	1.42	15.09	13.30	1.88	22.29	16.36	0.73
FYM @ 15 t/ha + RDF	7.20	5.05	1.77	19.79	12.61	1.64	26.99	18.21	0.67
100% RDF	7.20	4.18	1.58	17.59	17.31	1.98	24.79	21.49	0.87
FYM @ 7.5 t/ha+50% RDF+biofert.	7.20	4.94	1.69	18.69	17.77	1.95	24.98	22.72	0.88
SEm±		0.46	0.07		0.61	0.06		0.86	0.07
CD (P=0.05)		1.40	0.21		1.85	0.18		2.60	0.21

Price of seed: Rs/kg: Greengram, 26.00; clusterbean, 19.00; pearlmillet, 7.00; wheat, 9.00, straw of all the crops 1.00/kg

fetched the maximum net return and benefit: cost ratio followed by clusterbean; and pearlmillet gave the lowest because of lower market price of its grain compared with that of the other two crops. Raising of wheat after clusterbean provided the maximum net returns and benefit: cost ratio, followed by the preceding greengram. This increase was owing to the production of maximum wheat yield due to beneficial effect of the preceding clusterbean and greengram compared with that of pearlmillet. Economics of crop sequences as a whole indicated that greengram-wheat sequence gave maximum net returns (Rs 25,418) and benefit: cost ratio (1.02), followed by that of clusterbean-wheat sequence and pearlmillet-wheat sequence the lowest. Beneficial effect on wheat yield and market price of greengram and cluster bean attributed towards the increase of monetary benefit compared with that of pearlmillet.

Application of FYM @ 15 t/ha in wheat realized the maximum net returns and benefit : cost (B : C) ratio of *kharif* crops, followed by FYM @ 7.5 t/ha + 50% RDF + biofertilizer. The monetary benefit was owing to the improvement in yield of kharif crops due to residual effect of FYM. The maximum net returns (Rs 22,722) and benefit : cost ratio (0.88) of wheat and crop sequences were recorded with the application of FYM @ 7.5 t/ha+ 50% RDF + biofertilizer in wheat, due to greater yield low cost of the treatment.

The interaction effect of preceding crops and nutrient management on wheat grain- equivalent yield and net returns was significant (Table 4). Growing of wheat after greengram along with integrated application of FYM @ 7.5 t/ha + 50% RDF + biofertilizer resulted in highest wheat grain equivalent yield (6.05 t/ha) and net returns (Rs 28,655/ha), followed by the application of 100% RDF in wheat under greengram–wheat sequence. Wheat raised after clusterbean with the application of FYM @ 7.5 t/ha + 50% RDF+ biofertilizer to wheat also increased the wheat grain-equivalent yield markedly as well as the net returns under clusterbean–wheat sequence. But growing of wheat after pearlmillet under these treatments did not increase its yield.

Thus it was concluded that growing of wheat after greengram or clusterbean with integrated application of FYM @ 7.5 t/ha + 50% RDF (50 kg N + 13.25 kg P/ha) + biofertilizer (*Azotobacter*+ PSB) is effective and economically beneficial for attaining maximum and sustain-

Table 4. Interaction effect of preceding crops and nutrient management on wheat grain equivalent yield and economics

Nutrient management	Preceding crops		
	Pearlmillet	Greengram	Clusterbean
	Wheat grain equivalent yield		
Control	3.56	4.89	4.61
FYM @ 15 t /ha	4.28	5.63	5.20
100% RDF	4.47	5.78	5.16
FYM @ 7.5 t/ha + 50% RDF + Biofert.	4.68	6.05	5.72
Mean	4.25	5.58	5.07
SEm±		0.35	
CD (P=0.05)		1.05	
	Net returns (x 10^3 Rs ha)		
Control	10.25	21.70	17.12
FYM @ 15 t /ha	10.22	23.85	20.57
100% RDF	15.27	27.46	21.73
FYM @ 7.5 t/ha + 50% RDF + Biofert.	15.81	28.65	23.69
Mean	12.89	25.41	20.78
SEm±		1.02	
CD (P=0.05)		3.06	

Table 3. Effect of preceding crops and nutrient management on nutrient uptake and nutrient balance

Treatment	Nutrient uptake (kg/ha)				Net available soil nutrients (kg/ha)		Loss or benefit over initial value (%)	
	Kharif crops		Wheat					
	N	P	N	P	N	P	N	P
Preceding crops								
Pearlmillet	43.9	26.1	146.4	36.3	120	12.2	-3.3	6.1
Greengram	55.6	21.9	154.9	40.0	135	13.1	8.9	13.9
Clusterbean	60.5	24.5	168.8	40.2	137	13.4	14.2	16.5
SEm±	3.1	1.2	2.7	1.9	3.0	0.6		
CD (P=0.05)	9.8	NS	7.8	NS	8.5	NS		
Nutrient management								
Control	38.0	18.4	122.2	32.1	117	11.4	-6.0	-0.08
FYM @ 15 t /ha + RDF	63.8	27.8	155.6	38.0	142	14.1	14.6	22.6
100% RDF	51.4	25.6	165.6	42.1	126	13.3	1.6	15.7
FYM @ 7.5 t + 50% RDF + Biofert.	60.4	24.8	183.4	43.4	137	13.6	10.5	18.3
SEm±	3.9	3.2	4.9	2.21	3.3	0.9		
CD (P=0.05)	11.8	9.6	14.4	6.4	9.7	2.9		

able yield of wheat and crop sequence in the arid region of Rajasthan.

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