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Total productivity, nitrogen, phosphorus and potassium removal and economics of rice (*Oryza sativa*)–wheat (*Triticum aestivum*) cropping system with integrated nitrogen management in rice

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ABSTRACT

A field experiment was conducted during 2000–2001 and 2001–2002 to evaluate the effect of 5 organic sources of nutrients along with 4 levels of N to rice (*Oryza sativa* L.) and 3 levels of N to wheat (*Triticum aestivum* L. emend. Fiori & Paol.) on the total productivity, nutrient removal and economics of rice–wheat system. Integrated use of *Sesbania* green–manure along with 180 kg N/ha gave 7.1 tonnes/ha of rice grain and subsequent application of 150 kg N/ha to succeeding wheat crop yielded 6.0 tonnes/ha of wheat grain, thus giving a total production of 13.1 tonnes/ha from rice – wheat sequence. At this production level and fertilizer use, rice removed 136.7, 24.2 and 165.1 kg N, P and K/ha and respective values for wheat were 107.8, 20.0 and 124.7 kg/ha, making a total removal of 578.5 kg nutrients (NPK/ha/annum) from rice–wheat system. The same treatment also gave higher, net return and benefit : cost ratio in the system.

Key words : Productivity, Integrated N management, Economics, Cropping system, Nutrient removal

The food grain requirement of the country is estimated at 243.2 million tones by 2006–07. Rice and wheat combinedly contribute 77%, of which rice–wheat cropping system shares 29% of national food grain production (Hegde, 1998). Rapid spread of rice–wheat system in India caused an unfavourable effect on sustainability of soil productivity (Rattan and Singh, 1997). To meet the food-grain 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 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 are important. 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, present study was undertaken to generate information for sustainable yield 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 2000–2001 and 2001–2002. The soil was silty clay loam with pH 7.3 and 7.2, organic carbon 1.066 and 0.783%, available nitrogen 227 and 205 kg/ha, available phosphorus 20.5 and 18.8 kg/ha and available potassium 149 and 124 kg/ha from 0–20 and 20–40 cm depth respectively. Five organic sources of nutrients, i.e. *Sesbania cannabina* (Retz.) Pers., *Crotalaria juncea* L. and *Vigna unguiculata* (L). Walp. green manuring, wheat-straw incorportion and no-organic management (fallow), with 4 inorganic nitrogen levels (0, 60, 120 and 180 kg N/ha) were applied to rice crop. The second crop wheat also received 3 levels of nitrogen (0,75 and 150 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 applied to wheat in sub-sub-plot, with 3 replications, and the treatments were kept in the same plots during both the years. Green-manuring crops, viz. *Sesbania, Crotalaria* and *Vigna* were sown on 22 May 2000 and 1 May 2001. These crops were incorporated at 8 weeks old stage and small pieces (4–5 cm) of wheat straw @ 10.0 tonnes/ha were incorporated at puddling according to treatments during 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. Seedlings of 20-day-old 'Plant Dhan 4'rice were transplanted on 2 July and 29 June during 2000–2001 and 2001–2002, respectively, at a spacing of 20 cm × 15 cm. 'UP 2338' wheat was sown on 24 and 17 November in 2000–2001 and 2001–2002, respectively, in lines of 23 cm apart using 100 kg seed/ha.

RESULTS AND DISCUSSION

Grain yield of rice–wheat system

Sesbania green-manured plots recorded the highest total grain production (Table 1). Interaction effects were significant in both the years. The highest rice–wheat grain production of 13.3 tonnes/ha in 2000–2001 and 12.9 tonnes/ha during 2001–2002 was recorded with *Sesbania* along with 180 kg N/ha applied to rice and 150 kg N/ha applied to wheat in the sequence. The higher total grain production in this rice–wheat system might be owing to additive effect of better growth and yield attributes of individual crop, higher nutrient available through supply of organic and inorganic-N to the crops in this system. Aulakh *et al.* (2000) and Paikray *et al.* (2001), also reported similar results.

Nutrient removal by rice–wheat system

Total N, P and K uptake in rice – wheat system increased significantly due to *Sesbania* green manure to rice (Table 2). *Sesbania* green-manuring resulted in removal of 244.5 kg N, 44.4 kg P and 289.8 kg K/ha and application of N at 180 kg/ha to rice removed 237.2 kg N, 43.7 kg P

Table 1. Total grain production (tonnes/ha) in rice–wheat system as influenced by intergrated nitrogen management

Treatement to rice	Nitrogen to wheat (kg/ha)					
	2000–2001			2001–2002		
	0	75	150	0	75	150
Fallow (F)	3.7	5.1	5.8	3.2	4.6	5.7
F + 60 kg N/ha	4.2	5.7	6.2	4.0	5.4	6.5
F + 120 kg N/ha	4.7	6.3	7.0	5.6	7.1	8.1
F + 180 kg N/ha	5.1	6.6	7.2	6.4	7.8	8.6
Mean (F)	4.4	5.9	6.5	4.8	6.2	7.2
Wheat straw (W)	5.2	5.9	7.0	5.3	6.1	7.2
W + 60 kg N/ha	5.6	6.4	7.5	6.0	7.0	8.0
W + 120 kg N/ha	6.6	7.5	8.6	7.1	8.1	9.1
W + 180 kg N /ha	7.1	8.0	9.0	7.9	9.0	9.8
Mean (W)	6.1	6.9	8.0	6.6	7.5	8.5
Vigna (V)	5.8	6.3	7.6	6.7	7.2	8.4
V + 60 kg N/ha	6.4	7.3	8.3	7.0	7.8	8.8
V + 120 kg N/ha	7.1	8.1	9.2	8.1	8.8	9.9
V + 180 kg N/ha	7.7	8.5	9.6	8.7	9.8	10.5
Mean (V)	6.7	7.5	8.7	7.6	8.4	9.4
Crotalaria (C)	6.8	7.3	8.3	7.4	8.0	9.1
C + 60 kg N/ha	7.7	8.3	9.5	8.0	8.8	9.6
C + 120 kg N/ha	9.1	9.9	11.1	9.1	9.7	10.9
C + 180 kg N/ha	9.7	10.3	11.8	9.9	10.5	11.7
Mean (C)	8.3	9.0	10.2	8.6	9.3	10.3
Sesbania (S)	7.0	7.4	8.6	8.5	9.0	10.1
S + 60 kg N/ha	8.3	9.1	10.3	8.8	9.4	10.6
S + 120 kg N/ha	10.2	11.1	12.3	9.8	11.0	11.8
S + 180 kg N/ha	10.9	11.9	13.3	10.7	11.9	12.9
Mean (S)	9.1	9.9	11.1	9.4	10.3	11.3
Mean (N to rice)	6.5	7.4	9.1	7.1	8.9	9.7
Mean (N to wheat)	6.9	7.8	8.9	7.4	8.3	9.4
	Organic source (M)		N to rice (S)		N to wheat (SS)		M × S × SS	
	2000–2001	2001–2002	2000–2001	2001–2002	2000–2001	2001–2002	2000–2001	2001–2002
CD(P=0.05)	0.5	0.5	0.3	0.3	0.8	0.05	0.03	0.2

and 300.2 kg K/ha from rice–wheat system. Similarly, total N, P and K uptake by rice-wheat system was 222.9 kg N, 41.5 kg P and 277.5 kg K/ha with the application of 150 kg N/ha to wheat.

Sesbania green-manured plots removed 285.4 and 255.9 kg more total nutrients (NPK) than fallow (306.8 and 309.5 kg) during 2000–2001 and 2001–2002, respectively, and were superior to any other organic source tried

Table 2. Total nitrogen (N), phosphorus (P), potassium (K) and NPK uptake by rice – wheat system as influenced by intergrated nitrogen management

Treatment	N uptake (kg/ha)		P uptake (kg/ha)		K uptake (kg/ha)		NPK uptake (kg/ha)	
	2000–2001	2001–2002	2000–2001	2001–2002	2000–2001	2001–2002	2000–2001	2001–2002
Origanic source to rice								
Fallow	115.8	119.3	21.6	22.9	169.4	167.3	306.8	309.5
Wheat straw	155.4	151.9	28.4	28.8	221.4	198.0	405.3	378.7
Vigna	175.3	177.8	31.7	32.8	238.4	129.2	445.4	429.9
Crotalaria	220.5	214.2	39.5	39.0	275.0	255.6	433.0	508.9
Sesbania	247.3	241.8	44.4	44.3	300.5	279.2	592.2	565.4
CD (P=0.05)	12.8	8.0	2.6	1.5	13.0	7.3	28.3	15.9
N (kg/ha) to rice								
0	133.8	135.1	24.0	24.9	183.0	170.8	340.8	330.8
60	157.9	153.3	28.4	28.3	207.3	189.9	393.6	371.6
120	202.9	198.1	36.9	36.8	263.9	243.3	503.8	478.2
180	236.9	237.6	43.2	44.2	309.5	291.4	589.6	573.2
CD (P=0.05)	9.4	7.4	1.8	1.4	10.4	8.8	21.4	17.2
N (kg/ha) to wheat								
0	144.5	147.0	26.2	26.8	196.6	186.6	367.3	360.4
75	177.1	177.3	32.4	32.5	235.8	220.4	445.3	430.3
150	227.0	218.8	40.7	41.4	290.5	264.6	558.2	524.7
CD (P=0.05)	3.4	2.1	0.7	0.4	4.5	2.6	8.6	5.0

Table 3. Net return and benefit : cost rario in rice –wheat system (total) under different treatments (mean data of 2 years)

Treatment to rice	N to wheat (kg/ha)					
	Net returns (Rs/ha)			Benefit : cost ratio		
	0	75	150	0	75	150
Fallow (F)	3,278	10,854	15,924	0.203	0.644	0.906
F +60 Kg N/ha	6,246	14,550	18,817	0.381	0.850	1.055
F+120 kgN/ha	11,691	20,580	23,018	0.703	1.185	1.272
F+180 kg N /ha	15,203	23,205	26,895	0.900	1.316	1.464
Wheat straw (W)	10,016	13,746	19,852	0.498	0.660	0.651
W+ 60 kg N/ha	12,050	16,419	22,206	0.592	0.778	1.017
W+120 kg N/ ha	17,215	22,171	28,120	0.834	1.038	1.272
W+180 kg N/ha	20,708	25,938	30,608	0.991	1.199	1.369
Vinga(V)	16,555	19,260	26,027	0.912	1.020	1.327
V+60 kg N /ha	18,864	23,252	28,736	1.024	1.214	1.946
V+120 kg N/ha	23,614	27,844	33,716	1.264	1.434	1.669
V+ 180 kg N /ha	26,489	31,420	36,501	1.397	1.596	1.788
Crotalaria (C)	23,303	24,445	29,927	1.298	1.309	1.542
C+60 kg N/ha	25,212	28,847	34,587	1.384	1.523	1.758
C+120 kg N/ha	31,775	35,279	41,868	1.719	1.836	2.100
C+180 kg N /ha	35,583	38,736	46,202	1.897	1.988	2.286
Sesbania (S)	25,259	27,353	33,697	1.407	1.464	1.737
S+60 kg N /ha	29,106	32,633	39,277	1.598	1.722	1.996
S+120 kg N /ha	36,387	42,318	47,712	1.968	2.203	2.393
S+180 kg N/ha	40,963	46,853	53,766	2.184	2.405	2.660

(Table 2). Application of N even up to 180 kg ha to rice and also 150 kg/ha to wheat resulted in significantly higher total NPK uptake by rice–wheat system during both the years. This might be owing to higher total grain production, more nutrient (N, P and K) concentration in grain and straw of both rice and wheat which could be resultant of more nutrient availability in soil solution directly or indirectly through supply of organic source to rice and fertilizer N to both rice and wheat. Bindra and Thakur (1996) and Paikray *et al.* (2001) also reported similar results.

Economics of rice–wheat system

The mean values of 2 years revealed that maximum net returns and benefit : cost ratio were obtained under rice–wheat system with *Sesbania* green manure (Table 3). The parameters were in order of *Sesbania*>*Crotalaria*>*Vigna*> wheat straw>fallow treatments. Net returns and benefit : cost ratio of rice–wheat system increased with increasing levels of N applied to rice and wheat irrespective of any organic sources tried. The rice-wheat system resulted in net returns of Rs 53,776/ha with *Sesbania* green-manuring and application of 180 kg N/ha to rice and wheat crops (Table 3). Inclusion of *Sesbania* or *Crotalaria* as green manure crop before rice in rice–wheat system increased the cost of cultivation by Rs 1,838/ha, while for *Vigna* it increased by Rs 2,038/ ha. But additional cost of production of these green manures was compensated by the additional grain yield from rice and wheat owing to them, which in turn gave higher net profit as well as higher benefit : cost ratio. These results are in agreement with the findings of Singh *et al.* (1996) and Thakur *et al.* (1999).

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