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RELATIVE PERFORMANCE OF RICE-POTATO-GREEN GRAM SYSTEM IN RED AND LATERITIC ZONE OF WEST BENGAL UNDER ORGANIC, INORGANIC AND INTEGRATED NUTRIENT MANAGEMENT

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ABSTRACT

An experiment was carried out during *rabi* and *summer* seasons from 2006 to 2009 in the dry sub-humid red and lateritic zone of West Bengal to study the effect of inorganic fertilizers alone or in combination with organic manures (FYM) on crop yield, nutrient uptake and soil properties under rice-potato-green gram cropping sequence. The experiment was laid out in split plot design with three sources of nutrients in main plot and three levels of nutrients in sub plots with three replications. Pooled data revealed that integrated sources of nutrients (combination of inorganic and organic sources) applied @125% recommended doses (RD) increased the yield of rice by 32.5%, potato by 81.5% and green gram by 47.3%, over the inorganic source applied @ 75% RD, under common practice. The maximum uptake of N, P and K by rice (114, 19 and 67.5 kg ha^{-1}, respectively), potato (174, 18 and 187 kg ha^{-1}, respectively) and green gram (78, 14.8 and 35 kg ha^{-1}, respectively) was observed at 125% RD applied through integrated source. Pooled data over three years showed that conjoint use of chemical fertilizers and FYM has significantly improved the soil organic carbon by 17.07%, and available N, P, K and moisture content by 12.9%, 10.3%, 8.89% and 7.82%, respectively, over the inorganic fertilizer alone. It can be summarized that in this red and lateritic zone NPK should be applied at 125% of RD for each crop; half of this through inorganic fertilizer and the rest amount through FYM for increasing the productivity of the cropping sequence and sustaining the soil fertility.

INTRODUCTION

The theme of the present day agriculture is to achieve the targeted production to meet the increasing food demand while sustaining soil productivity. The most limiting factor that has affected the production of crops and productivity of Indo Gangetic plain is fertilizer: through imbalanced and indiscriminate use on one hand and withdrawal of organic matter from the schedule of inputs on the other (Kumar *et al.*, 2008). Therefore integrated nutrient management (INM) has been an increasing necessity especially for the tropical Indian soils.

A large geographical area (2.48 m ha) in the lower Gangetic plain of West Bengal, India, has red and lateritic soils characterized by poor fertility and ever declining productivity. Cultivation in this area is largely rain-fed. Hence improving agricultural productivity of this large area seems to be an important task that needs to be imparted through low input sustainable and profitable cropping system on the fatigued natural resource base (Ladha *et al.*, 2003). Selection of crops and cropping pattern is an important factor for maintaining productivity of a soil. Researches based on cropping systems revealed that potato based cropping systems may play important role in improving productivity of the eastern Indo-Gangtic plains of India (Kumar *et al.*, 2009) and rice-potato-green gram cropping sequence has emerged as the most stable and efficient in terms of production and economic return, both (Singh and Lal, 2011). Therefore introduction of this crop sequence in the fertility poor lateritic soil of this zone would be an appropriate alternative of rice-wheat/ rice-potato/ rice-mustard crop sequences practiced commonly. The other aspect is INM which needs framing for a crop sequence and soil type. Boosting yield, reducing production cost and improving soil health are three inter-linked components of the INM (Singh *et al.*, 2008). Numerous reports of INM revealed that highest crop yield could be achieved through certain amount of substitution of inorganic fertilizers with organic manures (OM) and /or addition of OM with 100% chemical fertilizers, e.g., 50% substitution of NPK with OM was as good as 100% chemical fertilizers for grain yields in mustard-cowpea-rice cropping sequence grown in the lateritic soils of Maharashtra (Babar and Dongale, 2013); adding 10 t FYM ha^{-1} along with 100% NPK recorded higher yield of wheat in the Jammu and Kashmir than 100% NPK alone (Chesti *et al.*, 2013). All these are consistent with the enhancing yield effects of INM. Similarly, reports are there to show that INM approach has increased the soil organic C and available nutrients (Sharma *et al.*, 2013, Parmar, 2014); improved the bulk density, porosity, OC and available nutrients (Babar and Dongale, 2013). Considering these, we decided to generate information on the rice-potato-green gram cropping sequence under the INM system on red and lateritic soils of West Bengal because there is no report available so far. Thus our aim was to evaluate the effect of farm yard manure (FYM) prepared with commonly available resources like straw, crop residue and cow dung on (i) the yield of crops (ii) uptake and stability of soil nutrient status (iii) the economic profitability of the system.

MATERIALS AND METHODS

Site Description

A field experiment was conducted from 2006 to 2009 at the Zonal Adaptive Research Station, Government of West Bengal at Nalhati, Birbhum, India. It is located in the lower Gangetic Plain at 24.29ºN latitude and 87.84ºE longitudes. The area falls under the hot, dry sub-humid zone, 60 m above mean sea level. The soil of the experimental location is very deep, well-drained, clay loam (Inceptisol) with 33.3% sand, 39.3% silt and 27.4% clay in the surface layer (0-0.15 m) classified as mixed Hyperthermic Typic Haplustalfs to Haplustepts. Initial composite soil sample, collected at the beginning of the field experiment, was strongly acidic (pH 5.36) (1:2.5 soil: water) and had 0.57% organic carbon, 121 kg ha^{-1} available nitrogen, 78.8 kg ha^{-1} available P, 112 kg ha^{-1} available K. The bulk density of 0-0.15 m soil depth was 1.22 Mg m^{-3} and that of 0.15-0.30 m soil depth was 1.34 Mg m^{-3}. The maximum water holding capacity (MWHC) of the soil was 37.4%. During our experiment the weather varied most with respect to precipitation. Other parameters were similar to the long term average; with precipitation averaging 1400 mm during winter, maximum temperature between 26º and 36ºC, minimum average temperature was around 13ºC in winter and between 21º and 25ºC during two other seasons.

Experimental design and treatments

The experiment included three crops per year, namely, winter rice (July-November), potato (November-March) and green gram (March-May). The experiment was laid out in split plot design with net plot size of 5×4 m^2 and 2 m margin around each plot. The experiment consisted of three sources of nutrients viz., inorganic fertilizer (S_1), organic source through FYM (S_2) and integrated source through fertilizer and FYM (S_3) as main plot and three levels of nutrients, viz., 75% of State Department of Agriculture recommended doses (RD) of N-P-K (N_1), RD of N-P-K (N_2), and 125% of RD of N-P-K (N_3) as sub plots with three replications. The RD of N: P: K (kg ha^{-1}) for rice was 60:13.1:24.8 and for potato was 200:65.5:124. In the integrated source 50 per cent of N was applied through FYM and the rest amount through chemical fertilizer. In doing so the respective contribution of P and K from FYM was also considered. The fertilizers used were urea for N, single super phosphate for P, and muriate of potash for K. Well decomposed FYM was prepared from the farm wastes namely, straw of rice and wheat, fresh cow dung @ 10 kg per 100 kg of straw material, and finally urea solution @ 0.25kg N per 100 kg of straw to reduce the C/N ratio. The physical and chemical properties of FYM were analyzed in the laboratory following standard methodologies and are presented in Table 1. Before transplanting of rice (*Oryza sativa* L. var. MTU 7029) and sowing of potato (*Solanum tuberosum* L. var. K. Jyoti) in rainy and winter seasons respectively, the entire amount of FYM was incorporated at the time of land preparation. Green gram (*Vignaradiata* L.var. Samrat) was sown without any nutrient inputs in order to study the residual effect of FYM and fertilizers after harvest of potato. After harvest of pods the green plants were chopped into pieces and mixed with the soil in presence of standing water. Rice equivalent yield (REY) was calculated to compare system performance by converting the yield of each crop into equivalent dry season rice yield on a price basis, using the following relation (Biswas *et al.*, 2006)

$$REY\ (of\ crop\ x) = Yx\,(Px / Pr)$$

Where Yx is the yield of crop x (t ha^{-1}), Px and Pr are the price of crop x and rice, respectively.

Soil and plant analysis

Table 1: Chemical composition of the organic manure (FYM) applied

Parameters		Methodology
Moisture (by weight)	13.2%	Heating at 105º C for 24 h
pH (1:2.5)	6.37	Digital pH meter
EC (dSm^{-1})	8.64	Conductivity bridge
Total N (%)	1.53	Kjeldahl procedure, Jackson (1958)
Organic C (%)	29.8	Walkley and Black, Jackson (1956)
Total P (%)	0.24	Digestion by 3:1:1, HNO_3:$HCLO_4$:H_2SO_4 and vandomolybdate yellow colour method (Jackson, 1973)
Total K (%)	0.73	Digestion by 3:1:1, HNO_3:$HCLO_4$:H_2SO_4 and spectrophotometer determination
Exchangeable bases (cmolp$^+$kg^{-1})		Leaching with 1N ammonium acetate
Na	0.58	Flame photometer
Ca	13.5	Chelometric titration with EDTA
Mg	12.6	Chelometric titration with EDTA
C/N	19.5	OC (%) / Total N
Total ash	47.4%	Igniting samples at 750º C for 4 h

Initial soil sample was collected with an auger from 0- 15 cm soil depth. This was thoroughly mixed, dried and passed through 2 mm sieve for chemical analysis. Soil samples were also analysed each year after the crop cycle. Available N was estimated by Subbiah and Asija's (1956) method, and available phosphorus was determined by shaking the soil with 0.5 M $NaHCO_3$ (pH 8.5) (1:20: soil:extractant) for 30 minutes and estimating in a visible spectrophotometer (Systronics 128) by the L-ascorbic acid method (Murphy and Riley, 1962). Available K was estimated using neutral 1M NH_4OAc as stated by Pratt (1965). Undisturbed soil cores were collected in a stainless-steel core sampler (5.0 cm diameter and 8.0 cm long) from 0-15 cm and 15-30 cm soil layers and used for determination of bulk-density (BD) (Blake and Hartge, 1986). The maximum water-holding capacity (MWHC) of the soil was measured with the help of a Keen–Rackzowski box (Baruah and Barthakur, 1997). At maturity, samples of rice grain, potato tubers and green gram pods were collected each year, oven dried at 70°C to constant weight and ground to pass through a 0.5 mm sieve for chemical analysis. Also the plant samples of rice, potato and green gram were collected, as above, for dry-matter weight and analysis of nutrients. Nitrogen in plant sample was determined by micro-Kjeldahl method (Jackson, 1973). Plant samples were digested in tri-acid mixture (HNO_3: H_2SO_4: $HClO_4$: 10:1:4, by volume), and in the digest P was measured by vanadomolybdate yellow colour method (Jackson, 1973), and K by flame photometer (Tandon, 1993). Crop uptake of N, P and K was calculated by multiplying the dry matter yield (after drying at 70°C) by plant nutrient concentration.

The experimental data were analysed statistically in SAS® version 9.3 and interpreted accordingly.

RESULTS AND DISCUSSION

Performance of crop yield

Different sources and levels of nutrient application significantly influenced the grain yield of rice, tuber yield of potato and seed yield of green gram as well as the rice system equivalent yield (Table 2). The highest grain yield of rice (4.69 t/ha in 2006-07, 4.94 t/ha in 2007-08 and 5.27 t/ha in 2008-09), tuber yield of potato (20.6 t/ha, 21.8 t/ha and 25.7 t/ha in the corresponding years) and rice system equivalent yield (RSE) (23.0 t/ha, 24.2 t/ha and 28.3 t/ha respectively, for the years), was recorded through the integrated source of nutrient addition (S_3) (50% through inorganic fertilizer and 50% through FYM). The residual effect of S_3 also led to highest seed yield of green gram (0.92 t, 0.95 t and 1.00 t/ha respective years). Pooled data of yield of different crops as well as RSE also showed similar results and revealed that adoption of INM (S_3) increased the yields of rice, potato and green gram by 8.5%, 10% and 13%, respectively, and RSE by 10.04% over the inorganic source of nutrient alone (S_1). These higher yields and RSE in integrated source might be attributed to a steady supply of all the plant nutrients released from organic manures (Sharma *et al.*, 2013). However, the organic source alone (S_2) produced the lowest grain yield of rice (4.14 t/ha in 2006-07, 4.18 t/ha in 2007-08 and 4.26 t/ha in 2008-09) and tuber yield of potato (16.4 t, 17.4 t and 19.9 t/ha in respective years) and RSE (18.5

Table 2: Effect of source and rate of crop nutrients on yield of rice-potato-green gram cropping system

Treatments	Rice grain yield (t ha⁻¹)				Potato tuber yield (t ha⁻¹)				Green gram seed yield (t ha⁻¹)				Rice system equivalent yield (t ha⁻¹)			
	2006-07	2007-08	2008-09	Pooled	2006-07	2007-08	2008-09	Pooled	2006-07	2007-08	2008-09	Pooled	2006-07	2007-08	2008-09	Pooled
Sources of nutrients (S)																
Fertilizer (S_1)	4.39b	4.61b	4.73b	4.58b	18.7a	19.9b	21.3b	20.6b	0.84a	0.84a	0.84b	0.84b	21.1b	22.2a	25.3b	22.9b
FYM (S_2)	4.14b	4.18c	4.26c	4.18c	16.4b	17.4c	19.9c	17.9c	0.60b	0.62b	0.62c	0.61c	18.5c	19.3c	21.8c	19.9c
Fertilizer + FYM (S_3)	4.69a	4.94a	5.27a	4.97a	20.6a	21.8a	25.7a	22.7a	0.92a	0.95a	1.00a	0.95a	23.0a	24.2a	28.3a	25.2a
LSD	0.26	0.07	0.17	0.1	1.05	0.7	0.26	0.35	0.05	0.07	0.02	0.03	0.94	0.51	0.74	0.5
Application rate of nutrients (N)																
75% RD (N_1)	4.19c	4.12c	4.10c	4.14c	15.5c	14.8c	15.3c	15.2c	0.73c	0.71c	0.70c	0.71c	18.0c	17.4c	18.2c	17.9c
100% RD (N_2)	4.43b	4.61b	4.91b	4.65b	18.8b	20.5b	24.5b	21.4b	0.78b	0.82b	0.86b	0.82b	21.0b	22.6b	26.7b	23.4b
125% RD (N_3)	4.61a	4.95a	5.25a	4.94a	21.5a	23.9a	29.2a	24.9a	0.85a	0.89a	0.91a	0.88a	23.6a	25.8a	30.5a	26.6a
LSD	0.04	0.18	0.16	0.14	0.88	1.19	0.28	1.84	0.02	0.03	0.02	0.05	0.72	1.03	0.76	0.64
Significance level																
Interaction																
S x N	**	*	*	*	*	*	**	*	**	**	**	*	*	*	*	NS

Each value represents mean yield from three replicated plots and values that differ significantly ($p < 0.05$) within each column are followed by different letters. **, * Significant at 0.01 and 0.05 probability levels, respectively. NS, Non significant

Table 3: Effect of the source and rate of crop nutrients on uptake of nutrients by rice-potato-green gram cropping system (pooled data over three years)

Treatments	Nutrient uptake by rice (kg/ha)			Nutrient uptake by potato (kg/ha)			Nutrient uptake by green gram (kg/ha)		
	N	P	K	N	P	K	N	P	K
Sources of nutrients (S)									
Fertilizer (S_1)	93.37b	14.88c	54.55b	103.7b	11.87b	124.7b	56.36b	11.22b	28.05b
FYM (S_2)	80.16c	15.90b	49.02c	83.30c	9.60c	98.85c	37.46c	6.85c	18.81c
Fertilizer + FYM (S_3)	106.5a	18.06a	62.19a	144.6a	14.95a	160.1a	70.09a	13.59a	33.23a
LSD	1.58	0.365	1.62	4.21	0.426	3.81	2.42	0.679	0.891
Application rate of nutrients (N)									
75% RD (N_1)	82.74c	14.29c	48.76c	82.31c	9.44c	99.05c	45.67c	8.93c	22.28c
100% RD (N_2)	92.42b	16.59b	56.24b	112.99b	12.26b	130.7b	55.59b	10.84b	27.51b
125% RD (N_3)	104.8a	17.96a	60.75a	136.4a	14.70a	153.9a	62.65a	11.89a	30.29a
LSD	3.52	0.873	4.013	3.53	0.608	1.74	2.35	0.399	1.27
Significance level									
Interaction									
S x N	**	*	*	**	*	**	**	**	**

Each value represents pooled data of mean nutrient uptake of three replicated plots over three years and values that differ significantly ($p < 0.05$) within each column are followed by different letters. **, * Significant at 0.01 and 0.05 probability levels, respectively.

Table 4: Changes in soil properties in the rice-potato-green gram cropping system as influenced by the source and rate of crop nutrients (pooled data over three years)

Treatment	pH	OC (%)	Avail. N (kg ha^{-1})	Avail. P (kg ha^{-1})	Avail. K (kg ha^{-1})	Bulk density (Mg m^{-3})		MWHC (%)
						0-15 cm	15 -30 cm	
Initial values	5.36	0.57	121	78.8	112	1.22	1.34	37.4
Sources of nutrients (S)								
Fertilizer (S_1)	5.33b	0.574c	120.9b	78.85b	114.7b	1.267a	1.337a	39.15c
FYM (S_2)	5.31c	0.623b	119.8b	74.87c	106.7c	1.207c	1.290c	44.25a
Fertilizer + FYM (S_3)	5.49a	0.672a	136.5a	86.96a	124.9a	1.237b	1.299b	42.21b
LSD	0.009	0.008	1.417	0.559	3.712	0.012	0.0182	0.724
Application rate of nutrients (N)								
75% RD (N_1)	5.35b	0.585c	119.4c	74.49c	106.8c	1.250a	1.325a	39.79c
100% RD (N_2)	5.37ba	0.622b	124.8b	81.06b	116.4b	1.236b	1.307b	42.17b
125% RD (N_3)	5.41a	0.662a	132.9a	85.13a	123.2a	1.222c	1.294c	43.64a
LSD	0.04	0.015	3.136	1.507	2.212	0.0125	0.0129	0.4326
Significance level								
Interaction								
S x N	**	*	NS	**	*	**	**	**

Each value represents pooled data of mean values of soil properties of three replicated plots over three years and values that differ significantly ($p < 0.05$) within each column are followed by different letters. **, * Significant at 0.01 and 0.05 probability levels, respectively. NS, Non significant.

t, 19.3 t and 21.8 t/ha in respective years). This could be due to want of timely supply of nutrients from FYM particularly at critical stages of crop growth (Chetri *et al.*, 2004). The pooled data over 3 years revealed that increasing the level of nutrients from 75% to 125% increased the grain yield of rice by 19.3%, tuber yield of potato by 63.8% and seed yield of green gram by 23.9%. The possible reason for the increase in biological yield with the increasing level of nutrients could be due to higher vegetative growth resulting in more photosynthates (Sarkar *et al.*, 2007). Sharma *et al.* (2013) also reported that application of NPK at doses 75% and 50% of RD reduced the grain yield of wheat. In the present study, the interaction of level and sources of nutrients were found to be significant for yield of different crops and the interaction effect of pooled data is represented in Fig. 1. This revealed that integrated sources of nutrients applied @125% RD (S_3N_3) augmented the yield of rice by 32.5%, potato by 81.5% and green gram by 47.3%, over the inorganic source applied @ 75% RD (S_1N_1) under common practice. Kumar *et al.* (2014) also reported that application of 125% RDF + 5 t/ha vermicompost increased the rice grain yield by 31.15% over control. Interestingly the yield of rice and green gram at 75% RD through INM (S_3N_1) was at par with 100% RD of nutrients from inorganic sources (S_1N_2) but it was not the case for heavy feeder crop potato. The higher yield at the highest level of nutrients through S_3 might have been the result of higher availability and uptake of plant nutrients under favourable physical environment in the root rhizosphere and also conservation of the excess nutrients by forming organic-mineral complexes. This ensured slow and synchronized nutrient supply to crops. Similar results were reported by Sarkar *et al.* (2007) and Meena *et al.* (2013).

Impact on nutrient uptake

It is apparent from the Table 3 that conjoint use of chemical fertilizers and FYM (S_3) had significant positive effect on uptake of nutrients over inorganic fertilizers (S_1) and FYM (S_2) alone. Pooled data revealed that among different sources the highest N uptake by rice, potato and green gram (106.5, 144.6, 70.09 kg/ha, respectively) was observed in INM (S_3) while the lowest was in the organic source alone (S_2). The nitrogen derived

Table 5: Economic analysis of rice-potato-green gram cropping system as influenced by source and application rate of crop nutrients (pooled data over three years)

Treatments	Total cost of cultivation (A) (Rs ha^{-1})				Total value of produce (B) (Rs ha^{-1})				Net profit [NP = (B-A)] (Rs ha^{-1})				B:C [NP/B]			
	Rice	Potato	Green gram	System	Rice	Potato	Green gram	System	Rice	Potato	Green gram	System	Rice	Potato	Green gram	System
Sources of nutrients (S)																
Fertilizer (S_1)	25118	61292	13900	100310	26567b	137192b	16086b	179846b	1449b	75901b	2186b	79536b	0.066b	1.22b	0.145b	0.781b
FYM (S_2)	25489	61297	13900	100686	24506c	119260c	11789c	155557c	-982.6c	57963c	-2111c	54870c	-0.029c	0.929c	-0.162c	0.536c
Fertilizer + FYM (S_3)	25483	62981	13900	102365	28819a	152462a	18463a	199744a	3336a	89481a	4563a	97379a	0.138a	1.39a	0.309a	0.934a
LSD	NS	NS	NS	NS	758.09	5910.3	529.5	5813.1	758.2	5910.3	529.55	5813.3	0.031	0.095	0.039	0.0586
Application rate of nutrients (N)																
75% RD (N_1)	24992	60018	13900	98911	24053c	100688c	13614b	138355c	-939.4	40670c	-285.9b	39445c	-0.025b	0.680c	-0.029b	0.402c
100% RD (N_2)	25365	61870	13900	101135	27067b	141920b	15776ba	184762b	1702	80050b	1875a	83627b	0.075a	1.273b	0.119a	0.814b
125% RD (N_3)	25733	63683	13900	103316	28772a	166307a	16949a	212029a	3039	102624a	3049a	108713a	0.125a	1.586a	0.203a	1.035a
LSD	NS	NS	NS	NS	884.45	16875	2544.3	19201	1318	14632	1965.5	15145	0.055	0.189	0.128	0.117
Significance level																
Interaction																
S x N	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Price: Rice - 580, 645, 850 Rs./q (2006-07, 2007-08, 2008-09; respectively), Potato - 6000, 6800, 8000 Rs./q (2006-07, 2007-08, 2008-09; respectively); Green gram - 1520, 1700, 2520 Rs./q (2006-07, 2007-08, 2008-09; respectively); Each value represents pooled data of mean values of economic parameters of three replicated plots over three years and values that differ significantly ($p < 0.05$) within each column are followed by different letters. NS, Non significant.

from the organic matter and fertilizer source improved the N use efficiency and consequently improved the uptake by crops in S_3. The results are in agreement with the findings of Kumar *et al.* (2014) and Mitra *et al.* (2010). Similar effect was also observed for P uptake by different crops. Highest P uptake by rice (18.06 kg/ha), potato (14.95 kg/ha) and green gram (13.59 kg/ha) was also noted in S_3 possibly due to the increased mobilization of native insoluble P through organic acids, better inoculation with phosphate solubilizing microorganisms which are also known to produce organic acids and reduced phosphate fixation resulted from protective cover by organic matter on sesquoxides present in this red and lateritic soils. Similar findings were also observed by Biswas (2010) and Bahadur *et al.* (2012). Inclusion of FYM with inorganic fertilizer increased the uptake of potassium in rice, potato and green gram by 14%, 28% and 18.5%, respectively, over S_1. Such increase in K uptake with addition of FYM might be due to the increase in CEC of soil holding more exchangeable K on the surface and also dissolution of K from the K bearing minerals by the organic acids. Similar results were also observed by Majumdar *et al.* (2014) and Sawarkar *et al.* (2013). With increase in the level of nutrients from 75% RD to 125% RD the uptake of N, P and K by rice were increased by 22.1, 3.06 and 48.76 kg/ha respectively, that for potato were 54.09, 5.26 and 54.85 kg/ha, respectively. This higher uptake of nutrients associated with higher amount of nutrient application might be due to the greater biomass yield. This result corroborates with the findings of Satyanarayana *et al.* (2002) and Singh *et al.* (2013).

Fig. 2 shows the interaction study of the levels and sources of nutrients on N, P and K uptake by crops which were significant. The maximum uptake of N, P and K by rice (114, 19 and 67.5 kg ha^{-1}, respectively), potato (174, 18 and 187 kg ha^{-1}, respectively) and green gram (78, 14.8 and 35 kg ha^{-1}, respectively) was observed at 125% RD applied through integrated source (S_3N_3). This was due to greater yield of crops and thereby higher assimilation of nutrients under favourable soil physical, chemical and biological environment as explained earlier. Satyanarayana *et al.* (2002) and Satish *et al.* (2011) also reported higher uptake of nutrients in low land rice and rice-maize cropping sequence, respectively, with higher doses of nutrient applied through integrated source.

Impact on soil properties

The pooled data on the effect of different sources and levels of nutrient application on soil chemical and physical properties after each year of cropping cycle are presented in table 4. The increase of pH under integrated source (S_3) after 3 years might be ascribed to the increased base retention capacity (Laxminarayana and Patiram, 2006). However, the decrease of soil pH from the initial value in the organically amended treatment (S_2) could be partly due to formation of various organic acids during mineralization of nutrients from FYM and partly due to decomposition of incorporated green gram plants in soil. Pooled data over 3 years (Table 4) revealed that conjoint use of chemical fertilizers and FYM (S_3) has significantly increased the soil organic carbon by 17.07% , available N, P, K and moisture content by 12.9%, 10.3%, 8.89% and 7.82%, respectively, over the inorganic fertilizer (S_1). However, in FYM treated plots (S_2) the available N, P and K were least (119.8,

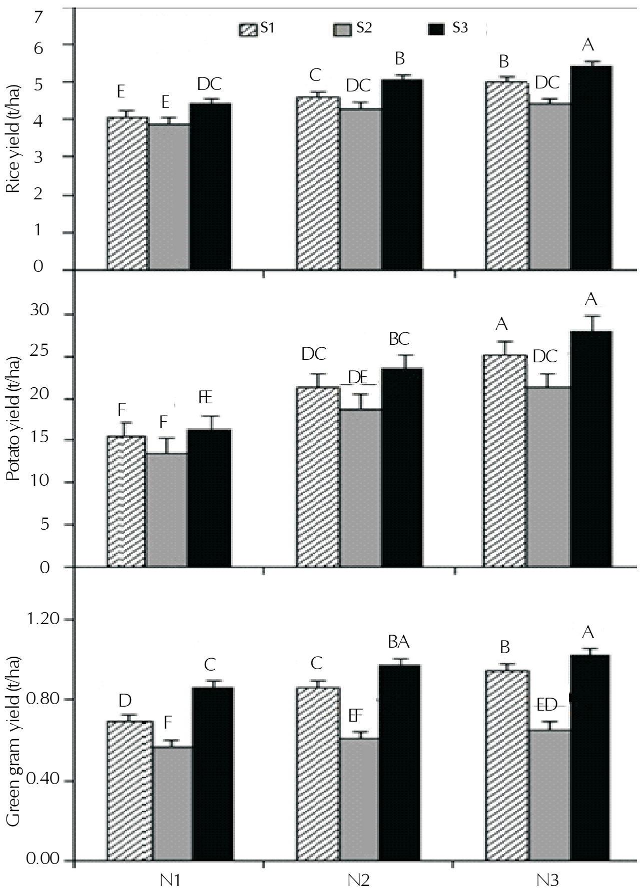

Figure 1: Interaction effect of source and application rate of crop nutrients on yield of rice (a), potato (b) and green gram (c) (pooled data over three years). Values that differ significantly ($p < 0.05$) in each figure are followed by different letters. S_1, S_2 and S_3 represent fertilizer, FYM and fertilizer + FYM source of nutrient respectively and N_1, N_2 and N_3 represents 75%, 100% and 125% level of RD of NPK respectively

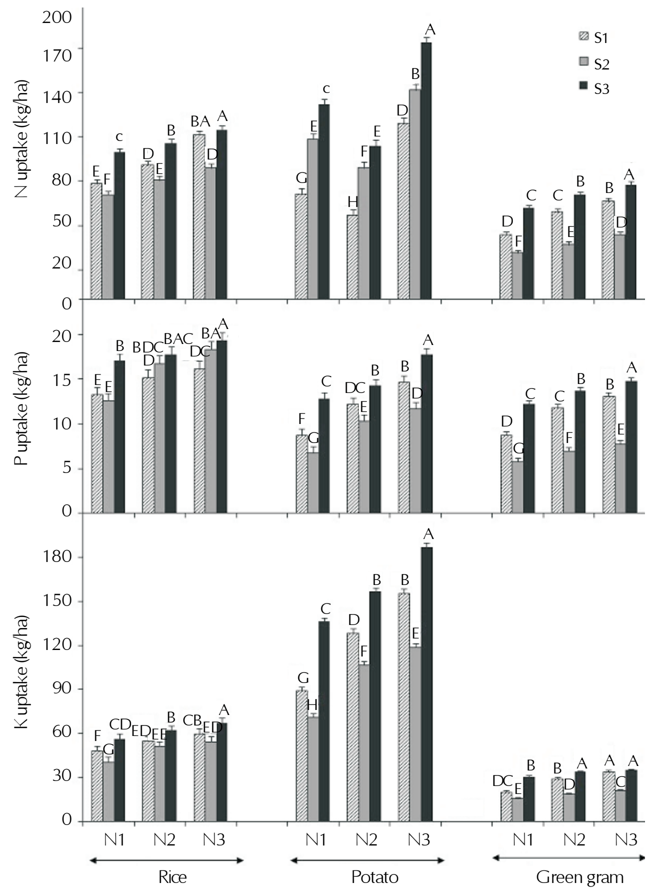

Figure 2: Interaction effect of the source and rate of nutrients on uptake of N, P and K (kg/ha) by rice, potato and green gram (pooled data over three years). Values that differ significantly ($p < 0.05$) in each segment are followed by different letters. S_1, S_2 and S_3 represent fertilizer, FYM and fertilizer + FYM as source of nutrients respectively, and N_1, N_2 and N_3 represents 75%, 100% and 125% level of RD of NPK respectively

74.87 and 106.7 kg/ha, respectively) because of the higher crop demand than the supply but the mean water holding capacity (MWHC) (44.25%) was higher. Application of 125% RD of nutrients also significantly increased the OC (0.662%), available N, P and K (132.9, 85.13 and 123.2 kg/ha) and MWHC (43.644%) than 75% RD (N_1) and 100% RD (N_2). Increased OC in S_3 might be the result of increased mineralization of soil organic C by the microbial activity (Lv Meirong *et* al., 2011), and return of large amount of crop residues in the form of roots and stubbles to soil (Biswas, 2010). The N build up of soil may be due to the positive balance of OC and slow release of N from mineralization of FYM. While higher available P build up may be due to the addition of FYM in soil since FYM is known to mobilize native insoluble P through several organic acids (Dixit and Gupta, 2000). The S_3 as source of nutrients was able to increase the cation exchange capacity of soil such that the added K or that released from soil was protected from leaching loss and /or re-fixation in soil. Earlier authors (Sharma *et al.* 2013) also reported similar findings. A significant decrease in bulk density (BD) and increase in MWHC was noted after the experiment in organically treated plots (S_2). This was due to the enhanced organic matter content in soil (Bandyopadhyay *et al.*, 2011) leading to better aggregation, and increased volume of micropores (Schj´ønning *et al.*, 1994). Similar results were reported by Bandyopadhyay *et al.* (2011). On the other hand with increase in the level of nutrients there was reduction in bulk density and increase in water holding capacity; might be due to the higher root volume and thereby more plant residue addition (Bellaki and Badanur, 1997). The interaction effect of different sources and levels of nutrients was found significant for all the soil parameters except for available N (Table 4). The highest build up of OC (0.719%), available N (143.89 kg/ha), P (90.14 k/ha) and K (129.5 kg/ha) was observed @ 125 RD supplied through INM (S_3N_3). Similar improvement in OC content of soil, different soil available plant nutrients and bulk density was recently reported by Kumar *et al.* (2012) in potato based cropping system and by Babar and Dongale (2013) in lateritic soil in mustard-cowpea-rice cropping system.

Economics of integrated nutrient management

The total cost of cultivation and annual net profit were considered for evaluating the best nutrient management practice in the selected cropping system (Table 5). The pooled analysis revealed that amongst sources the highest net profit (97379 Rs. ha^{-1}) and B: C (0.934) of the system was obtained in the integrated source (S_3), while 125% (N_3) RD of nutrient level recorded highest net profit (108713 Rs. ha^{-1}) and B: C (1.035). This was due to higher economic yield of the crops associated with low input cost of FYM in the integrated approach compared to the inorganic source. Because of low yield and involvement of the cost of bulk FYM these economic parameters were low in the organic source (S_2). Similar higher economical profit with combined application of inorganic and organic source was reported by Ray and Mukhopadhyay (2013) in *kharif* rice and Nayek *et al.* (2013) in sesame at West Bengal.

Our study in an Inceptisol of the acid red and laterite zone of Gangetic plain revealed that inclusion of FYM in the nutrient management schedule with fertilizers produced significant greater yield and nutrient uptake by crops in an intensive cultivation. It was noted that the soil productivity in terms of OC, available N, P and K could be improved using 25% higher doses of nutrients than the recommended. The pooled yields of rice and green gram with 125% RD of inorganic fertilizers were at par with the RD through INM. This was possible because of greater agronomic efficiency of the cropping sequence (having green gram without inputs) and INM practice. The economic benefits of INM at the recommended level of nutrient can attract the farmers, via the implementers, to adopt the practice. This study draws attention on immediate adoption of INM practice in this rainfed zone in order to prevent further deterioration of soil health and yield level. Further research may look for long term experiment, for the biochemical properties of soil.

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