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Effect of integrated nutrient management on rice (*Oryza sativa*)-wheat (*Triticum aestivum*) cropping system in Central Plains Zone of Uttar Pradesh

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ABSTRACT

A field study was carried out at Kanpur, Uttar Pradesh during 1999–2000 and 2000–2001 to evaluate the efficacy of organic sources, viz. farmyard manure (FYM), wheat (*Triticum aestivum* L. emend. Fiori & Paol.) straw and green leaf manure (GLM) in organic, inorganic combinations in rice (*Oryza sativa* L.)–wheat cropping system. Rice yield was maximum with 25% N substitution through green leaf manure (GLM) and wheat yield was higher with 50% substitution of N through GLM in rice + 100% NPK fertilizer in wheat. However, 100% NPK fertilizers in both crops yielded at par with best treatments in both rice and wheat for different parameters. The NPK uptake in rice and wheat was higher with 100% NPK to both crops and in the treatments with 50 or 25% NPK substitution through GLM in rice and 100 or 75% NPK through fertilizers in wheat. The application of 100% inorganic NPK to both crops earned maximum net profit of Rs 20,202/ha from rice–wheat system. This treatment also maintained maximum values of organic carbon, available P and available K in residual soil.

Key words: Integrated nutrient management, Rice–wheat system, Growth, Yield, Economics, Nutrient uptake

Cropping system in India has attained great significance in terms of area, production and productivity. Both crops of the rice–wheat system are fertility exhaustive and had resulted in decline of soil organic carbon and deteriorating soil health in general. The use of excessive chemical fertilizers and pesticides are causing environmental hazards. It is, therefore, necessary to develop a sustainable production system with maximum productivity and minimum environment pollution. In this context, integrated use of chemical fertilizers and organics like farmyard manure (FYM), green manure and crop residue assumes greater significance. It is also important to ensure that such production system would be within the approach of Indian farmers. Keeping this is view, an experiment was conducted to evaluate the productivity and economics of rice–wheat cropping system under integrated nutrient supply system and its influence on residual soil-fertility status.

MATERIALS AND METHODS

The experiment was carried out in permanent plots under All-India Co-ordinated Research Project on Cropping Systems at Crop Research Farm, Pura, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, during rainy and winter seasons of 1999–2000 and 2000–2001. The experimental crop of rice received 657.8 mm rain in 30 days and 411.4 mm in 21 days during the first and second year of trial respectively. At the start of experiment in 1983, the soil contained 0.4% organic carbon, with 0.10 dS/m EC, 18 kg/ha available P and 182 kg/ha available K. Soil was sandy loam in texture having 60.3% sand, 23.5% silt and 16.2% clay fractions, with 7.8 pH.

There were 12 treatment combinations, replicated 4 times in randomized block design in permanent fixed layout. Rice 'Sarjoo 52' (through transplanting) and wheat 'HD 2285' were grown. The recommended dose of fertilizer was 120 kg N, 60 kg P_2O_5 and 60 kg K_2O/ha for both rice and wheat crops. In the rainy season, integrated nutrient supply system was accomplished by supplementing 25 or 50% fertilizer N through farmyard manure (FYM), wheat straw and green leaf (*Sesbania*) manure (GLM). In the winter season, only inorganic fertilizers were used as per treatments (Table 1). The FYM, wheat straw and green leaves of *Sesbania* were analysed for N content and their required amount was applied 3 weeks before rice transplanting as per treatment to substitute a specified amount of N. Both crops of the system were given irrigations as and when required. For nutrient uptake and soil-fertility status, composite samples for all replications were used in analysis. Results were pooled over years. The grain yield data of rice and wheat for all previous years were averaged for every 3 years to know the yield trends from beginning of experiment. Economics of treatments was calculated on present market price of yield and inputs. The soil was analysed after wheat harvest during 2000–2001 to monitor the changes in nutrient status from initial levels.

RESULTS AND DISCUSSION

Yield of rice and wheat

Rice grain yield was highest when 25% of N in rice was substituted by green-leaf manure (GLM), though the yield with 100% inorganic NPK application was also at par with it (Table 1). The grain yield of wheat was highest when 50% of N in rice was sibstituted by GLM and 100% inorganic NPK was applied in wheat. However, 100% inorganic NPK to both crops and substitution of 25% N in rice through GLM + 75% inorganic NPK in wheat also gave wheat yield at par with top yielding treatments (T_5). The yield attributes, viz. spikes/m^2 and grain weight/spike, were found responsible for higher grain yield of rice and wheat in above-mentioned treatments, and straw yield of rice and wheat also behaved in similar manner to grain yield and these may be supported by more dry weight/ plant.

The better performance of GLM may be explained that it might have helped in improving the nutrients availability for a prolonged period in rice, whereas in wheat more roots penetration due to improvement in physical condition of soil allowed more utilization of plant nutrients from soil. These results are in close confirmity to those of Singh *et al.* (2000), who also reported that combined application of green manure and NPK fertilizers in rice–wheat system produced about 75% higher root biomass than the application of NPK fertilizers alone.

System productivity

The production of grain and straw from rice–wheat system was significantly higher under the treatments of recommended fertilizer NPK to both crops compared to 25% N through GLM in rice + 75% NPK to both crops and 50% NPK + 50% N through GLM to rice and 100% NPK to wheat. Substitution of N through FYM or wheat straw could not compete with GLM or 100% NPK fertilizers perhaps because of their later decomposition. Hegde (1998) also reported that in semi-arid ecosystem, only green manure could substitute a part of fertilizer N in rice under rice–wheat cropping system. Thus a saving of 25–50% NPK in rice is possible with use of GLM without affecting the production of rice–wheat system.

Yield trend over years

The grain yield level of rice either reduced or remained stagnant up to 1995–96, the thirteenth year of experimentation, compared to yields at start of experiment (Table 3) in almost all treatments. After it, grain yield showed improvement with application of organic manures in rice or 100% inorganic NPK to both crops. In final years of 1999 and 2000, application of sub-optimum doses of NPK and unfertilized crop showed remarkable reduction in the rice yield compared to initial yield levels. Maximum reduction of 38.7% in rice yield was found when both crops were fertilized with 50% inorganic NPK. A minimum yield reduction of 13.2% was recorded when both crops were fertilized with 75% inorganic NPK. Unfertilized plots showed the reduction of 35.4% in rice yield. Application of 100% inorganic NPK to both crops increased rice yield by 7.6% during 18 years experimentation. Maximum increase of 13.40% in rice yield was computed when 25% N in rice was substituted by GLM and wheat was fertilized with 75% recommended NPK.

Wheat yield showed an improvement with time under almost all treatments except the control. In the control plots, wheat yield reduced by 6.6% during 18 years experimentation. Maximum increase of 27.3% in wheat yield was recorded when both crops of system were fertilized with 100% of recommended NPK through inorganic fertilizers and it was followed by the treatment where both crops were fertilized with 75% inorganic NPK. It may thus be inferred that sustainability of wheat production was not influenced by organic manuring while rice productivity was sustained owing to the application of organic manures, among which GLM was proved most effective.

Economics

In rice, the maximum net profit of Rs 4,935/ha with 1.27 benefit : cost ratio was recorded when 100% NPK fertilizers were applied and was followed by when 25% N in rice was substituted through GLM (Rs 4,582/ha with 1.24 benefit : cost ratio). Yadav (2001) also reported similar results. It is matter of consideration that half number of treatments applied in rice gave loss rather than profit. The loss in these treatments seems to be associated with lesser gross income and high cost of cultivation in T_8 and T_9 where 20-50% N was substituted by wheat straw. It may be also explained for T_2, T_3 and T_{12} that under continuous rice-wheat cropping with lower doses of fertilizers deteriorated the soil health which caused reduction in available of nutrients in soils (Hegde and Sarkar, 1992). Control treatment (T_1) gave maximum loss of Rs 6,214/ha with 0.53 benefit : cost ratio. It might be due to continuous cropping without fertilizer application. Yadav *et al.* (1998) reported on an average 57% yield reduction in rice under unfertilized plots on the basis of 16 crops cycles.

Wheat crop gave maximum net profit of Rs 15,468 and 1.80 benefit : cost when 50% N in rice was substituted by

Table 1. Growth, yield attributes, yields and economics of rice and succeeding wheat under integrated nutrient management practices (2 years mean)

Treatment		Dry matter (g/plant)		Spikes/ m^2		Grain weight (g/spike)		Grain yield (q/ha)			Net profit (Rs/ha)		
Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat	Total	Rice	Wheat	Total
T_1, Control (no fertilizer or manure)	Control (no fertilizer or manure)	6.47	2.08	189.3	376.8	1.552	1.104	12.54 (15.29)	12.50 (29.41)	25.04 (44.70)	(-) 6,214 (0.53)	(-) 2,765 (0.80)	(-) 8,979 (0.66)
T_2, 50% NPK	50% NPK	9.73	3.68	242.6	437.7	2.190	1.208	19.96 (24.49)	29.44 (47.56)	49.40 (72.05)	(-)4,334 (0.72)	5,740 (1.35)	1,406 (1.05)
T_3, 50% NPK	100% NPK	10.69	4.94	264.3	515.4	2.226	1.252	21.28 (26.18)	39.79 (64.63)	61.06 (90.81)	(-)3,742 (0.76)	11,908 (1.63)	8,166 (1.24)
T_4, 75% NPK	75% NPK	11.77	4.54	294.8	481.3	2.553	1.304	32.51 (38.15)	37.38 (58.75)	69.88 (96.90)	567 (1.04)	10,810 (1.60)	11,377 (1.33)
T_5, 100% NPK	100% NPK	12.97	5.40	320.2	550.8	2.700	1.474	43.60 (50.53)	44.56 (73.94)	88.26 (124.47)	49,35 (1.27)	15,267 (1.80)	20,202 (1.54)
T_6, 50% NPK+50% N (FYM)	100% NPK	12.57	5.18	296.2	530.7	2.438	1.464	37.20 (43.12)	41.94 (67.72)	79.14 (110.84)	999 (1.06)	13,302 (1.70)	14,301 (1.38)
T_7, 75% NPK + 25% N (FYM)	75% NPK	12.85	4.70	306.8	513.4	2.605	1.340	38.64 (48.68)	38.06 (62.47)	76.70 (111.15)	2,113 (1.12)	11,470 (1.64)	13,583 (1.38)
T_8, 50% NPK+50% (WH)	100% NPK	12.42	4.34	290.8	492.7	2.485	1.385	35.28 (40.49)	36.94 (57.09)	72.22 (97.58)	(-) 4,410 (0.81)	9,682 (1.53)	5,272 (1.13)
T_9, 75% NPK+25% N (WH)	100% NPK	12.88	4.23	291.0	489.8	2.644	1.374	36.90 (42.91)	35.56 (55.71)	72.46 (98.62)	(-) 934 (0.96)	9,514 (1.54)	8,580 (1.23)
T_{10}, 50% NPK + 50% N (GLM)	75% NPK	13.38	5.34	306.7	574.9	2.860	1.595	41.66 (47.42)	44.88 (72.44)	86.54 (119.86)	2,578 (1.13)	15,468 (1.80)	18,046 (1.47)
T_{11}, 75% NPK + 25% N (GLM)		13.89	5.12	314.5	544.7	2.945	1.374	44.43 (50.93)	43.13 (68.63)	87.55 (119.56)	4,582 (1.24)	14,676 (1.80)	19,258 (1.52)
T_{12}, FP (80:30:kg NP/ha)	FP (80:30 kg NP/ha)	10.82	3.99	275.6	443.8	2.458	1.275	28.32 (34.73)	32.81 (51.16)	61.13 (85.89)	(-) 502 (0.97)	8,382 (1.51)	7,880 (1.25)
CD (P=0.05)		0.33	0.26	11.6	15.6	0.105	0.069	1.97 (2.14)	1.94 (3.76)	3.60 (5.87)	895 (0.05)	1,892 (0.11)	2,313 (0.06)

FYM, Farmyard manure; WH, wheat straw; GLM, green leaf manure; FP, farmers' practice
Figures given in parentheses are for straw yield and benefit : cost ratio

Table 2. Uptake of nitrogen, phosphorus and potassium in rice–wheat system and soil fertility after final harvest

Treatment		Rice			Wheat			Rice–wheat sequence			Soil fertility		
Rice	Wheat	N	P	K	N	P	K	N	P	K	Organic carbon %	Average P (kg/ha)	Average K (kg/ha)
T_1, Control	Control	17.28	3.28	18.40	29.72	6.54	36.48	47.01	9.82	54.89	0.27	9.8	99
T_2, 50% NPK	50% NPK	28.58	5.69	30.01	69.61	11.44	63.46	98.18	17.13	93.46	0.36	15.0	139
T_3, 50% NPK	100% NPK	30.77	6.48	32.73	88.87	17.08	89.85	129.66	23.56	122.58	0.37	16.6	140
T_4, 75% NPK	75% NPK	46.95	9.88	48.71	92.76	15.84	81.39	139.71	26.35	130.10	0.38	18.4	143
T_5, 100% NPK	100% NPK	66.24	15.43	66.66	120.88	21.72	97.50	187.13	37.15	164.16	0.47	23.4	164
T_6, 50% NPK + 50% N (FYM)	100% NPK	56.43	13.19	58.41	108.55	18.42	93.70	164.98	31.60	152.10	0.39	20.3	155
T_7, 75% NPK + 25% (FYM)	75% NPK	58.98	14.51	61.25	100.30	17.02	90.09	159.28	31.52	151.33	0.39	20.5	158
T_8, 50% NPK + 50% (WH)	100%NPK	53.63	13.06	55.21	99.58	17.36	86.19	153.22	30.42	141.41	0.38	19.7	148
T_9, 75% NPK + 25% N (WH)	75% NPK	57.45	14.42	58.65	88.95	15.77	79.50	151.40	30.17	138.15	0.39	20.9	158
T_{10}, 50%NPK + 50% N (GLM)	100% NPK	64.34	15.67	64.58	115.32	21.17	105.27	179.66	36.84	169.84	0.41	21.1	159
T_{11}, 75% NPK + 25%N(GLM)	75% NPK	68.99	17.42	70.00	112.35	19.67	97.26	181.35	37.09	167.26	0.44	22.0	165
T_{12}, FP (80:30 kg NPK/ha)	FP (80:30 kg NP/ha)	42.77	10.69	49.12	96.72	14.84	71.92	131.66	25.28	121.03	0.37	19.1	159

Table 3. Average grain yield (q/ha) of rice and wheat under integrated nutrient management practices in long-term field trial

Treatment		1983–84		1984–85 to 1986–87		1987–88 to 1989–90		1990–91 to 1992–93		1993–94 to 1995–96		1996–97 to 1998–99	
Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat
T_1, Control	Control	19.40	13.38	17.33	12.24	14.33	10.63	13.83	11.77	15.10	13.27	14.45	10.42
T_2, 50% NPK	50% NPK	32.55	25.01	28.38	27.61	30.55	26.93	28.91	29.86	22.82	33.86	26.84	28.11
T_3, 50% NPK	100% NPK	32.90	34.98	29.44	37.38	32.39	36.79	33.51	37.45	23.95	40.15	27.88	40.86
T_4, 75% NPK	75% NPK	37.44	30.01	35.13	35.46	34.42	34.93	33.43	35.60	33.67	36.58	40.09	35.20
T_5, 100% NPK	100% NPK	40.50	35.01	39.59	46.84	39.77	45.57	38.50	45.99	38.46	45.30	50.42	43.29
T_6, 50% NPK + 50% N (FYM)	100% NPK	34.70	38.05	34.25	46.34	34.96	46.00	34.29	46.39	31.00	45.92	40.92	40.49
T_7, 75% NPK + 25% (FYM)	7%% NPK	38.25	34.00	38.03	42.36	36.57	43.63	35.91	44.09	32.50	42.55	44.12	37.73
T_8, 50% NPK + 50% (WH)	100% NPK	35.50	37.71	33.54	44.10	32.77	45.06	32.93	47.35	30.09	45.79	39.85	37.92
T_9, 75% NPK + 25% N (WH)	75% NPK	33.25	31.11	34.47	40.90	34.40	42.65	33.63	43.67	32.68	42.23	41.42	37.04
T_{10}, 50% NPK + 50% N (GLM)	100% NPK	37.20	38.51	35.81	45.74	36.35	47.79	36.02	47.97	37.68	48.14	47.76	44.23
T_{11}, 75% NPK + 25% N (GLM)	75% NPK	39.18	35.19	39.75	42.02	38.84	45.29	37.99	46.92	39.70	45.65	52.11	42.40
T_{12}, FP (80:30 kg NP/ha)	FP (80:30 kg NP/ha)	35.00	29.61	28.96	30.40	34.43	30.76	30.78	33.50	25.68	35.81	30.35	33.20
CD (P=0.05)		3.17	3.97	3.43	4.49	2.37	1.00	2.99	1.00	6.99	1.97	3.58	2.64

GLM and 100% inorganic NPK were applied in wheat. It was closely followed (Rs 15,267 and 1.80 benefit : cost ratio) by 100% NPK through inorganic source to both crops. Wheat cultivation in rice–wheat sequence without any fertilizer application was not found economical, as it caused a loss of Rs 2,765/ha which might be because of declining wheat yields (Yadav *et al.,* 1998).

In case of rice–wheat system, maximum net profit of Rs 20,202/ha with 1.54 benefit : cost ratio was obtained when both crops were fertilized with recommended NPK through inorganic source. It was followed (Rs 19,258/ha and 1.52 benefit : cost ratio) by when 25% N in rice was substituted by GLM and 75% NPK fertilizers were applied in wheat, and when 50% N in rice was substituted by GLM and in wheat 100% inorganic NPK were applied (Rs 18,046/ha and 1.47 benefit : cost ratio). These results corroborate to the findings of Tiwana *et al.* (1999) and Yadav (2001), who also reported higher profit from rice–wheat system with integrated nutrient management or recommended dose of NPK fertilizers.

NPK uptake

In rice, maximum NPK uptake was recorded when 25% N was substituted by GLM. Uptake of NP in wheat was maximum when 100% NPK were applied to the both crops. Uptake of K in wheat was the maximum when 50% N in rice was substituted by GLM and 100% NPK were applied in wheat. In rice–wheat system, the maximum uptake of NP was recorded when both the crops were fertilized with 100% NPK, whereas K uptake was the maximum when 50% N in rice was substituted by GLM and wheat crop was fertilized with 100% NPK. Higher production of crops in alone treatments seems to be responsible for higher NPK uptake in both individual crops and the system. Tiwana *et al.* (1999) also reported that the uptake pattern of nutrients in rice–wheat system behaves in a similar manner to yield of component crops.

Soil-fertility status

After final harvest of experiment, 100% NPK to both crops maintained higher values of organic carbon and available phosphorus in the soil, while available potassium was maximum when 25% N in rice was substituted by GLM and 75% NPK applied in wheat. As compared with initial soil fertility, 100% NPK to both crops increased organic carbon and available P by 0.06% and 3.5 kg/ha, respectively, while available K decreased by 24 kg/ha. Next best treatment in this respect was when 50% N rice was substituted by GLM + 100% NPK in wheat which enhanced organic carbon by 0.02% and available P by 2.5 kg/ha. An increase of 2.0 kg/ha available phosphorus was also recorded when 25% N in rice substituted by GLM and 75% NPK were applied in wheat. Treatments with sub-optimum dose of NPK fertilizers in both crops showed deterioration in soil-fertility parameters. The control showed maximum reduction to the tune of 0.12% in the organic carbon, 8.0 kg/ha available P and 83 kg/ha available K. Available K content reduced in all treatments compared to initial soil fertility. These results are in close conformity to those of Yadav (2001).

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