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Integrated nitrogen management in rice (*Oryza sativa*)–wheat (*Triticum aestivum*) cropping system

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ABSTRACT

A field experiment was conducted during 1996–97 and 1997–98 to evaluate the effect of 4 organic sources of nutrients along with 4 levels of N to rice (*Oryza sativa* L.) and 4 levels of fertilizer N to wheat (*Triticum aestivum* L. emend. Fiori & Paol.) on the productivity and nutrient removal in rice–wheat system. Grain yields of rice obtained at 40 kg N/ha with green-manuring of *Sesbania* was similar to that obtained with application of 120 kg N/ha under cowpea [*Vigna unguiculata* (L.) Walp.] fodder, wheat straw incorporation and the control, indicating a saving of 80 kg N/ha. Application of 120 kg N/ha to wheat grown in *Sesbania* green-manured rice plots yielded about 0.6 tonne/ha more wheat grain than that only with 120 kg N/ha. However, integrated use of *Sesbania* green manure along with 120 kg N/ha gave 6.8 tonnes/ha of rice grain and subsequent application of 120 kg N/ha to succeeding wheat crop yielded 4.7 tonnes/ha of wheat grain, thus giving total production of 11.5 tonnes/ha from rice–wheat sequence. At this production level and fertilizer use, rice removed 155.7, 27.7 and 172.4 kg N, P and K/ha and respective values for wheat were 126.2, 24.3 and 140.0 kg/ha, making a total removal of 646.3 kg nutrients (MPK)/ha/annum from rice–wheat system.

Key words : Integrated nitrogen management, Yield, Nutrient uptake, Rice–wheat cropping

The foodgrain requirement of the country is estimated at 243.2 million tonnes by 2006–07. Rice and wheat combinedly contribute 77%, while rice–wheat cropping system shares 22% of current national foodgrain production. Rapid spread of rice–wheat system in India caused an eclipse on sustainability of soil productivity (Rattan and Singh, 1997). To meet the foodgrain requirement of the growing population and sustainability at reasonably higher productivity level, especially in developing countries like ours is the need of the hour. In this context low-input sustainable agriculture (Grubinger, 1992) and reduced chemical inputs (Kirchner *et al.*, 1993) concepts which focus on the reconsideration of agricultural practices, such as green manuring, recycling crop residues and animal manures, and inclusion of legumes in rotation will be important. However, since these practices cannot meet the total nutrient needs of modern agriculture, integrated use of nutrients from fertilizers and organic sources seems to be more appropriate. Therefore the present study was undertaken to generate information for sustained yields of rice–wheat system through integrated N management.

MATERIALS AND METHODS

The experiment was carried out at Crop Research Centre of the Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, during 1996–97 and 1997–98. The soil of the experimental field was silty clay loam with pH 7.4, organic carbon 1.092%, available nitrogen 224 kg/ha, available phosphorus 20.2 kg/ha, and available potassium 140 kg/ha. Four organic sources of nutrients (*Sesbania aculeata* Pers.) green manuring, inclusion of cowpea fodder crop in rotation, wheat straw incorporation and no organic management) along with 4 inorganic nitrogen levels (0, 40, 80 and 120 kg N/ha) were applied to rice crop. The second crop wheat also received 4 levels of nitrogen (0, 40, 80 and 120 kg N/ha) in rice–wheat system. The trial was laid out in split split-plot design, keeping organic sources in main plot, level of nitrogen applied to rice in sub-plot, and level of nitrogen to wheat in sub-sub-plot, with 3 replications, during both the years in the same plots. *Sesbania aculeata* and cowpea and cowpea fodder were sown on 19 May 1996 and 12 May 1997. Green-manure crop was incorporated at 55 days old stage, cowpea fodder crop was harvested at 50% flowering stage (50 days old) and small pieces (4 – 5 cm) of wheat straw @ 7.5 tonnes/ha were incorporated at puddling according to the treatments in both the years. Nitrogen was applied in 3 splits (50% at planting, 25% at tillering and 25% at panicle initiation) to rice and in 2 splits (50% at sowing and 50% after first irrigation) to wheat. Phosphorus @ 40 kg/ha to both the crops and potassium @ 30 kg/ha to rice only were applied as basal dose. Thirty-day-old seedlings of 'Pant Dhan 4' rice were transplanted on 16 and 6 July during 1996 and 1997, respectively, at a spacing of 20 cm × 15 cm. 'WH 542' wheat was sown on 21 November 1996 and 24 December 1997 in lines of 23 cm apart using 100 kg seed/ha. The N content was analysed by micro-Kjeldhal's method, phosphorus by vanado-molybdo phosphoric acid yellow colour method and potassium was estimated by flame photometry method as per Jackson (1973). The composition and dry-matter production of organic sources used in the experiment are given in Table 1.

RESULTS AND DISCUSSION

Yield and yield attributes of rice

Rice grain yield was significantly highest with *Sesbania* green manure and minimum with the control (Table 2). Yield of rice obtained with cowpea in rotation and wheat straw incorporation, being at par, were significantly higher than that under the control. Increase in rice grain yield owing to green-manure over cowpea fodder, wheat straw incorporation and the control was respectively 7.4, 7.0 and 20% in 1996; and 13.2, 12.8 and 27.8% in 1997. These results are in close conformity with the findings of Thakur *et al.* (1995). This might be due to more panicles/m^2, spikelets/panicle and 1,000-grain weight. Higher values of yield attributes under organic source of nutrients might be due to contribution of more nutrients towards nutrition of rice crop since *(i)* organic materials, acting as slow-release source of N, are expected to more closely match N supply with rice N demand, and this could reduce N losses (Becker *et al.*, 1994) and *(ii)* green-manure incorporation might lead to better P nutrition by reducing the bonding energy and P sorption maxima (Hundal *et al.*, 1988).

Increase in level of applied nitrogen brought significant improvement in rice yield and yield attributes even up to 120 kg N/ha (Table 2). There was 29.6, 50.7 and 59.6% increases in rice grain yield owing to 40, 80 and 120 kg N/ha over the control during 1996–97, and 24.8, 37.5 and 51.7% during 1997–98. The results confirm the findings of Mahapatra and Sharma (1995). Interaction effect of *Sesbania* green manure and 120 kg N/ha resulted in 6.5 tonnes/ha and 7.1 tonnes/ha of rice grain during 1996 and 1997 respectively. Based on regression model for grain yield to fertilizer N applied to rice, it was estimated that *Sesbania* green-manure without addition of fertilizer N increased the grain yield by 822 kg/ha in 1996 and 1,202 kg/ha in 1997 which was equal to that predicted with application of 34 kg fertilizer N/ha in 1996 and 49 kg fertilizer N/ha during 1997 to rice.

Likewise, *Sesbania* green-manure along with 40 kg fertilizer N/ha applied to rice, increased the grain yield by 1,969 and 2.337 kg/ha which was equal to that predicted when 95 and 143 kg fertilizer N/ha was applied to rice without green manure, indicating a saving of 55 and 103

Table 1. Biomass production, nutrient content and accumulation in organic source

Character	Organic source					
	Sesbania aculeata		Wheat straw		Cowpea	
	1996–97	1997–98	1996–97	1997–98	1996–97	1997–98
Green manure biomass (tonnes/ha)	26.3	24.6			21.5	20.6
Dry matter (tonnes/ha)	5.4	4.8	7.5	7.5	6.1	5.9
Organic carbon (%)	38.6	39.2	45.2	44.3	Harvested at	
Nitrogen content (%)	2.27	2.32	0.592	0.571	50% flowering for	
Phosphorus content (%)	0.36	0.34	0.040	0.038	fodder	
Potassium content (%)	2.03	2.10	1.78	1.81		
C : N ratio	17.0	16.9	76.4	77.6		
C : P ratio	107.2	115.3	1,130.0	1,165.8		
N accumulation (kg/ha)	122.6	111.4	44.4	42.8		
P accmululation (kg/ha)	19.4	16.3	3.0	2.85		
K accumulation (kg/ha)	109.6	100.8	133.5	135.8		

Table 2. Yield and yield-attributing characters of rice in rice–wheat cropping system

Treatment	Grain yield (tonnes/ha)		Straw yield (tonnes/ha)		Panicles/ m^2		Fertile spikelets/panicle		1,000-grain weight (g)	
	1996–97	1997–98	1996–97	1997–98	1996–97	1997–98	1996–97	1997–98	1996–97	1997–98
Organic source										
Sesbania	5.57	6.06	6.73	7.35	283	300	98	111	29.0	29.1
Cowpea	5.18	5.35	5.99	6.82	252	271	92	106	28.6	28.7
Wheat straw	5.20	5.37	6.10	6.85	249	273	92	106	28.7	28.8
Control	4.68	4.75	5.77	6.05	238	251	85	100	28.3	28.3
CD (P=0.05)	0.33	0.27	0.72	0.32	39	19	3	2	0.5	0.6
Nitrogen (kg/ha)										
0	3.82	4.19	5.56	5.50	210	225	79	87	27.7	27.5
40	4.95	5.23	5.99	6.68	250	270	92	101	28.4	28.5
80	5.76	5.76	6.24	7.27	273	290	96	113	29.0	29.2
120	6.10	6.35	8.80	7.63	290	311	99	122	29.9	29.9
CD (P=0.05)	0.33	0.25	0.63	0.20	36	40	1	2	0.6	0.5

Table 3. Yield and yield-attributing characters of wheat in rice–wheat cropping system

Treatment	Grain yield (tonnes/ha)		Straw yield (tonnes/ha)		Spikes/m length		Grains/ spikelet		1,000-grain weight (g)	
	1996–97	1997–98	1996–97	1997–98	1996–97	1997–98	1996–97	1997–98	1996–97	1997–98
Organic source to rice										
Sesbania	3.41	2.80	4.64	3.92	76	63	35	33	42.3	41.7
Cowpea	3.23	2.35	4.45	3.34	74	62	35	32	41.8	41.0
Wheat straw	3.22	2.69	4.51	3.73	75	63	36	33	41.9	41.2
Control	3.13	2.29	4.52	3.27	73	61	33	31	41.6	40.8
CD (P=0.05)	0.19	0.03	NS	0.10	0.5	NS	0.2	1.2	0.3	NS
N (kg/ha) to rice										
0	3.03	2.31	4.47	3.25	73	61	34	32	41.6	40.7
40	3.14	2.48	4.45	3.50	74	61	35	32	41.8	41.1
80	3.32	2.62	4.51	3.72	74	62	35	33	42.0	41.3
120	3.50	2.73	4.68	3.79	73	61	36	33	42.3	41.5
CD (P=0.05)	0.13	0.05	NS	0.07	NS	NS	0.2	0.5	NS	NS
N (kg/ha) to wheat										
0	1.86	1.54	2.02	2.45	56	46	25	25	40.8	40.6
40	2.77	2.18	3.74	3.18	76	63	33	31	41.8	41.2
80	3.66	2.80	5.56	3.87	80	67	38	35	42.3	41.3
120	4.69	3.61	6.81	4.76	86	72	43	38	42.7	41.6
CD (P=0.05)	0.14	0.05	0.23	0.08	2.8	0.7	1.2	3.0	0.4	0.3

kg fertilizer N/ha during 1996 and 1997 respectively. Similar results were reported by Thakur *et al.* (1995).

Yield and yield attributes of wheat

Sesbania green-manuring to rice increased the grain yield of wheat by 5.5, 5.9 and 8.9% in 1996–97 and 19.2; 4.0 and 22.1% during 1997–98 over cowpea fodder, wheat straw and the control respectively (Table 3). An application of 40, 80 and 120 kg/ha fertilizer N to rice also increased the grain yield of the succeeding wheat crop by 3.5, 9.5 and 15.7% during 1996–97 and 7.6, 13.7 and 18.7% in 1997–98, respectively, over the control. Further nitrogen applied to wheat resulted in significant increase in grain yield up to 1.20 kg N/ha. The increase in wheat yield was 49, 97 and 152% in 1996–97 and 41, 82 and 134% in 1997–98 owing to 40, 80 and 120 kg N/ha over the control respectively. Interaction effect was non-significant. However, integrated use of *Sesbania* green-manure along with 120 kg N/ha to rice and 120 kg N/ha to wheat yielded 5.2 tonnes/ha of wheat grain during 1996–97 and 4.2 tonnes/ha during 1997–98. This might be due to more nutrients available for crop growth and development, higher nutrient uptake by crop and higher yield attributes. Kolar *et al.* (1993) also reported such beneficial effects of integrated nitrogen management in rice and fertilizer N applied to succeeding wheat crop.

Grain yield of rice–wheat system

Sesbania green-manure plots recorded the highest total grain production. Application of nitrogen up to 120 kg N/ha to rice resulted in 9.6 and 9.1 tonnes/ha and to wheat produced 9.8 and 9.0 tonnes/ha of

Table 4. Nutrient uptake of rice in rice–wheat cropping system (mean data of 2 years)

Treatment	Nitrogen uptake (kg/ha)			Phosphorus uptake (kg/ha)			Potassium uptake (kg/ha)		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
Organic source to									
Sesbania	83.6	39.8	123.4	16.5	5.3	21.8	25.6	121.9	147.5
Cowpea	65.8	32.2	98.0	14.5	4.6	19.1	22.9	110.3	133.2
Wheat straw	68.1	33.1	101.2	14.7	4.7	19.4	24.6	112.0	136.6
Control	57.6	28.3	85.9	12.9	4.1	17.0	20.5	100.6	121.1
CD (P=0.05)	6.1	4.1	8.5	1.4	0.7	1.9	2.4	9.5	11.5
N (kg/ha)									
0	42.2	23.9	66.1	10.1	3.5	13.6	16.8	93.0	109.8
40	60.4	30.3	90.7	13.5	4.3	17.8	22.1	108.2	130.3
80	79.9	37.2	117.1	16.3	5.0	21.3	25.9	117.1	143.0
120	92.6	42.0	134.6	18.8	5.9	24.7	28.7	126.3	155.0
CD (P=0.05)	5.0	3.9	6.9	1.1	0.5	1.4	2.3	7.1	8.3

Table 5. Nutrient uptake of wheat in rice–wheat cropping system (mean data of 2 years)

Treatment	Nitrogen uptake (kg/ha)			Phosphorus uptake (kg/ha)			Potassium uptake (kg/ha)		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
Organic source to rice									
Sesbania	53.8	22.5	76.3	12.9	1.8	14.7	16.0	78.3	94.3
Cowpea	51.9	19.8	71.7	10.8	1.5	12.3	13.8	70.2	84.0
Wheat straw	50.4	21.4	71.8	11.6	1.7	13.3	15.2	75.0	90.2
Control	44.6	19.6	64.2	10.4	1.5	11.9	13.2	70.4	83.6
CD (P=0.05)	2.4	0.8	2.2	0.5	NS	0.8	0.8	4.2	3.8
N (kg/ha) to rice									
0	44.2	19.1	31.6	10.3	1.5	11.8	13.0	69.6	82.6
40	47.1	20.4	33.7	11.0	1.6	12.6	14.2	71.8	86.0
80	50.4	21.4	71.8	11.8	1.7	13.5	15.0	74.9	89.9
120	53.4	22.3	75.7	12.6	1.7	14.3	16.1	77.6	93.7
CD (P=0.05)	1.6	0.8	1.6	0.4	NS	0.5	0.4	2.9	2.8
N (kg/ha) to wheat									
0	23.1	9.7	32.8	5.8	0.8	6.6	8.0	39.5	47.5
40	39.2	16.9	56.1	9.3	1.3	10.6	12.3	62.2	74.5
80	56.2	24.8	81.0	13.1	2.0	15.1	16.4	85.8	102.2
120	76.6	31.8	108.4	17.7	2.5	20.4	21.5	106.4	127.9
CD (P=0.05)	2.1	1.2	2.2	0.8	0.5	0.8	0.7	3.9	2.8

total grains from rice–wheat system (Table 6). Interaction effects were not significant. But green-manuring along with 120 kg N/ha to rice as well as to wheat recorded a total grain production of 11.5 tonnes/ha from rice–wheat system.

Nutrient uptake by rice

Total (in grain and straw) N, P and K uptakes by the rice crop due to *Sesbania* green manuring was higher over all other organic sources (Table 4). An increase in N level to rice up to 120 kg N/ha significantly increased N, P and K uptake in grain and straw and ultimately their total uptake by rice crop. Green-manured rice crop along with application of 120 kg N/ha removed 155.7, 27.7 and 172.4 kg N, P and K/ha respectively. This might be due to increased supply of nutrients directly through organic and inorganic sources and indirectly through checking of loss of nutrients from soil solution. This is an agreement with findings of Bindra and Thakur (1996).

Nutrient uptake by wheat

Total N, P and K uptake by wheat varied significantly due to organic and fertilizer sources of nutrients to rice and fertilizer N to wheat (Table 5). Total N uptake by wheat grown after rice with cowpea fodder and wheat straw

Table 6. Total grain production and nutrient uptake of rice–wheat system as influenced by integrated nitrogen management (mean data of 2 years)

Treatment	Grain yield (tonnes/ha)	N uptake (kg/ha)	P uptake (kg/ha)	K uptake (kg/ha)	NPK uptake (kg/ha)
Organic source to rice					
Sesbania	8.91	199.85	36.50	241.90	478.25
Cowpea	8.04	162.75	31.50	217.35	411.60
Wheat straw	8.22	166.40	32.65	227.05	426.10
Control	7.41	150.10	29.00	205.05	384.15
CD (P=0.05)	1.06	8.60	1.52	12.62	21.02
N (kg/ha) to rice					
0	6.65	129.60	25.30	192.70	347.60
40	7.90	157.90	30.45	216.60	404.95
80	8.75	188.85	34.85	233.30	457.00
120	9.40	209.35	38.95	248.80	497.10
CD (P=0.05)	0.38	7.62	1.64	10.84	17.44
N (kg/ha to wheat					
0	6.95	134.45	25.90	182.25	342.60
40	7.70	157.95	30.00	209.80	397.95
80	8.50	182.85	34.30	236.70	453.85
120	9.35	210.35	39.45	262.65	512.45
CD (P=0.05)	0.10	3.22	0.86	3.52	4.76

incorporation being at par was significantly higher than the control. The P uptake of wheat showed that *Sesbania* green manure, cowpea and wheat straw plots removed 14.7, 13.3, and 11.9 kg/ha. Application of N to rice as well as to wheat gradually increased P uptake with increasing N levels. Potassium uptake was also similar to P uptake pattern. However, it was observed that *Sesbania* green manuring along with 120 kg N to each rice and wheat removed 126.2 kg N, 24.3 kg P and 140.3 kg K/ha. Similar results were reported by Bhandari *et al.* (1992).

Nutrient uptake by rice–wheat system

Total N, P and K uptake in rice–wheat system significantly increased due to *Sesbania* green manure (Table 6). *Sesbania* green-manured treatment resulted in removal of 199.8 kg N, 36.5 kg P and 241.9 kg K/ha. Application of N at 120 kg/ha to rice removed 209.3 kg N, 38.9 kg P and 248.8 kg K/ha. Similarly, total N, P and K uptake by rice–wheat system were 210.3, 39.4 and 262.6 kg/ha due to application of 120 kg N/ha to wheat.

Both rice and wheat are exhaustive feeders of nutrients and a rice–wheat cropping system, yielding 11.5 tonnes/ha grains removed as much as 281.9 kg N, 52.0 kg P and 312.7 kg K/ha/annum making total removal of 646.3 kg nutrients (NPK)/ha/annum.

REFERENCES

Becker, M., Ladha, J.K. and Ottow, J. C. G. 1994. Nitrogen losses and lowland rice yield as affected by residue N release. *Soil Science Society of America Journal* **58** : 1,660–1,665.

Bhandari, A. L., Sood, A., Sharma, K.N. and Rana, D.S. 1992. Integrated nutrient management in a rice-wheat system. *Journal of Indian Society of Soil Science* **40** : 742–747.

Bindra, A.D. and Thakur, R.C. 1996. Influence of green manures along with fertilizers on nitrogen, phosphorus and potassium contents in rice. *Oryza* **33** : 143–145.

Grubinger, V.P. 1992. Organic vegetable production and how it related LISA. *Horticultural Science* **27** : 759–760.

Hundal, H.S., Biswas, C.R. and Vig, A.C. 1988. Phosphorus sorption characteristics of flooded soil amended with green manure. *Tropical Agriculture* (Trinidad) **65** : 185–188.

Jackson, M.L. 1973. *Soil Chemical Analysis.* Prentice Hall Pvt. Ltd., India.

Kirchner, M.J., Wollum II, A.G. and King, L.D. 1993. Soil microbial populations and activities in reduced chemical input agroecosystem. *Soil Science Society of America Journal* **57** : 1,289–1,295.

Kolar, J.S., Grewal, H.S. and Singh, B. 1993. Nitrogen substitution and higher productivity of a rice–wheat cropping system through green manuring. *Tropical Agriculture* (Trinidad) **70** : 301–304.

Mahapatra, B.S. and Sharma, G.L. 1995. Effect of summer legumes on growth and yield of lowland rice and its residual effect on succeeding wheat in rice–wheat system. *The Indian Journal of Agricultural Sciences* **65** : 557–561.

Rattan, R.K. and Singh, A.K. 1997. Role of balanced fertilization in rice–wheat cropping system. *Fertiliser News* **42**(4) : 79–97.

Thakur, R.C. Bindra, A.D., Sood, R.D. and Bhargava, M. 1995. Effect of fertilizer application and green manuring on physico-chemical properties of soil and grain yield in rice–wheat crop sequence. *Indian Journal of Agronomy* **40** : 4–13.