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Integrated nutrient supply on crop productivity and soil fertility in rice (*Oryza sativa*)–rice system

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ABSTRACT

A study carried out at 4 locations in coastal area for the last 4–10 years in rice (*Oryza sativa* L.)–rice system indicated that 25–50% N need of rice in rainy season could be substituted by organic sources like farmyard manure (FYM) and green-manure at Bhubaneshwar and Maruteru, whereas a part of fertilizer N could also be substituted by even rice straw at Karamana. However, at Kharagpur it was not possible to substitute N without any significant reduction in productivity. Continuous rice–rice cropping led to increase in organic carbon status, whereas it had variable impact on available P and K status at different locations. Integrated nutrient supply had favourable effect on organic carbon status only at Bhubaneshwar, but had no effect on available P and K status. There was positive N and P balance and negative K balance with the recommended levels of nutrient application. Integration of FYM and rice straw with chemical fertilizers had more favourable effect on nutrient balance than with green-manures.

Rice (*Oryza sativa*)–rice sequential cropping is an important double-cropping system in the coastal area of the country (Hegde, 1993). This system needs large amount of nutrients to achieve high productivity. Long-term experiments at many locations have indicated that even with application of recommended amounts of fertilizers (NPK), it will not be possible to sustain the productivity of rice–rice system (Nambiar *et al.*, 1992) and emphasized the importance of integrated nutrient-supply system in sustaining productivity (Hegde, 1992). This involves the use of chemical fertilizers in conjunction with organic sources such as farmyard manure (FYM), crop residues, green-manures etc. This approach restores and sustains soil health and productivity in the long run (Mohanty *et al.*, 1992) besides meeting the nutritional deficiencies which are likely to occur due to continuous and intensive cultivation (Nambiar and Abrol, 1989; Patnaik *et al.*, 1989; Suzuki *et al.*, 1990; Prasad and Power, 1991). The present study was therefore initiated to study the effect of integrated nutrient supply of chemical fertilizers and organic sources on crop productivity and soil fertility in rice–rice system in coastal area of the country.

MATERIALS AND METHODS

The study was initiated during 1988–89 at Kharagpur (West Bengal), 1983–84 at Bhubaneshwar (Orissa), 1989–90. at

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Maruteru (Andhra Pradesh) and 1985–86 at Karamana (Kerala). The soil type and important physico-chemical characteristics of the soil in different locations are presented in Table 1. There were 12 treatments (Table 2), which included 4 treatments of different levels of recommended fertilizers in rainy and winter seasons, 6 treatments of integration of chemical fertilizers with organic sources

Table 1. Physico-chemical properties of soils in the experimental fields

Character	Kharagpur	Bhubaneshwar	Maruteru	Karamana
Soil taxonomic class	Udic Ustochrepts	Haplu-stults	Chromus-terts	Typic Tropofluvent
Soil texture	Sandy clay loam	Sandy loam	Clayey	Sandy loam
Sand (%)	59.4	88.3	10.0	72.0
Silt (%)	20.9	5.7	29.0	8.0
Clay (%)	19.7	6.0	61.0	20.0
pH (1 : 2.5)	5.4	5.9	7.0	5.2
Electrical conductivity (dS/m)	0.15	0.37	0.44	0.02
Organic carbon (%)	0.38	0.43	0.97	1.19
Available N (kg/ha)		255		
Available P (kg/ha)	20.4	20.0	24.6	31.2
Available K (Kg/ha)	192	210	580	101

Table 2. Details of fertilizers treatments in rainy and winter seasons

Treatment	Rainy season	Winter season
T_1	No fertilizer, no organic matter (control)	No fertilizer, no organic matter (control)
T_2	50% recommended NPK dose through fertilizers	50% recommended NPK dose through fertilizers
T_3	50% recommended NPK dose through fertilizers	100% recommended NPK dose through fertilizers
T_4	75% recommended NPK dose through fertilizers	75% recommended NPK dose through fertilizers
T_5	100% recommended NPK dose through fertilizers	100% recommended NPK dose through fertilizers
T_6	50% recommended NPK dose through fertilizers + 50% through FYM	100% recommended NPK dose through fertilizers
T_7	75% recommended NPK dose through fertilizers + 25% through FYM	75% recommended NPK dose through fertilizers
T_8	50% recommended NPK dose through fertilizers + 50% through rice straw	100% recommended NPK dose through fertilizers
T_9	75% recommended NPK dose through fertilizers + 25% through rice	75% recommended NPK dose
T_{10}	50% recommended NPK dose through fertilizers + 50% through green-manures	100% recommended NPK dose through fertilizers
T_{11}	75% recommended NPK dose through fertilizers + 25% through green-manures	75% recommended NPK dose through fertilizers
T_{12}	Farmers' practice	Farmers' practice

FYM, Farmyard manure

Table 3. Recommended fertilizer level and varieties used at different locations

Particulars	Season	Kharagpur	Bhubaneshwar	Maruteru	Karamana
Fertilizers ($N : P_2O_5 : K_2O$, kg/ha)	Rainy	120 : 60 : 60	100 : 50 : 50	60 : 40 : 40	75 : 35 : 35
	Winter	120 : 60 : 60	100 : 50 : 50	120 : 80 : 40	75 : 35 : 35
Varieties	Rainy	'IR 50' (1988–89) 'IR 36' (1989–90 to 1992–93)	'OR 131-3-3' (1983–84 to 1985–86) 'Pratap' (1986–87 to 1989–90) 'Lalata' (1990–91) 'OR 621-6' (1991–92, 1992–93)	'MTU 2067' (all years)	'Jaya' (all years)
	Winter	'IR 36' (all years)	'OR 201-40-4' (1983–84) 'Lalata' (1984–84 to 1988–89 and 1992–93) 'Pratap' (1989–90) 'Pothana' (1990–91, 1991–92)	'MTU 7104' (1989–90) 'IR 64' (1991–92 to 1992–93)	'Jaya' (all years)

like FYM, crop residues (rice straw) and green-manures (*Sesbania* biomass) along with one each of unfertilized control and farmers' practice of manuring. Farmers' practice of manuring consisted of 50% of recommended dose of NP application at Kharagpur, Bhubaneshwar and Karamana and 100 and 50% of recommended N and P at Maruteru respectively. The treatments were laid out in randomized block design with 4 replications. The varieties used in rainy and winter seasons in different years and recommended levels of fertilizers for all the locations are presented in Table 3. The N content in different organic materials were determined during each year and their quantities required to substitute a specified amount of recommended N was calculated. These materials were incorporated in the soil about 2 weeks before transplanting in rainy season. Standard package of practices recommended for different locations were adopted for raising the crop in both seasons.

The NPK uptake in grain and straw were determined separately and the total uptake was calculated. Nutrient balance was worked out for selected treatments during 1992–92 at Kharagpur and Maruteru and during 1991–93 at Bhubaneshwar. Soil was analysed for important chemical parameters like organic carbon (available N), available P and K after 4, 10, 3 and 7 years of experimentation at Kharagpur, Bhubaneshwar, Maruteru and Karamana respectively.

RESULTS AND DISCUSSION

System productivity

It was observed from the average yield data that rice–rice system required application of 100% of recommended fertilizers in both the seasons except at Karamana, where it was possible to reduce the total fertilizer needs by 25% without any adverse effect on system productivity (Table 4). This is probably due to low nutrient needs as evident from the low level of recommended fertiliz-

Table 4. Effect of integrated nutrient supply on productivity (kg/ha) of rice–rice system

Treatment	Kharagpur (average of 5 years)			Bhubaneshwar (average of 10 years)			Maruteru (average of 4 years)			Karamana (average of 8 years)		
	Rainy season	Winter season	Total	Rainy season	Winter season	Total	Rainy season	Winter season	Total	Rainy season	Winter season	Total
T_1	2,871	3,073	5,944	1,590	1,558	3,148	2,477	2,060	4,537	3,167	2,417	5,584
T_2	4,163	4,577.	8,740	2,483	2,745	5,228	3,275	3,155	6,430	3,554	2,845	6,399
T_3	4,400	4,605	9,005	2,593	3,803	6,396	3,229	4,733	7,962	3,636	3,036	6,672
T_4	4,460	4,714	9,174	2,934	3,383	6,317	3,932	3,847	7,779	3,647	2,900	6,547
T_5	5,206	5,421	11,127	3,616	3,862	7,478	4,718	4,512	9,230	3,680	2,989	6,669
T_6	5,037	5,172	10,209	3,619	4015	7,634	4,406	4,990	9,396	4,033	3,333	7,366
T_7	4,650	4,616	9,266	3,448	3,532	6,980	4,906	3,969	8,875	3,854	3,022	6,876
T_8	4,733	5,051	9,784	2,960	3,843	6,803	3,526	4,790	8,316	3,680	2,987	6,667
T_9	5,034	5,002	10,036	3,214	3,486	6,700	4,070	4,003	8,073	3,657	2,876	6,533
T_{10}	5,007	4,933	9,940	3,402	4,014	7,416	3,911	5,138	9,049	3,758	3,018	6,776
T_{11}	4,789	4,680	9,369	3,653	3,598	7,251	4,723	4,427	9,150	3,626	2,944	6,570
T_{12}	4,368	4,264	8,632	2,477	2,719	5,196	3,942	4,113	8,055	3,629	2,596	6,225
CD ($P = 0.05$)	185	211		42	48		180	196		156	121	

Details of treatments are given in Table 2 ers. At Kharagpur, application of 100% of nutrients through chemical fertilizers in both seasons gave significantly higher yield and it was not possible to substitute a part of N needs of rice through any organic source without any significant adverse effect on system productivity. The reduction in yield was 8.3–16.7% with different organic sources compared to that with 100% through fertilizers in both seasons. Results from Bhubaneshwar and Maruteru clearly indicate the possibility of substituting 50% N needs of rice in rainy season through FYM without any reduction in the total productivity. At Bhubaneshwar, 50% N substitution through green-manures during the rainy season was also equally effective as 100% nutrient supply through fertilizers in both seasons. However, at Maruteru 25% N substitution through green-manures in rainy season, followed by 75% of recommended fertilizers application in the winter was almost comprable to the treatment which received all the recommended nutrients through fertilizers. At both these locations, N substitution by rice straw markedly reduced the system productivity compared with application of all the nutrients through fertilizers. At Karamana, all the 3 organic sources, viz. FYM, rice straw and green manures, could effectively substitute 25–50% N need without any adverse effect on productivity. Use of FYM to substitute 50% N needs increased the total rice production by 10.5% over that which received all the recommended nutrients through only fertilizers. N substitution up to 25% through any source also enabled fertilizer economy to the extent of 25% in the winter season without any significant adverse effect. Patnaik *et al.* (1989), Nambiar *et al.* (1992) and Hegde (1992) also reported possibilities of integrated use of fertilizers and organic manures in rice–rice cropping system.

The differential response to N substitution by organic sources could probably be related to temperature regimes at these 4 locations (Prasad and Power, 1991). The mean temperatures at Kharagpur is lowest, whereas at Karamana highest. The low temperature at Kharagpur might have delayed the mineralization of nutrients in organic sources. However, at Bhubaneshwar and Maruteru, due to higher temperature, easily mineralizable sources like FYM and green-manures could easily substitute a part of fertilizer N. At Karamana even the material like rice straw, which is difficult to decompose, could be used to substitute a part of N need due to high temperature even during winter which aided in its quick decomposition and mineralization.

Soil fertility

At Kharagpur, after 4 years of continuous cropping, all the fertilized plots had higher available N than the unfertilized plot (Table 5). This may be due to recycling of more organic matter from stubbles left in the fields, which upon decomposition released nitrogen to the soil. Among the fertilized plots, application of 100% NPK through fertilizers in both seasons and N substitution through green-manures resulted in markedly higher available N than with others.

The organic carbon status of soil increased substantially in all the treatments compared with its initial level. Continuous flooding in rice–rice system is generally reported to increase soil organic carbon status (Nambiar *et al.*, 1992). Fertilization either with chemical fertilizers alone or in combination with different organic sources had no marked effect on the organic carbon status at Maruteru and Karamana. However, at Bhubaneshwar there was marked increase in

Table 5. Effect of integrated nutrient supply on soil-fertility status

Treatment	Kharagpur (after 4 years)			Bhubaneshwar (after 10 years)			Maruteru (after 3 years)			Karamana (after 7 years)		
	N (kg/ha)*	P (kg/ha)*	K (kg/ha)*	O.C. (%)	P (kg/ha)*	K (kg/ha)*	O.C (%)	P (kg/ha)*	K (kg/ha)*	O.C. (%)	P (kg/ha)*	K (kg/ha)*
T_1	130	5.5	55	0.49	16.0	135	1.21	14.6	565	1.37	23.3	101
T_2	144	7.4	65	0.54	26.0	170	1.13	17.4	379	1.27	28.2	106
T_3	150	7.8	66	0.61	24.5	190	1.21	23.8	499	1.24	31.2	112
T_4	176	7.5	77	0.56	25.0	185	1.25	17 4	552	1.18	26.7	122
T_5	198	8.5	77	0.67	27.0	170	1.30	22.0	512	1.38	29.0	108
T_6	165	8.9	96	0.84	24.0	155	1.01	17.4	525	1.36	24.7	116
T_7	153	8.8	88	0.79	28.0	180	1.25	30.2	565	1.36	30.3	120
T_8	154	7.5	84	0.87	26.0	195	1.29	20.1	525	1.56	30.1	125
T_9	176	8.3	76	0.91	24.5	190	1.21	25.6	539	1.33	30.3	132
T_{10}	198	8.3	88	0.90	26.0	145	1.25	21.0	539	1.43	28.9	122
T_{11}	198	8.2	86	0.84	25.5	140	1.21	19.2	539	1.39	30.8	108
T_{12}	134	7.3	75	0.92	24.0	135	1.25	14.6	499	1.26	23.5	100

*Available N, P and K; O.C., organic carbon
Details of treatments are given in Table 2

Table 6. Balance sheet of major nutrients in selected treatments

Treat-ment	Nutrient (kg/ha)	Kharagpur (1991–92)			Bhubaneshwar (1992–93)			Maruteru (1991–92)		
		N	P	K	N	P	K	N	P	K
T_5	Addition	240.0	52.4	100.8	200.0	43.7	84.0	180.0	52.4	67.2
	Removal	240.5	23.5	194.9	152.1	28.2	208.1	133.5	36.4	163.6
	Balance	—0.5	+28.9	—94.1	+47.9	+15.5	—124.1	+46.5	+16.0	—96.4
T_6	Addition	240.0	63.3	135.6	200.0	52.8	113.0	180.0	53.7	75.4
	Removal	201.5	21.0	222.4	148.5	27.8	196.4	121.4	36.0	162.4
	Balance	+38.5	+42.3	—85.6	+51.5	+25.0	—83.4	+58.6	+17.7	—87.0
T_7	Addition	210.0	51.3	105.6	175.0	42.8	88.0	150.0	48.7	62.9
	Removal	194.9	15.6	181.7	148.8	23.1	188.3	101.6	30.9	155.8
	Balance	+15.1	+35.7	—76.1	+26.2	+19.7	—100.3	+48.4	+17.8	—92.9
T_8	Addition	240.0	51.3	159.6	200.0	42.8	133.0	180.0	48.7	85.4
	Removal	239.0	20.9	212.3	110.3	22.1	180.5	115.4	31.9	162.7
	Balance	+1.0	+30.4	—52.7	+89.7	+20.7	—47.5	+64.6	+16.8	—77.3
T_9	Addition	210.0	45.3	117.6	175.0	37.8	98.0	150.0	46.2	67.9
	Removal	209.2	18.9	183.8	133.4	22.8	188.1	105.2	36.5	123.2
	Balance	+0.8	+26.4	—66.2	+41.6	+15.0	—90.1	+44.8	+9.7	—55.3
T_{10}	Addition	240.0	44.0	103.7	200.0	36.7	86.4	180.0	45.5	62.1
	Removal	224.5	23.5	199.6	145.7	27.5	190.3	121.8	38.1	177.5
	Balance	+15.5	+20.5	—95.9	+54.3	+9.2	—103.9	+58.2	+7.4	—115.4
T_{11}	Addition	210.0	41.7	89.7	175.0	34.6	74.7	150.0	44.6	56.2
	Removal	200.0	18.1	206.8	147.6	23.0	189.9	110.2	29.0	149.3
	Balance	+10.0	+23.6	—117.1	+27.4	+11.6	—115.2	+39.8	+15.6	—93.1

Details of treatments are given in Table 2

organic carbon status when organic sources were used to substitute a part of fertilizer N which is obviously due to addition of organic matter to the soil (Patnaik *et al.*, 1989).

There was a decline in available P status in all the treatments after continuous rice–rice cropping compared with its initial level at Kharagpur. The decline, however, was more severe in the control treatment where P was not applied. Similar results were also recorded at Karamana. The decline in available P even with P application at these locations was probably due to high P-fixation capacity of lateritic soils containing large amounts of soluble aluminium and iron. At Bhubaneshwar, there was some build-up in available P status in all the plots receiving P. Nambiar *et al.* (1992) also reported similar build up in P at Bhubaneshwar. At Maruteru, however, generally there was no build-up in available P status except under 25% N substitution through the FYM.

For the available K, it declined in all the plots at all the locations except at Karamana where slight build-up was recorded. The decline was more in unfertilized plots compared with those which received K through chemical or organic source. As the K application was much below its removal by the crop, the decline in K status was quite expected and the K release from the minerals was probably not adequate to maintain the initial K level. At Karamana it was possible to maintain the initial K status even after 7 years of continuous rice–rice cropping in unfertilized plots also, probably due to adequate K release which must have been influenced by favourable temperature.

Nutrient balance

The nutrient balance worked out for selected treatments indicated that with recommended nutrient application there was positive N balance at all the locations whether N was supplied only through fertilizers or through both fertilizers and organic sources except at Kharagpur in the treatment where 100% NPK was supplied through fertilizers in both the seasons (Table 6). Nitrogen uptake was maximum when all the N was suplied through chemical fertilizers. Phosphorus balance was also positive in all the treatments. The highest balance was observed when 50% N was substituted by FYM, followed by N substitution with rice straw and green-manures. This was mainly due to larger amount of P supplied through FYM when a specified amount of N was substituted. Potassium balance was negative at all locations even with recommended level of K application. However, it was of lower magnitude when rice straw substituted a part of N due to high K content in rice straw. It is clear that FYM and rice straw increased and green-manures reduced P and K addition when a proportion of N was substituted by these sources. Therefore it is obvious to expect greater improvement in soil fertility with FYM and rice straw than with green-manures when these are used to supplement chemical fertilizers.

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