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Balance sheet of nitrogen, phosphorus and potassium under different rice (*Oryza sativa*)-based cropping systems

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ABSTRACT

The field experiment conducted at the Indian Agricultural Research Institute, New Delhi, during the crop years 1995-96 and 1996-97 indicated that rice (*Oryza sativa* L.)–berseem (*Trifolium alexandinum* L.) cropping system removed the maximum quantity of NPK (1,140 kg/ha), followed by rice–potato (*Solanum tuberosum* L.)–greengram (*Phaseolus radiatus* L.) (1,060 kg/ha) and rice–Indian mustard [*Brassica juncea* (L.) Czerng. & Cosson]–greengram (1,029 kg/ha) cropping system. Heavy depletion of NPK by rice–berseem cropping system resulted in negative balance of nitrogen (144 kg/ha), phosphorus (23 kg/ha) and potassium (416 kg/ha). Rice–Indian mustard–greengram cropping system also resulted in negative balance of 131 kg/ha of N and 330 kg/ha of K. Nitrogen and phosphorus balance was found positive in rice–wheat (*Triticum aestivum* L. emend. Fiori & Paol.)–greengram and rice–potato–greengram cropping systems, whereas potassium balance was negative in these cropping systems. These results, thus, show that potassium was found to be most removable nutrient by the crops, which results in mining of soil K and thus calls for adequate K fertilization.

Key words : Rice based cropping systems, NPK uptake & Balance sheet

Until now, nutrient uptake studies were conducted mostly on individual crops. Reports on nutrients uptake in cropping systems are limited. The high-yielding varieties grown in multiple crop sequences with recommended package of practices remove considerable amount of nutrients from soil and thus information is urgently needed to understand the mining of soil nutrients and to work out the nutrient balance over a period of time. The present study was, therefore, conducted to study the nutrient removal by 5 rice-based cropping systems, having 200 to 300% cropping intensities. An attempt was also made to work out balance sheet of NPK of different cropping systems.

MATERIALS AND METHODS

A field experiment was conducted

during crop years 1995-95 and 1996-97 at New Delhi, in split-plot design with 3 replications. There were 5 cropping systems (rice-wheat, rice–wheat–greengram, rice–berseem, rice–potato–greengram and rice–Indian mustard–greengram) in main plots and 6 nutrient combinations (N, NP, NK, NPK, NPK + Zn and NPK + FYM) in subplots. The recommended dose of N, P, K, Zn and FYM applied to different crops of 5 cropping systems are given in Table 1. Greengram was grown on residual fertility. The soil of experimental field was sandy clay loam, having 52.5% sand, 21.0% silt and 26.5% clay. The initial soil-test values were: pH 8.3, organic carbon 0.55% available N 319.2 kg/ha, available P 19.0 kg/ha and available K 285.3 kg/ha. The experiment was started with rice crop. The field was flooded with water, tilled with puddler and levelled. After making layout, whole quantity of P, K, Zn and FYM as per treatments was applied before transplanting of rice. Nitrogen was applied in 2 splits, half 10 days after transplanting and half at panicle initiation. Rice 'Pusa Basmati 1' seedlings (25–30 days old) were transplanted in the first fortnight of July and harvested in second fortnight of October.

After rice harvest, field was irrigated and at optimum moisture condition, it was prepared for sowing of winter crops. Berseem, Indian mustard and potato crops were sown during the first week of November and wheat in the third week of November. Half dose of N and full dose of P, K, Zn and FYM were applied before sowing of winter (*rabi*) crops and the remaining N was applied 30 days after sowing of winter crops. Four to five cuttings were taken in berseem. Potato and Indian mustard were harvested in the second week of March and wheat in the second week of April.

Greengram was sown in the third week of March after potato and Indian mustard and in the third week of April after wheat. Greengram grown after potato and Indian mustard gave 2 pickings, whereas the crop sown after wheat gave only 1 picking. The first picking of matured pods of greengram grown after potato and Indian mustard was done in the third week of May and second picking in the second week of June. In case of greengram sown after wheat pods were picked up in the last week of June. After harvesting of each crop, grain or tuber and straw samples were collected and analyzed for total N, P and K by modified macro-Kjeldahls, method, molybdovanadophosphoric acid yellow colour method and by flame-emission spectro-photometry method, respectively (Jackson, 1973). Total

Table 1. Recommended doses of nutrients applied to different crops

Nutrient	Rice	Wheat	Indian mustard	Potato	Berseem	Greengram
N (kg/ha)	120.0	120.0	60.0	120.0	40.0	
P (kg/ha)	26.2	26.2	17.5	26.2	26.2	
K (kg/ha)	33.2	33.2	24.9	66.4	33.2	
Zn (kg/ha)	6.5	6.5	6.5	6.5	6.5	
FYM (tonnes/ha)	10.0	10.0	10.0	10.0	10.0	

N, P and K uptake was calculated by multiplying dry matter with their respective concentrations.

RESULTS AND DISCUSSION

Productivity of cropping systems

Rice–potato–greengram cropping system gave the highest productivity and rice–wheat the lowest (Table 2). Although the differences between the productivity of rise–berseem and rice–Indian mustard–greengram in 1995-96 and of rice–wheat–greengram and rice–wheat cropping systems in both years were not significant, the productivity of these cropping systems in both the years was in the following order rice–potato–greengram > rice–berseem > rice–Indian mustard–greengram > rice–wheat–greengra > rice–wheat.

In rice–wheat cropping system 58% of the total productivity was contributed by rice and 42% by wheat. It was reverse in case of rice–berseem cropping system where only 42–45% contributed by rice and 55– to 58% by berseem. In the rice–potato–greengram, potato contributed 41–51%, rice 37–38% and summer greengram 12–18%. In rice–Indian mustard–greengram cropping system, rice contributed about half of the total productivity and rest half was contributed by Indian mustard (32–34 %) and greengram (17–21 %).

These results indicate that both potato and berseem were more contributor to the productivity than rice. This might possibly be owing to higher production potential of these crops than grain crops (Sarkar and Gangwar, 1998). Prasad and Kerketta (1992) and Padhi (1993) also reported similar findings. Sharma (1987) and Tomar and Tiwari (1990) also reported about substantial contribution of greengram in rice–potato–greengram and rice–Indian mustard–greengram cropping systems.

Nitrogen uptake

In 1995-96, the maximum N uptake was recorded in rice–Indian mustard–greengram and it was significantly higher than that in all the other cropping systems, whereas in 1996-97, the maximum uptake of N was found in rice–potato–greengram and it was significantly higher than that in rice–wheat, rice–wheat–greengram and rice–berseem. The minimum uptake of N was observed in rice–wheat in both the years.

Among individual crops, berseem removed maximum quantity of N, followed by Indian mustard, and wheat (Table 4). Prasad and Kerketta (1992) also reported the higher amount of nitrogen removal by rice–berseem due to higher tonnage of biomass produced by berseem in the respective rotation.

Phosphorus uptake

The phosphorus removed by different cropping systems in a year was 31–66 kg P/ha. The order of P removal by different cropping systems was in order of rice–berseem > rice–potato–greengram > rice–Indian mustard–greengram > rice–wheat–greengram > rice–wheat. However, the difference in P removal between rice–wheat and rice–wheat–greengram in 1995–96 and rice–wheat–greengram and rice–Indian mustard–greengram in 1996–97 was non-significant. The higher amount (62-66 kg P/ha) of phosphorus removed by rice–berseem was due to higher amount of biomass produced by berseem as well as higher phosphorus concentration in plant. Maha-

Table 2. Productivity of different crops in rice-based cropping systems (rice-equivalent yield, q/ha)

Cropping system	1995–96				1996–97				Pooled			
	Rainy season	Winter season	Summer*	Total	Rainy season	Winter season	Summer	Total	Rainy season	Winter season	Summer	Total
Rice–wheat	45.7	32.6		78.3	46.9	34.4		81.2	46.3	33.5		79.8
Rice–wheat–greengram	46.7	32.6	6.9	86.2	49.8	36.0	3.9	89.7	48.3	34.3	5.4	88.0
Rice–berseem	46.3	64.7		111.0	51.1	62.7		113.8	48.7	63.6		112.3
Rice–potato–greengram	47.3	64.5	14.5	126.3	52.2	59.4	24.3	135.9	49.8	61.9	19.4	131.1
Rice–Indian mustard–greengram	46.4	31.6	16.4	94.4	49.4	30.3	21.2	100.9	47.9	30.9	18.8	97.6
CD (P=0.05)	0.68	5.15	5.46	6.63	3.10	8.15	3.16	9.89	1.56	6.58	2.67	7.50

Price (Rs/q) : Rice grain 800, rice straw 20, wheat grain 550, wheat straw 50, berseem 40, potato tubers 200, Indian mustard grain 1,200, Indian mustard stover 20, greengram 1,200

*Straw of greengram was incorporated in to the soil

Table 3. Nutrient removal (kg/ha) of rice-based cropping systems

Cropping system	1995–96				1996–97				Pooled			
	N	P	K	Total	N	P	K	Total	N	P	K	Total
Rice–wheat	181.8	30.6	206.3	418.7	188.1	31.3	207.1	426,5	184.9	30.9	206.7	422.5
Rice–wheat–greengram	200.2	32.9	207.9	441.0	211.5	35.8	223.8	470.6	205.8	34.3	215.6	455.8
Rice–berseem	228.0	65.7	271.4	565.1	235.9	62.4	277.1	575.4	231.8	64.0	274.2	570.0
Rice–potato–greengram	217.5	47.8	232.8	498.1	253.9	54.4	253.9	562.2	235.7	51.1	243.3	530.1
Rice–Indian mustard–greengram	240.6	36.5	228.9	506.0	250.8	38.8	233.6	523.2	245.6	37.5	231.2	514.3
CD (P = 0.05)	13.27	2.84	8.57	21.00	11.83	3.16	24.47	34.77	10.48	4.37	12.83	12.95

Table 4. Nutrient removal and balance sheet of nutrients in rice-based cropping systems

Cropping system	Total nutrient applied to soil in 2 years (kg/ha)	Nutrient removed								Total nutrient (NPK) in two years (kg/ha)	Nutrient balance in soil (kg/ha)
		1995–96				1996–97					
		Rainy season	Winter season	Summer season	Total	Rainy season	Winter season	Summer season	Total		
					Nitrogen						
Rice–wheat	480.0	90.0	91.8		181.8	94.5	93.6		188.1	369.9	+ 110.1
Rice–wheat–greengram	480.0	91.7	91.9	16.6	200.2	102.0	100.0	9.5	211.5	411.7	+ 68.2
Rice–berseem	320.0	91.5	136.5		228.0	102.2	133.7		235.9	463.9	-143.9
Rice–potato–greengram	480.0	91.8	90.2	35.5	217.5	103.4	91.1	59.4	253.9	471.4	+8.6
Rice–Indian mustard–greengram	360.0	90.8	110.0	39.8	240.6	98.7	100.4	51.7	250.8	491.4	-131.4
					Phosphorus						
Rice–wheat	104.8	14.8	15.8		30.6	15.5	15.8		31.3	61.9	+ 42.9
Rice–wheat–greengram	104.8	15.1	15.8	2.1	33.0	17.1	17.5	1.2	35.8	68.8	+36.0
Rice–berseem	104.8	14.2	51.5		65.7	16.7	45.7		62.4	128.1	-23.3
Rice–potato–greengram	104.8	14.9	28.3	4.6	47.8	17.3	29.2	7.9	54.4	102.2	+2.6
Rice–Indian mustard–greengram	87.4	15.1	16.6	4.8	36.5	16.1	16.2	6.5	38.8	75.3	+12.1
					Potassium						
Rice–wheat	132.8	102.2	104.1		206.3	106.7	100.4		207.1	413.4	-280.6
Rice–wheat–greengram	132.8	99.9	104.0	4.0	207.9	110.5	110.5	2.3	223.3	431.2	-298.4
Rice–berseem	132.8	98.9	172.5		271.4	113.2	163.9		277.1	548.5	-415.7
Rice–potato–greengram	199.2	98.5	126.1	8.2	232.8	110.1	129.5	14.3	253.9	486.7	-287.5
Rice–Indian mustard–greengram	132.8	100.4	118.8	9.7	228.9	108.8	111.8	13.0	233.6	462.5	-329.7
					Total						
Rice–wheat	717.6	207.0	211.7		418.7	216.7	209.8		426.5	845.2	-127.6
Rice–wheat–greengram	717.6	206.7	211.7	22.7	441.1	229.6	228.0	13.0	470.6	911.7	-194.1
Rice–berseem	557.6	204.6	360.5		565.1	232.1	343.3		575.4	1,140.5	-582.9
Rice–potato–greengram	784.0	205.2	244.6	48.3	498.1	230.8	249.8	81.6	562.2	1,060.3	-276.3
Rice–Indian mustard–greengram	580.2	206.3	245.4	54.3	506.0	223.6	228.4	71.2	523.2	1,029.2	-449.0

patra *et al.* (1974) also reported higher P uptake by the fodder crops included in rotation than other crops.

Potassium uptake

Rice–berseem sequence resulted in the maximum potassium uptake followed by rice–potato–greengram and rice–Indian mustard–greengram (Table 3). The lowest uptake of K was observed in rice–wheat sequence mainly due to 2 crops sequence.

Among individual crops, berseem removed the maximum quantity of K, followed by potato, Indian mustard, wheat and greengram. Deka and Singh (1984) also observed significant differences in K uptake due to different cropping sequences.

Balance sheet of nutrients

Budgeting of nutrients added as fertilizer and removed by the crops showed a deficit of nitrogen in rice–berseem and rice–mustard–greengram cropping systems (Table 4). This deficit is mainly because the quantity of N applied to legume crops was small and N content in plant material was higher. Similarly, the N content of seed and stover of Indian mustard was higher.

The balance of P was positive under all cropping systems except rice–berseem (11.6 kg P/ha/year) and it varied from 1.3 kg/ha/year in rice–potato–greengram cropping system to 21.4 kg/ha/year in rice–wheat cropping system.

The balance of K was negative under all rotations. Maximum deficit of K was observed under rice–berseem and lowest deficit under rice–wheat cropping system. Rice–wheat–greengram, rice–potato–greengram and rice–Indian mustard–greengram cropping systems resulted in 17.8, 6.9 and 49.1 kg/ha higher negative balance compared with rice-wheat cropping system. These results confirm those of George and Prasad (1989).

The results indicate an alarming situation for mining of nutrients particularly nitrogen and potassium and call for heavy fertilization of crops and cropping systems.

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