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Effect of integrated nutrient management on productivity and residual soil-fertility status under different rice (*Oryza sativa*) – pulse cropping systems in rainfed lateritic belt of West Bengal

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ABSTRACT

A field trial was conducted on red and laterite soil of Sekhampur, West Bengal, during June 1996–April 1998, to evaluate the prospect of growing rice (*Oryza sativa* L.)–pulse sequence under rainfed condition and study the effect of residual soil-fertility status on pulses inoculated with or without *Rhizobium* sp. Higher yield and yield attributes of rainy-season rice, lentil (*Lens culinaris* Medikus), gram (*Cicer arietinum* L.) and grass pea (*Lathyrus sativus* L.) crops were achieved where 25% of chemical fertilizer in rainy-season rice was replaced either by FYM or rice straw @ 3.0 or 3.65 tonnes/ha. Addition of FYM or decomposed straw of rice improved the N, P, K status of the soil. Seed inoculation of pulses with *Rhizobium* sp. also played a positive role towards the total crop productivity and residual soil-fertility status.

Key words : Rice, Pulse, Integrated nutrient management, Residual soil fertility, Lateritic

There is a gap between crop removal and replenishment of nutrients through the application of chemical fertilizers alone. This seems to be one of the reasons at present towards near stagnation in productivity of some food crops in some areas. The organic sources like farmyard manure, well-decomposed rice straw or crop residues of pulses are not only the storehouses of a large number of macro- and micro-elements but also helps considerably to improve the physico-chemical properties of soil. Introduction of pulse crop in crop rotation is another option to increase the per caput availability of pulses in our country as well as to economize the use of costly nitrogenous fertilizer. Therefore, the approach of integrated nutrient management through the judicious mixing of organic as well as inorganic sources of nutrients is an imperative, which will not only economize the use of chemical fertilizers but also improve the physico-chemical status of the soil. Keeping these in mind, an effort was made to find out the effect of integrated nutrient management on the crop productivity and residual nutrient status of soil in rice–pulse cropping systems under rainfed lateritic belt of West Bengal.

MATERIALS AND METHODS

The field experiment was carried out in red and lateritic acid soil (pH 5.9), having 0.062% N, 16.7 and 161.5 kg/ha available P_2O_5 and K_2O, respectively, at the Regional Research Station, Sekhampur, West Bengal, during June 1996–April 1998. The experiment was started with 7 treatments consisting of integrated nutrient management (replacing 25 and 50% of chemical fertilizers either with FYM @3.0 and 6.0 tonnes/ha or with well-decomposed rice straw @ 3.65 and 7.3 tonnes/ha) in the rainy-season rice, tried in randomized block design with 3 replications. During the winter the experiment was continued in split split-plot design, wherein 7 treatments of residual effects applied to preceding rice as main plots (F_0, control; F_1, 100% N, P_2O_5, K_2O @ 60, 30 and 30 kg/ha; F_2, 75% N, P_2O_5, K_2O + 3.0 tonnes FYM/ha; F_3, 75% N, P_2O_5, K_2O + 3.65 tonnes well-decomposed rice straw/ha; F_4, 50% N, P_2O_5, K_2O + 6.0 tonnes FYM/ha; F_5, 50% N, P_2O_5, K_2O + 7.3 tonnes well-decomposed rice straw/ha; F_6, 75% N, P_2O_5, K_2O); 3 winter pulses, viz. lentil, gram and grass pea, were sown in 3 subplots and with (Rh_1) or without inoculation (Rh_0) of pulses with *Rhizobium* sp. were tried in 2 sub-subplots. Different sources of organic matter were analysed on dry basis for determination of N, P, K content (FYM : 0.5, 0.28, 0.35% and well-decomposed rice straw : 0.41, 0.18, 0.43% respectively). As the yield attributes and yield of different pulses could not be compared among each other, analyses were done of all pulses in terms of lentil-yield equivalence in split split-plot design. Here, residual effects due to 7 fertilizer treatments applied to preceding rainy-season rice, considered as the main plot treatments, 3 pulses considered as subplots and with or without inoculation of *Rhizobium* sp. was also considered as 2 sub-subplot treatments in the statistical analysis. Among the winter pulses, lentil occupies the higher area in West Bengal. So, yields of pulses were compared in terms of lentil-yield equivalence.

Soil samples were collected initially and after harvest of each crop of rice, lentil, gram and grass pea in sequence. Total nitrogen of soil was estimated by modified macro-kjeldahl's method, available phosphorus by Olsen's method with photometric colorimeter and available potassium content was determined by flame photometer as described by Jackson (1967).

The total rainfall received during the cropping sequence (June to April) was 1,356.5 and 1,402.7 mm in 69 and 74 wet days, of which the maximum rainfall was precipitated during June to September in 1996 and 1997 respectively, while long-term average of 20 years of rainfall for both the crop season was 1,309.94 mm in this sub zone.

RESULTS AND DISCUSSION

Yield attributes and yield of rice

The highest values of all the yield attributes of rice was recorded under F_2

treatment, where 75% of recommended dose of N, P, K + 3.0 tonnes FYM/ha applied to the crop, followed by F_3 treatment, i.e. 75% of recommended dose of N, P, K + 3.65 tonnes well-decomposed rice straw/ha (Table 1). However, these were statistically at par with each other. The treatment F_2 was significantly differed from F_1, even when the crop received 100% dose of NPK alone under this treatment. Further reduction (more than 25%) of the recommended dose of N, P, K with or without addition of FYM or well-rotten rice straw as in case of F_4, F_5, F_6 and F_0 treatments reduced all the yield attributes significantly.

Substitution of 25% of chemical fertilizer from the recommended dose of 60, 30 and 30 kg N, P_2O_5 and K_2O /ha either with 3.0 tonnes FYM/ha or 3.65 tonnes well-decomposed rice straw/ha, increased the grain yield of rice by 15.38 and 13.38%, respectively, over F_1 treatment, i.e. 100% N, P_2O_5 and K_2O /ha (Table 1). This might be due to the fact that organic manure besides supplying additional amount of nutrients, also brought about an improvement towards the physical properties of soil, and thereby improving water and nutrient-holding capacity of the soil. Bhardwaj and Gaur (1985) also expressed the similar view of improvement of soil physical properties due to addition of decomposed farm and city wastes. However, 6.0 tonnes FYM or 7.3 tonnes well-rotten rice straw/ha when supplemented in lieu of 50% of reduction of chemical fertilizer (F_4 and F_5 treatment respectively), reduced the grain yield by 20.09 and 23.33%, respectively, from the treatment F_1, in which the crop was given full recommended dose of NPK alone. In the same way, 25% replacement of chemical fertilizer by 3.0 tonnes FYM/ha or 3.65 tonnes well-decomposed rice straw/ha increased the straw yield of rice by 7.24 and 5.64%, respectively, over F_1 treatment while 50% replacement of chemical fertilizer with 6.0 tonnes FYM/ha or 7.3 tonnes well-decomposed rice straw/ha was reduced the straw yield by 12.94 and 15.82%, respectively, over the same treatment. Jana

Table 1. Yield attributes and yield of rainy-season rice (pooled data of 2 years)

Treatment	Matured panicles/m²	Spikelets/ panicle	Filled grain (%)	1,000-grain weight (g)	Grain yield (kg/ha)	Straw yield (kg/ha)
F_0	255.30	68.97	70.80	20.76	1,745.57	2,252.05
F_1	380.08	88.22	89.15	21.67	3,671.31	4,033.98
F_2	398.87	91.08	91.38	23.08	4,235.85	4,326.27
F_3	385.62	89.50	89.93	22.66	4,162.72	4,261.40
F_4	349.33	80.60	80.70	21.31	2,933.83	3,511.87
F_5	334.58	77.23	78.67	21.49	2,814.73	3,395.87
F_6	323.35	74.30	75.62	21.00	2,816.88	3,230.83
CD (P = 0.05)	18.29	3.57	2.64	1.14	421.98	281.49

Details of treatments are given under Materials and Methods and Ghosh (1996) also observed that neither FYM nor rice straw @ 10 tonnes/ha could substitute 50% of recommended dose of chemical fertilizer in the rainy-season rice.

Yield attributes and seed yield of pulses

The residual effects of rainy-season treatments implied on transplanted rice had significant effect on all the yield attributes of pulses (Table 2). The maximum pods/plant, seeds/pod, 1,000-seed weight and dry weight of nodules were recorded under F_2 and it was followed by F_3 and F_1. However, performances of other treatments were even poorer. Inoculation of pulses with *Rhizobium* sp. significantly improved the yield attributes except test weight in case of lentil and grass pea and dry weight of nodules/plant. Sharma *et al.* (1982) also expressed the similar view.

Likewise, the residual nutrient of treatments F_2 and F_3 (Table 3) gave seed yield of 874 kg/ha and 742 kg/ha respectively in terms of grain equivalence of lentil, which was higher by 17.72 and 13.27%, respectively, than F_1 or 100% recommended dose of N, P, K alone. It was mainly because organic manures had a lasting effect on soil productivity (Yawalkar *et al.*, 1984). Sarkar and Singh (1997) though observed the highest rice yield with 100% recommended dose of N, P and K in the following winter (*rabi*) season, they recorded the maximum yield of lentil from the plots previously treated with 50% NPK + FYM. Among the different pulse crops, gram recorded the maximum equivalent yield, followed by lentil and grass pea. This might be due to the fact that, gram showed higher efficiency towards the utilization of residual soil moisture compared with lentil and grass pea in medium-land situation (Chatterjee and Sen, 1977). By and large, inoculation with *Rhizobium* sp. improved the yield of pulses by 2.78%, which is in conformity with the observations made by Bhattacharya and Sen (1989).

Soil-nutrient status after harvesting of each crop in the sequence

In 2 year experimentation on rice–pulse cropping sequence, availability of soil nutrients (N, P and K) was remarkably influenced due to addition and depletion of such nutrients in the soil (Figs. 1, 2, 3). This favourable influence was more pronounced, particularly, when soil enriched with sufficient quantity of humus materials (FYM or well-rotten crop residues) along with inorganic sources than that of application of fertilizers alone or control plots.

Availability of total N status in the soil over initial value was decreased considerably after transplanted rainy-season rice to almost all the treatments except F_2 and F_3, where 25% of chemical inorganic fertilizers was replaced either by 3.0 tonnes FYM/ha or 3.65 tonnes well-decomposed rice straw/ha (Fig 1). This increasing trend was continued up to the end of this cycles and this amount was 302.7 and 248.7 kg/ha over initial status of the soil in F_2 and F_3 respectively. This magnificent improvement of soil status has been possible not only owing to organic sources but also because of incorporation of pulses along with *Rhizobium* culture in the sequence, being 24.41 and 20.04%, respectively, over the initial

Table 2. Yield attributes of pulses (pooled data of 2 years)

Treatment	Pods/plant			Seeds/pod			1,000-seed weight (g)			Dry weight of nodules (mg/plant)		
	Lentil	Gram	Grass pea	Lentil	Gram	Grass pea	Lentil	Gram	Grass pea	Lentil	Gram	Grass pea
Residual effects of kharif *treatments*												
F_0	54.80	16.87	5.12	1.92	1.37	3.96	17.50	149.23	70.25	6.11	119.92	70.30
F_1	65.58	25.87	6.71	2.56	1.64	4.74	17.59	150.54	70.52	12.04	194.15	119.95
F_2	77.80	33.50	7.67	2.99	1.93	5.40	17.62	151.70	70.62	16.25	230.08	142.31
F_3	71.41	30.41	7.50	2.75	1.77	5.30	17.61	151.03	70.57	15.10	215.20	139.67
F_4	59.68	25.25	6.16	2.41	1.55	4.44	17.56	149.95	70.46	9.71	189.42	110.64
F_5	59.68	24.24	5.80	2.25	1.50	4.21	17.50	150.39	70.47	9.15	170.75	109.04
F_6	56.77	22.34	5.52	2.09	4.45	4.14	17.51	149.91	70.29	7.78	163.64	103.41
CD (P=0.05)	2.60	2.88	0.36	0.10	0.09	0.28	NS	1.18	0.16	1.19	11.17	8.93
Rhizobium												
Rh_0 (control)	63.06	25.73	6.27	2.40	1.59	4.45	17.54	150.17	70.45	10.71	181.96	109.27
Rh_1 (*Rhizobium*) inoculation	64.11	26.83	6.73	2.45	1.61	4.70	17.57	150.61	70.46	11.05	184.52	118.53
CD (P=0.05)	0.49	0.73	0.06	0.02	0.01	0.22	NS	0.38	NS	0.19	1.40	2.44

Details of treatments are given under Materials and Methods

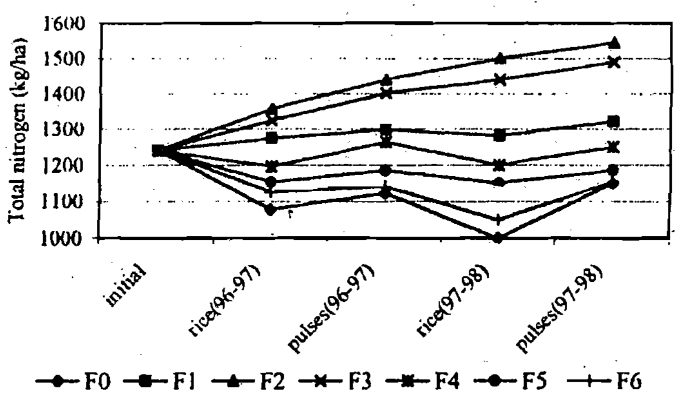

Fig. 1. Status of total nitrogen in soil after harvesting of each crop in sequence

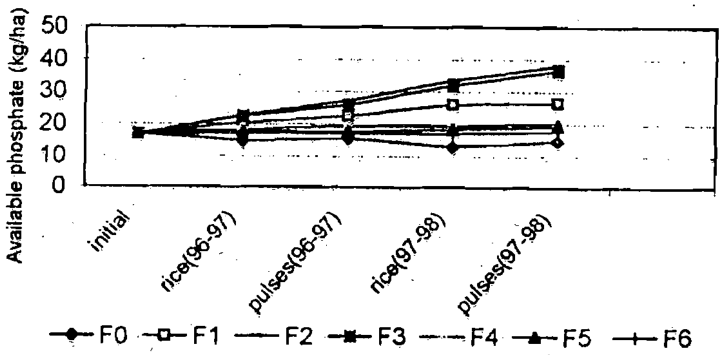

Fig. 2. Status of available phosphate (P_2O_5) in soil after harvesting of each crop in sequence

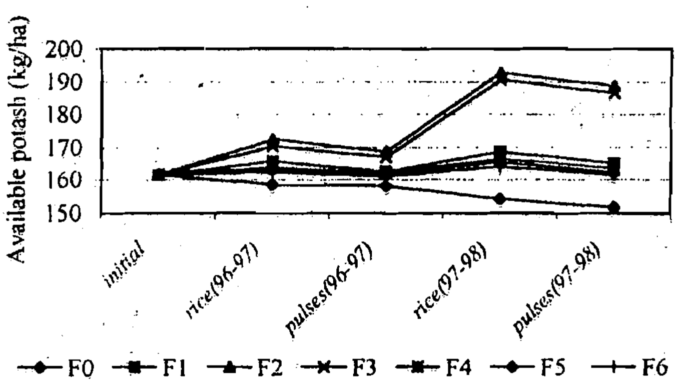

Fig. 3. Status of available potash (K_2O) in soil after harvesting of each crop in sequence

Table 3. Seed yield of different pulse crops in terms of grain equivalence of lentil

Treatment	Seed yield of pulses (kg/ha)		
	1996–97	1997–98	Mean
Residual effects of kharif *treatments*			
F_0	471.00	521.53	496.26
F_1	706.52	778.57	742.55
F_2	819.27	928.98	874.13
F_3	790.23	891.97	841.10
F_4	637.99	699.41	662.20
F_5	616.42	669.09	642.25
F_6	594.99	618.02	606.50
CD (P=0.05)	69.60	97.36	
Pulse crop			
Lentil	727.88	816.25	772.06
Gram	756.43	811.73	784.08
Grass pea	498.44	560.13	529.28
CD (P=0.05)	22.43	18.63	
Rhizobium			
Rh_0 (Control)	649.30	717.46	683.38
Rh_1 (*Rhizobium* inoculation)	666.53	738.28	702.40
CD (P=0.05)	11.17	6.99	

Details of treatments are under Materials and Methods

status of soil nitrogen. However, a slight increasing (2.72–6.55%) and decreasing (7.31–19.32%) trend of soil nitrogen status at every after crop in the sequence was more pronounced when crop was fertilized with 100% recommended dose of NPK and control plots and it could not be able to compensate this loss, even due to incorporation of legumes in rotation.

Incorporation of inorganic fertilizers + FYM or well-decomposed rice straw in the rice–pulse cropping system resulted gradual increase of available phosphorus (Fig. 2). But it decreased considerably when the crops were raised without incorporation of any fertilizers, FYM or rice straw and in this case, available P was depleted more by rice though the subsequent pulse crop restored it immediately. This might be depicted so, as rice is an exhaustive crop whereas pulses are soil-restorer crops. At the end of second year higher available P status of the soil was recorded from the plots, which received 75% of recommended N, P, K + 3.0 tonnes FYM/ha (F_2). Ahlawat *et al.* (1981) also reported that legume in rotation increased the total N and P_2O_5 status of the soil.

Likewise, incorporation of inorganic fertilizers + FYM or well-decomposed rice straw in the rice–pulse cropping system resulted gradual increase of available K (Fig. 3). Higher K build up over the initial K status was noticed in the treatment F_2, which was closely followed by F_3. The results confirm the findings of Kahnt (1985), where he clearly visualized the beneficial effect of grain legumes on the availability of soil nutrients, especially K, *in situ* and succeeding crops in the sequence. But available K status was decreased gradually when no fertilizer or FYM or rice straw was incorporated in the rice–pulse cropping system.

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