

Nutrient management for yield maximization of rice (*Oryza sativa*) – wheat (*Triticum aestivum*) cropping system

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Received : July 1997

ABSTRACT

A field investigation was carried out during winter 1990 – rainy season 1992 on loamy sand of average fertility status. The grain yield as well as the main crop productivity parameters significantly increased with maximum economic yield fertilizer level (MEYFL) of 180, 30 and 30 kg/ha to rice (*Oryza sativa* L.) and 180, 60 and 0 kg/ha to wheat (*Triticum aestivum* L. emend. Fiori & Paol.) (grown in sequence) over the recommended fertilizer level (RFL) of 120, 30 and 30 kg/ha to rice and 120, 60 and 30 kg/ha of N, P₂O₅ and K₂O respectively. The MEYFL was significantly superior to RFL with yield advantages of 16.2% in rice (average grain yield 8.6 tonnes/ha) and 13.5% in wheat (average grain yield 5.8 tonnes/ha). Green-manuring with *Sesbania aculeata* Pers. (20–25 tonnes/ha green matter) saved 60 kg/ha equivalent of N in rice without any residual effect on wheat. The higher levels of P and K and growth regulators cycocel (1 g/litre at 45 days), followed by cytokinin (50 mg/litre at 80 days) in 500 litres water/ha did not show any significant influence on rice and wheat.

The benefit : cost ratio with additional income over additional expenditure for the rice–wheat rotation at MEYFL was 2.35 with chemical fertilizer and 1.55 with green-manured series compared with 1.47 under RFL. Both crops showed higher uptake of N, P and K with MEYFL over RFL. The total uptake (kg/ha of N, P and K) was respectively 107, 18.8 and 94 in rice and 106, 18.3 and 97 in wheat at MEYFL; and 99, 16.5 and 88 in rice and 92, 15.8 and 97 in wheat at RFL. The rice and wheat straw component accounted only for 12 and 17% of N and 15 and 19% of P, though fraction of K retained was quite sizeable (92.1 and 82.1% respectively).

Key words: Nutrient management, Yield, Rice–wheat cropping

The rice–wheat is the dominant cropping system in the irrigated Indo-Gangetic Plains and it occupies 50% of 4.2 million ha in Punjab. The productivity of this very exhaustive system has thus far been sustained

through application of 120, 30 and 30 and 120, 60 and 30 kg/ha of N, P₂O₅ and K₂O respectively to rice and wheat grown at comparatively moderate population stands; achieved with spacing of 22.5 cm and seed

rate 80–100 kg/ha in wheat, and by planting 1 seedling/hill at 20 cm x 15 cm in rice. But, of late there has been a tendency for still higher fertilizer use though without commensurate increase in population. Heavy chemical fertilizer causes degradation of soil. Alternate integrated nutrient management (INM) strategy, therefore, needs to be explored for long-term sustainability of soil and crop productivity. Hence a study was undertaken to evaluate long-term effects of such practices on sustainability of rice–wheat productivity.

MATERIALS AND METHODS

The field experiment was conducted at Ludhiana (30°56'N, 75°52'E at 247 above mean sea-level from winter (*rabi*) 1990 to rainy (*kharif*) season 1992 on loamy sand (Typic ustochrepts) soil, low in organic carbon (0.34%) and medium in available P (13.4 kg/ha) and K (110 kg/ha), with pH 8.4.

The investigation comprised 2 sets of trials of 6 fertilizer schedules (N, P₂O₅ and K₂O kg/ha) applied to rice and wheat in sequence, with and without green-manuring to rice (Table 1). Rice was green-manured with *Sesbania aculeata* (green matter 20–25 tonnes/ha equivalent to 60–64 kg N/ha). Thirtyfive-day-old seedlings of 'PR 106' rice during 1991 and 'PR 110' during 1992 were transplanted on 16 and 19 June during 1991 and 1992 at a spacing of 15 cm x 15 cm (44 seedlings/hill). 'HD 2329' wheat was sown on 7 November during 1990 and 1991 in lines, 15 cm apart, using 100 kg seed/ha, i.e. at the spacings identified earlier as the optimum for realizing high potential yields with higher levels of fertilizer (Narang *et al.*, 1989). Rice was harvested in end of September and wheat in mid of April.

The uptake of N, P and K was estimated as per standard procedures (Jackson, 1973).

RESULTS AND DISCUSSION

Grain yield

Significantly higher grain yields of rice and wheat were obtained with MEYFL of 180, 30 and 30 kg/ha and 180, 60 and 30 kg/ha of N, P₂O₅ and K₂O ha over the RFL of 120, 30 and 30 and 120, 60 and 30 kg/ha respectively for rice and wheat (Tables 1, 2). The grain yield of rice was higher by 16.2% and of wheat by 13.5% under chemical fertilizer series and 16.2 and 9.4% respectively under green-manured series. Further increase to 240, 60 and 60 kg/ha and 240, 90 and 60 kg/ha of N, P₂O₅ and K₂O to rice and wheat did not increase the yield over the MEYFL. It rather depressed the yield in some cases. Nambiar and Abrol (1989) reported that 150% NPK increased the grain yield of wheat by 10% and of rice by 8.6% over RFL.

The highest grain yield of rice was at 120, 30 and 30 kg/ha + green-manure, which was equal to 180, 30 and 30 kg/ha of chemical fertilizer series (8.6 tonnes/ha). This shows that green-manure made contribution of about 60 kg N/ha equivalent. Narang *et al.* (1990) and Meelu *et al.* (1992) also reported economy of 60 kg N/ha with green-manuring to rice. Further, there was no residual effect of green-manure to rice on the succeeding crop of wheat, thus implying that wheat grown in sequence to rice would need higher application of N for sustained productivity.

Higher levels of P and K and plant-growth regulator (PGRs) did not show any significant influence on the grain yield or any of the productivity parameters of rice and wheat. Bhandari (1983) and Narang *et al.* (1990) also did not get any response to P and K on these soils.

Similarly, the primary grain productivity parameters such as dry-matter accumulation, leaf-area index (LAI), effective tillers/m², grains/spike and grains/panicle and 1,000-grain weight of rice (Table 1) and wheat (Table 2) increased significantly with MEYFL

Table 1. Yield and yield-attributing characters of rice in rice-wheat cropping system

N, P ₂ O ₅ , K ₂ O (kg/ha)		Grain yield (tonnes/ha)		Dry-matter production (tonnes/ha)			Leaf-area index			Effective tillers/ m ²	Grains/ panicle
Rice	Wheat	1991	1992	45 DAT	FLS	Harvest	45 DAT	FLS	Harvest		
<i>Chemical fertilizer series</i>											
120, 30, 30	120,60,30	7.2	6.7	2.0	5.5	6.4	2.06	6.32	1.54	388	175
180, 30, 30	180, 60, 30	8.4	6.2	2.2	5.7	6.6	2.37	6.41	1.83	406	179
180, 45, 45	180, 90, 45	8.5	6.4	2.2	5.8	6.6	2.39	7.49	1.82	409	178
240, 60, 30	180, 90, 60	7.2	6.1	2.6	5.9	6.6	2.63	7.98	2.02	448	174
240, 60, 60	240, 90, 60	7.6	6.2	2.5	5.8	6.7	2.47	7.85	1.86	438	172
240, 60, 60 +	240, 90, 60 +	7.4	6.4	2.5	5.9	6.7	2.55	7.93	1.77	435	170
GR	GR	0.84	NS								
<i>Green-manure series</i>											
120, 30, 30	120, 60, 30	8.6	6.3	2.1	5.6	6.5	2.27	6.42	1.65	403	178
180, 30, 30	180, 60, 30	7.5	6.2	2.3	5.8	6.5	2.55	7.54	1.90	416	174
180, 45, 45	180, 90, 45	7.4	6.2	2.3	5.9	6.6	2.58	7.48	1.88	419	174
240, 60, 30	180, 90, 60	7.2	6.1	2.6	5.9	6.6	2.63	7.98	2.02	448	174
240, 60, 30	180, 90, 60	7.2	6.1	2.6	5.9	6.6	2.63	7.98	2.02	448	174
240, 60, 60	240, 90, 60	7.6	6.1	2.6	6.0	6.7	2.65	7.96	1.92	445	173
240, 60, 90 +	240, 90, 60 +	7.6	6.2	2.6	5.9	6.8	2.61	8.06	1.97	449	172
GR	GR	0.6	NS								

GR, Growth regulators; DAT, days after transplanting; FLS, flag-leaf stage

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

N, P ₂ O ₅ , K ₂ O (kg/ha)		Grain yield (tonnes/ha)		Dry-matter production (tonnes/ha)			Leaf-area index			Effective tillers/m ²	Grains/panicle
Rice	Wheat	1990-91	1991-92	45 DAT	FLS	Harvest	45 DAT	FLS	Harvest		
<i>Chemical fertilizer series</i>											
120, 30, 30	120, 60, 30	5.2	5.2	1.48	4.3	5.1	1.25	5.28	1.37	403	44.0
180, 30, 30	180, 60, 30	5.9	5.9	1.72	4.6	5.6	1.49	6.60	1.68	420	47.4
180, 45, 45	180, 90, 45	5.9	5.8	1.78	4.6	5.5	1.54	6.58	1.61	422	48.0
240, 60, 30	180, 90, 60	5.9	5.9	1.79	4.6	5.5	1.52	6.65	1.74	420	47.5
240, 60, 60	240, 90, 60	5.8	5.8	1.92	4.9	5.4	1.65	7.26	1.84	431	48.4
240, 60, 60	240, 90, 60	5.8	6.0	1.95	4.8	5.6	1.61	7.34	1.81	435	48.2
+GR	+GR	0.53	0.57								
<i>Green-manure series</i>											
120, 30, 30	120, 60, 30	5.3	5.3	1.52	4.5	5.2	1.33	5.49	1.40	407	44.4
180, 30, 30	180, 60, 30	5.8	5.7	1.74	4.7	5.6	1.57	6.68	1.69	420	47.6
180, 45, 45	180, 90, 45	5.8	5.7	1.78	4.7	5.5	1.51	6.76	1.73	422	48.7
240, 60, 30	180, 90, 60	5.8	5.5	1.81	4.7	5.6	1.58	6.79	1.72	422	48.5
240, 60, 60	240, 90, 60	5.6	5.8	1.95	4.9	5.5	1.73	7.48	1.82	436	48.9
240, 60, 60	240, 90, 60	5.6	5.7	1.97	4.9	5.5	1.80	7.57	1.80	431	48.2
+GR	+GR	0.42	0.33								

GR, Growth regulators; DAT, days after transplanting; FLS, flag-leaf stage

of 180, 30 and 30 to rice and 180, 60 and 30 kg N, P₂O₅ and K₂O to wheat over the RFL. The LAI reached the peak at flag-leaf stage. More tillers were obtained at 180 kg N/ha (4.7% in rice and 3.3–4.2% in wheat) and at 240 kg N/ha (12.9% in rice and 7.3–8.3% in wheat). The MEYFL produced 4.2% more grains/panicle in rice and 7.2–7.7% more grains/spike in wheat over the RFL. But the fertilizer levels did not influence 1,000-grain weight of rice. Sharma and Mitra (1989) and Narang *et al.* (1990) also observed increased dry matter, LAI and higher panicles/spikes/unit area in rice and wheat at higher fertilizer levels in rice-wheat sequence.

Economics

The additional net returns/ha/annum from rice-wheat rotation with MEYFL were Rs 24,898 under chemical fertilizer and Rs 24,615 under green-manured series compared with Rs 20,840 under RFL (Table 3). The benefit : cost ratio with additional expenditure and additional income with MEYFL over RFL was 2.35 under chemical fertilizer and 1.55 under green-manure series compared with 1.47 with RFL, thus showing the MEYFL to be economically viable.

Nutrient uptake

Although no significant differential effect in tissue N, P and K content was obtained at any stage in both rice and wheat under different levels of fertilizer schedules, quite large differences were observed in the uptake of nutrients (Table 4).

Nitrogen uptake: Total N uptake significantly increased with MEYFL both in rice and wheat (Table 4). It was higher by about 20% at 180, 30 and 30 kg/ha over 120, 30 and 30 kg/ha of N, P₂O₅ and K₂O in rice; and 15% in wheat at 180, 60 and 30 kg/ha over 120, 60 and 30 kg/ha of N, P₂O₅ and K₂O. The trend in green-manure series was almost similar (data not reported).

The N uptake showed that continuous higher rate was maintained throughout the growth period. The N uptake (kg/ha) at 45-day, 85-day and harvest stages was 34, 66 and 101 at 20, 30 and 30 kg/ha compared with 39, 70 and 121 at 180,30 and 30 kg/ha of N, P₂O₅ and K₂O, similar to those observed by Narang *et al.* (1990) and Mishra *et al.* (1991).

Only 12% of the total N uptake was left in rice straw and almost the entire accumulated tissue N (88%) was translocated from foliage to the grains. This was much higher than reported by Gill (1979), who observed 30–35% in straw and 66–71% N in grains of rice at harvest. The respective value of N uptake (kg/ha) for wheat at 45-day, 85-day and harvest stages were 42, 72 and 105 at 180, 60 and 30 and 120, 60 and 30 kg/ha of N, P₂O₅ and K₂O. The N component in wheat straw was just 17% of the total N uptake. The bulk of the N removal (84%) like in rice, was apportioned by the grains. It seems that during the accelerated demand phase of grain development, all the accumulated N pools get translocated from foliage to grains. Boparai (1982) also observed that N in wheat straw was 18% and in grains 83%.

Table 3. Cost and returns of wheat in rice-wheat cropping system

N, P ₂ O ₅ , K ₂ O (kg/ha)		Gross returns (Rs/ha)	Variable cost (Rs/ha)	Returns over variable cost (Rs/ha)	Benefit : cost ratio
Rice	Wheat				
120, 30, 30	120, 60, 30	38,810	17,971	20,840	1.47
120, 30, 30 + GM	180, 60, 30	45,010	20,395	24,615	1.55
180, 30, 30	180, 60, 30	44,595	19,697	24,898	2.35

GM, Green-manuring

Table 4. Total uptake and percentage of total uptake by rice and wheat in rice-wheat cropping system (mean data of 2 years)

N, P ₂ O ₅ , K ₂ O (kg/ha)		Rice (kg/ha)				Wheat (kg/ha)				Total uptake at harvest			
Rice	Wheat	45 days	FLS	Harvest		45 days	FLS	Harvest		Rice		Wheat	
				Straw	Grain			Straw	Grain	Straw	Grain	Straw	Grain
<i>Nitrogen</i>													
120, 30, 30	120, 60, 30	36	68	14	87	39	75	16	84	12.5	85.5	15.0	76.5
120, 30, 30 + GM	180, 60, 30	37	67	13	87	42	73	17	83	13.5	90.5	17.5	86.5
180, 30, 30	180, 60, 30	39	69	14	87	40	70	17	84	14.0	92.5	17.5	88.0
240, 60, 60	240, 90, 60	46	74	15	86	46	75	17	83	15.0	94.5	18.0	92.0
<i>Phosphorus</i>													
120, 30, 30	120, 60, 30	38	77	12	88	36	75	18	82	2.0	14.5	2.8	13.0
120, 30, 30 + GM	180, 60, 30	39	78	13	88	38	75	20	81	2.3	15.5	3.5	13.0
180, 30, 30	180, 60, 30	41	80	15	85	37	72	18	82	2.8	16.0	3.3	15.0
240, 60, 60	240, 90, 60	45	78	19	82	42	78	21	79	3.2	16.5	3.9	15.5
<i>Potassium</i>													
120, 30, 20	120, 60, 30	48	81	78	22	42	88	82	19	67.5	18.5	68.0	16.0
120, 30, 30 + GM	180, 60, 30	50	82	77	23	44	84	81	19	70.0	21.0	78.0	18.5
180, 30, 30	180, 60, 30	53	80	77	24	44	82	80	23	72.0	22.0	77.5	19.5
240, 60, 30	240, 90, 60	54	77	74	27	48	87	78	22	80.5	28.5	80.5	22.5

GM, Green-manuring

Phosphorus uptake: The total P uptake at harvest increased in rice at MEYFL by 28.1% and in wheat by 13.8% over the RFL (table 4), though it was not influenced by application of higher levels of P and K. Similar results were also observed by Kolar and Grewal (1989) and Narang *et al.* (1990).

The P uptake spectrum showed that in rice, the P uptake at 45-day, 85-day and harvest stages was 6.1, 12.9 and 17.1 kg/ha at 180, 60 and 30 kg N, P₂O₅ and K₂O/ha respectively. The P uptake component was 12–18% in straw and 82–88% in grains (Table 4). The P uptake in wheat at 45-day, 85-day and harvest stages was 5.6, 11.6 and 16.0 kg/ha at 120, 60 and 30; and 6.7, 12.9 and 18.2 kg/ha at 180, 60 and 30 kg/ha of N, P₂O₅ and K₂O. The proportion of P uptake in wheat was 19% in straw and 81% in grains.

Thus, rice and wheat required a continuous liberal supply of N and P to sustain an accelerated demand for potential yield realization.

Potassium uptake: The N application significantly increased the total uptake of K in rice and wheat up to the highest level of 240 kg N/ha (Table 4). But the total uptake of K was not influenced significantly by higher levels of P and K. The MEYFL of 180, 30 and 30; and 180, 60 and 30 kg N, P₂O₅ and K₂O/ha increased the total uptake of K by 12.8% in rice and 13.0% in wheat, as also observed by Bhandari (1983).

The K uptake spectrum showed that the K uptake in rice at 45-day, 85-day and harvest stage was 42, 70 and 86 kg/ha with 120, 30 and 30 kg/ha; and 48, 75 and 97 kg/ha with 180, 30 and 30 kg/ha of N, P₂O₅ and K₂O respectively. The percentage of total K uptake was 75 in straw and 25 in grains.

In wheat the K uptake was 35, 72 and 85 kg/ha with 120, 60 and 30 kg/ha and 42, 79 and 96 kg/ha with 180, 60 and 30 kg/ha level at 45-day, 85-day and harvest stages respectively. At harvest the straw accounted for 81%

and grains for 19% of the total K uptake.

Maintaining a liberal supply of N, P and K thus seems to be the key to realizing higher yield potential of the intensive rice-wheat system on these soils of average productivity.

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