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Research Paper

Effect of fertilizer levels and organic sources of nitrogen on production potential of hybrid rice (*Oryza sativa*) and soil properties under system of rice intensification

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ABSTRACT

A field experiment was carried out during the rainy (*kharif)* seasons of 2010 and 2011 at Varanasi, Uttar Pradesh, to study the performance of hybrid rice (*Oryza sativa* L.) 'PHB 71' to fertilizer levels and nitrogen levels applied through organic sources on production potential, nutrient uptake and soil physic-chemical properties under system of rice intensification (SRI). The experiment was laid out in a split-plot design keeping 3 fertilizer levels [50%, 75% and 100% recommended dose of fertilizer (RDF)] in main plots and three levels of nitrogen (15, 30 and 45 kg N/ha) applied through 2 organic sources (FYM, farmyard manure and VC, vermicompost) in sub-plots comprising 18 treatment combinations replicated thrice. An application of 100% recommended dose of fertilizer (RDF) increased effective tillers/m^2 (10.1%), filled grains/panicle (18.6%), test weight (11.0%), grain yield (19.0%) and straw yield (24.2%) over the 50% RDF. As regards the 3 levels of N (15, 30 and 45 kg/ha) through organic sources, an application of 45 kg N either through VC or FYM resulted in higher values of yield attributes, grain and straw yields than 30 kg N/ha either through VC or FYM. Further, increasing fertilizer levels from 50% to 100% RDF, significantly enhanced the nutrient uptake (NPK) by grain and straw as well as soil organic carbon content and available NPK at harvesting. However, 45 kg N/ha applied either through FYM or VC resulted in the maximum NPK uptake by the crop and enhanced soil electrical conductivity, organic carbon as well as available N, P and K content of the soil, but reduced the soil *p*H at the end of two crop cycles. Interactive effect on grain yield was found significant between fertilizer levels and organic sources applied at varied N levels. Application of 75% RDF + 45 kg N/ha through VC resulted in markedly higher grain yield but remained at par with 100% RDF applied in conjunction with 30 or 45 kg N/ha as FYM and VC both. The integration of 100% RDF accompanied with 30 kg N/ha through VC gave the maximum net returns (₹59,804/ha).

Key words **:** FYM, Hybrid rice, NPK levels, Nutrient uptake, Soil fertility, SRI, Vermicompost

Rice is one of the most important staple food crops for more than half of the world's population and its cultivation secures livelihood for about two billion people. India will need to produce 130 million tonnes of rice by 2030 compared with the present production of 102.75 million tonnes. Rice productivity has reached a plateau and is now stagnant or attainted declining trend in intensive cropped areas even with high rate of fertilizer application and such a situation raises serious concern about sustainability of the production system. There is an urgent need to find ways to raise rice productivity with less water, fewer inputs and an eco-friendly production system. The system of rice intensification (SRI) provides ample scope for improving rice productivity by efficient use of available resources in a sustainable manner. Hybrid cultivars are known for their high yield potential compared to inbred cultivars. It is well known that integration of organic sources with inorganic offer balanced supply of nutrients and improves soil quality. Higher rice productivity on sustained basis can be maintained by judicious use of chemical fertilizers in combination with organic manures. However, under integrated nutrient management (INM), the big challenge is to ensure the efficient utilization of nutrients from applied sources. Organic manures as a source of humus and plant nutrients need to improve the soil fertility and soil health of tropical soils. Vermicompost, an improved organic manure possess excellent structure, high

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concentration of nutrients and low C: N ratio than other organic manures (Ismail, 2005). Under INM, VC and FYM may improve the efficiency of applied fertilizers and also improve soil physical, chemical and biological properties. The overall strategy for enhancing the crop yield per unit of resources and sustaining them at a high level must include an integrated approach to the management of soil nutrients. The INM practices for rice under conventional method of production have been developed but such information is lacking for SRI method particularly with respect to Varanasi condition. Hence present field investigation was carried to evaluate the effect of fertilizer levels and organic sources of nitrogen on the production potential of hybrid rice, nutrient uptake, economics and soil physic-chemical properties under SRI.

MATERIALS AND METHODS

A field experiment was conducted during rainy (*kharif*) seasons of 2010 and 2011 at the Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (25°18' N, 88°03' E at 128.93 m above mean sea-level in the Northern Gangetic alluvial plains), Uttar Pradesh. The soil was sandy clay loam (typic Ustochrepts) with 7.42 *p*H. It was moderately fertile being low in organic carbon (0.34%) and available N (201.1 kg/ha) but medium in available P (10.6 kg/ha) and K (176.7 kg/ha). The experiment was laid out in split-plot design and replicated thrice. The experiment consisted of 18 treatment combinations, comprising 3 fertilizer levels [50%, 75% and 100% recommended dose of fertilizer (RDF)] in main plots and combination of 3 levels of N (15, 30 and 45 kg N/ha) and 2 organic sources, viz. farmyard manure, (FYM) and vermicompost, (VC) in subplots. The RDF was 150 kg N, 75 kg P_2O_5 and 75 kg K_2O/ha. Basal application of half doses of N and full dose of P and K were applied as per treatment through urea, di-ammonium phosphate and muriate of potash, respectively. The remaining N was top-dressed as urea in 2 equal splits at active tillering and 5–7 days before panicle-initiation stage. Nutrient compositions of organic manures determined for each year separately (Table 1) and were then applied as per treatment to their respective plots before transplanting based on N-equivalent (dry weight basis) calculated by using formula:

$$\text{Fresh weight of manure (kg)} = \frac{\text{Moisture content of manure} \times \text{Dry weight of manure to supply the N (kg)}}{100} + \text{Dry weight of manure to supply the N (kg)}$$

A common basal dose of zinc sulphate (21% Zn) @ 25 kg/ha was applied uniformly to all the plots only during the first year of experimentation. Twelve days old seedlings of 'PHB 71' hybrid rice were transplanted in a square pattern (25 cm × 25 cm) using single seedling per hill in plots of 5 m × 4 m. Experimental crops were transplanted and harvested during the first week of July and the fourth week of October, respectively, in the same experimental site during both the seasons. Commercial crop of chickpea was raised as succeeding crop during both the years, so as to maintain the homogeneity of the experimental field. Two irrigations were given during the crop period as per the requirement. Standard cultural practices were performed as per SRI recommendations. As cono-weeding being a part of SRI was helpful in managing the weeds. The crop received 714.0 mm and 1,137.7 mm rainfall during period of 2010 and 2011, respectively. Grain and straw samples were dried, processed and analysed for their total N content by micro-Kjeldahl's, P by Vanadomolybdo phosphoric acid-yellow colour method and K was estimated by flame-photometer. Nutrient uptake was estimated by multiplying the content with the oven-dry weight of biological yield. The soil samples collected before transplanting and after harvesting of the crop during both the years were analysed for organic carbon by Walkley and

Table 1. Year-wise nutrient composition of organic manures with their application rate

Observation/calculation	FYM		VC	
	2010	2011	2010	2011
	Nutrient content on dry-weight basis (%)			
(a) Carbon	17.7	17.4	22.6	25.9
(b) Nitrogen (N)	0.47	0.44	1.2	1.3
(c) Phosphorus (P_2O_5)	0.19	0.21	0.6	1.0
(d) Potassium (K_2O)	0.49	0.44	0.27	0.23
C: N ratio	37.7	39.5	18.8	19.9
Moisture (%)	28	33	30	37
Manure applied for 15 kg N/ha (t/ha)	4.09	4.53	1.63	1.58
Manure applied for 30 kg N/ha (t/ha)	8.17	9.07	3.25	3.16
Manure applied for 45 kg N/ha (t/ha)	12.26	13.60	4.88	4.74

FYM, Farmyard manure; VC, vermicompost

Black's method, available N by alkaline permanganate method, P by Olsen's method, K by flame-photometer after extraction with 1 N NH_4OAc (*p*H 7). Bulk density, particle density and water-holding capacity were analysed as per procedure given by Black *et al*. (1965). Economics was calculated on the basis of prevailing market price of inputs and minimum support price of the produce. The data recorded were analysed on pooled basis as per analysis of variance technique for split-plot design.

RESULTS AND DISCUSSION

Yield attributes and yield

Yield attributes as well as grain and straw yields of hybrid rice were significantly influenced by fertilizer levels and organic sources (Table 2). Application of 100% RDF recorded the maximum value of yield-attributing characters followed by 75% and 50% RDF. All the fertilizer levels differed significantly among themselves, except 100 and 75% RDF for test weight. Higher fertilizer level (100% RDF) was found to enhance the process of tissue differentiation, i.e. from somatic to reproductive phase leading thereby to increased floret number and grain setting. Similar findings were reported by Maiti *et al*. (2006). Significant increase in grain and straw yield was observed with increasing in fertilizer levels up to 100% RDF and this was 5.9 and 19.0% higher in grain and 13.1 and 24.2% in straw yield than 75% and 50% RDF respectively, on pooled data basis. Continuous supply of nutrients in balanced quantity throughout the growth stages enables the plants to assimilate sufficient photosynthetic product and thus increased dry-matter accumulation. Therefore, plants at higher fertilizer levels produced more panicles and grains/panicle with increased test weight, resulting into higher grain yield. Our findings confirm the results of Sudhakar *et al*. (2006). Harvest index, remained unaffected due to fertilizer levels during study.

The yield attributes, viz. effective tillers/m^2, grains/panicle and test weight, of hybrid rice markedly influenced by organic mode of N which was maximum with 45 kg N applied through VC. Though this treatment remained at par with 45 kg N/ha through FYM, proved significantly superior to other lower doses of organic nitrogen. Organic sources applied at different N levels also influenced the grain and straw yields; application of VC at 45 kg N being at par with 30 kg N/ha resulted in significantly higher grain and straw yields than other combinations. However, the lowest grain and straw yields were associated with FYM applied at 15 kg N/ha. This might be because decomposition of the manures

Table 2. Effect of fertilizer levels and varied N rates by organic sources on yield attributes, yield and nutrient uptake by hybrid rice under SRI (pooled data of 2 years)

Treatment	Yield attributes			Yield (t/ha)						HI (%)	Nutrient uptake (kg/ha)					
				Grain			Straw				Nitrogen (N)		Phosphorus (P)		Potassium (K)	
	Effective tillers/m^2	Filled grains/ panicle	Test weight (g)	2010	2011	Pooled	2010	2011	Pooled		Grain	Straw	Grain	Straw	Grain	Straw
Fertilizer level																
50% RDF	228.0	150.4	21.47	5.36	5.56	5.46	8.04	8.28	8.14	40.1	62.3	50.5	11.2	7.58	13.1	115.4
75% RDF	240.0	162.1	22.75	6.06	6.21	6.14	8.89	8.99	8.94	40.8	73.5	56.0	12.9	8.5	15.0	134.3
100% RDF*	251.0	178.4	23.78	6.37	6.63	6.50	9.94	10.28	10.11	39.2	80.4	63.5	13.9	9.8	16.1	157.4
SEm±	2.64	1.86	0.31	0.07	0.81	0.06	0.10	0.12	0.11	0.40	1.05	0.78	0.16	0.12	0.23	2.07
CD (P=0.05)	10.36	7.30	1.22	0.28	0.29	0.24	0.40	0.46	0.41	NS	4.14	3.04	0.62	0.45	0.90	8.13
Organic source																
15 kg N/ha through FYM	230.5	151.4	21.19	5.50	5.64	5.57	8.31	8.35	8.33	40.0	64.3	51.5	11.2	7.7	13.2	117.0
30 kg N/ha through FYM	238.1	162.5	23.72	5.92	6.13	6.03	8.87	9.09	8.97	40.2	71.7	56.0	12.8	8.5	14.8	133.4
45 kg N/ha through FYM	246.2	172.4	23.28	6.12	6.27	6.19	9.18	9.43	9.30	40.0	75.3	58.5	13.3	8.9	15.4	143.9
15 kg N/ha through VC	233.9	151.7	22.68	5.61	5.77	5.69	8.35	8.18	8.27	40.8	66.5	51.3	11.5	7.8	13.6	118.6
30 kg N/ha through VC	242.0	168.0	23.06	6.15	6.43	6.29	9.42	9.79	9.61	39.7	75.7	60.2	13.5	9.2	15.5	145.2
45 kg N/ha through VC	247.4	174.9	22.08	6.30	6.56	6.43	9.62	10.24	9.91	39.5	78.9	62.7	13.9	9.6	16.1	156.2
SEm±	1.49	2.01	0.34	0.08	0.58	0.06	0.13	0.14	0.10	0.45	1.26	0.84	0.17	0.14	0.17	2.27
CD (P=0.05)	4.31	5.81	0.97	0.22	0.18	0.18	0.37	0.41	0.30	1.28	3.63	2.41	0.49	0.38	0.49	6.55

SRI, System of rice intensification; HI, harvest index; RDF, recommended dose of fertilizer; FYM, farmyard manure; VC, Vermicompost
*100% RDF: 150 kg N, 75 kg P_2O_5 and 75 kg K_2O/ha

releases nutrients slowly throughout the growth period that leads to better nutrient supply for chlorophyll synthesis, healthy root growth as translocation of photosynthates. The increase in grain and straw yields owing to VC application could be ascribed to better mineralization leading thereby to higher availability of nutrients, higher occurrence of beneficial micro-organisms, growth-promoting hormones, antibiotics as well as enzymes (Banik *et al*., 2006). However, application of 15 kg N/ha through VC showed the maximum harvest index compared to higher levels of N applied either through fertilizers or the organic sources.

Interaction between fertilizer levels and organic sources at different N levels on grain and straw yields of hybrid rice was significant (Table 3). Application of 75% RDF + 45 kg N as VC though remained comparable to 100% RDF compared with 30 and 45 kg N/ha through VC or FYM recorded significantly higher grain yield than other the combinations of fertilizer levels and organic sources. Further, the data indicate that application of 100% RDF either with 30 kg or 45 kg N/ha applied through VC showed higher straw yield. It is perusable that integration of organic manures with inorganic nutrient sources might have regulated balanced supply of nutrients in adequate quantities over prolonged period that ultimately resulted in increased crop yield. However, the minimum grain and straw yields were recorded with combined application of 50% RDF along with 15 kg N/ha through FYM. These results are in close conformity with the findings of Ramesh and Vayapuri (2008).

Nutrient uptake

Significant improvement in NPK uptake by grain and straw of hybrid rice was observed with each increment of fertilizer levels up to 100% RDF (Table 2). The nutrient-uptake pattern followed the trend of grain and straw yields. The maximum uptake of NPK by grain and straw was recorded when the crop was fertilized with 100% RDF and it was found significantly superior to 75% and 50% RDF. This could be ascribed to the increase in the available N, P and K contents in soil resulting from the increased availability of nutrients which ultimately increased nutrient content in the plant tissues and also greater biomass production at higher rates of fertilizer application. Since the uptake of nutrient is a function of dry matter and nutrients content, the increased grain and straw yields together with higher NPK content resulted in greater uptake of these elements. The result confirm the findings of Balasubramaniyan (2004). Uptake of NPK by grain and straw of hybrid rice was also positively influenced by N levels of 45, 30 and 15 kg N/ha applied either through FYM or VC. Application of increasing levels of

Table 3. Interactive effect of fertilizer levels and varied N rates by organic sources on grain and straw yields and economics of hybrid rice under SRI (pooled data of 2 years)

Treatment	Grain yield (t/ha)			Straw yield (t/ha)			Net returns (×10³₹/ha)			Benefit: cost ratio		
	50% RDF	75% RDF	100% RDF*	50% RDF	75% RDF	100% RDF	50% RDF	75% RDF	100% RDF	50% RDF	75% RDF	100% RDF
15 kg N/ha through FYM	4.74	5.73	6.23	7.63	7.90	9.45	40.6	49.9	56.7	2.51	2.74	2.84
30 kg N/ha through FYM	5.63	5.95	6.50	8.32	8.76	9.84	49.1	51.5	57.7	2.67	2.64	2.73
45 kg N/ha through FYM	5.73	6.24	6.61	8.46	9.30	10.14	47.8	53.1	56.8	2.49	2.56	2.57
15 kg N/ha through VC	5.14	5.70	6.23	7.74	7.81	9.24	44.3	48.7	55.5	2.61	2.65	2.76
30 kg N/ha through VC	5.78	6.40	6.68	8.30	9.83	10.69	49.0	57.0	59.8	2.58	2.73	2.71
45 kg N/ha through VC	5.74	6.81	6.75	8.39	10.06	11.28	45.3	58.5	58.3	2.32	2.60	2.52
	SEm±	CD (P=0.05)		SEm±	CD (P=0.05)		SEm±	CD (P=0.05)		SEm±	CD (P=0.05)	
F at same OM	0.12	0.31		0.18	0.51		0.88	2.6		0.03	0.12	
OM at same/diff F	0.12	0.37		0.19	0.62		0.89	2.7		0.04	0.13	

SRI, System of rice intensification; HI, harvest index; RDF, recommended dose of fertilizer; FYM, farmyard manure; VC, Vermicompost, *100% RDF: 150 kg N, 75 kg P_2O_5 and 75 kg K_2O/ha

nitrogen up to 45 kg N/ha through organic sources significantly enhanced uptake of NPK by grain and straw. An increased uptake of nitrogen, phosphorus and potassium by rice might be due to constant release of nutrients that satisfied the demand of the hybrid rice at every phenophase as opined by Sudhakar and Kuppuswamy (2007). However, 30 kg or 45 kg N/ha through VC significantly improved the uptake of NPK than FYM at the same rate of application. This could be attributed to the comparatively lower C: N ratio of VC, which resulted in faster decomposition and release of nutrients as compared to FYM (Pareek and Yadav, 2011).

Economics

The maximum net returns were obtained with application of 100% RDF accompanied by 30 kg N/ha through VC (Table 3). Amongst the different combinations of fertilizer levels and organic mode of nitrogen, the maximum benefit: cost ratio of 2.84 was recorded under 100% RDF integrated with 15 kg N/ha through FYM. This might be owing to higher productivity of hybrid rice and relatively low production cost per unit of yield under the treatment. Owing to better response of rice to VC, the net returns were greater at higher rates of application, i.e. 30 and 45 kg N/ha both at 75% and 100% RDF than FYM. However, owing to comparatively higher cost of VC, the benefit: cost ratio was better with the application of FYM. The results confirm the finding of Kumar *et al*. (2006).

Soil physic-chemical properties

The physical properties of soil, viz. bulk density and water holding capacity, were not influenced by fertilizer levels and organic mode of N (Table 4). However, soil bulk density numerically reduced and water-holding capacity of soil was slightly improved due to application of 45 kg N/ha, both through FYM and VC compared to their initial values. During the process of organic matter decomposition, polysaccharides, cellulose and humus are produced which are responsible for firm binding among soil particles in more stable aggregate causing reduction in bulk density. Similar results were reported by Pareek and Yadav (2011). Further, the soil chemical properties like *p*H and EC did not exhibit the response to varying fertilizer levels, though there were influenced significantly by the addition of N at variable rates through organic sources. The values of soil organic carbon, available N, P and K significantly increased from initial values up to the highest owing to application of increasing doses of fertilizers up to 100% RDF. Similarly, the maximum organic carbon build up and available N, P and K was accrued with appli-

Table 4. Effect of fertilizer levels and varied N rates by organic sources on soil physic-chemical properties of soil under SRI (pooled data of 2 years)

Treatment	Physical properties		Chemical properties					
	Bulk density (Mg/m^3)	Water holding capacity (%)	Soil *p*H	Soil EC (dS/m)	Organic carbon (%)	Available nutrient (kg/ha) N	P_2O_5	K_2O
Fertilizer level								
50% RDF	1.39	41.4	7.48	0.176	0.33	211.1	18.5	162.5
75% RDF	1.41	42.5	7.44	0.182	0.34	227.0	22.1	169.3
100% RDF*	1.42	43.0	7.35	0.186	0.35	238.7	24.6	174.2
SEm±	0.012	0.48	0.02	0.001	0.003	1.7	0.19	1.0
CD (P=0.05)	NS	NS	NS	NS	0.011	6.7	0.74	3.9
Organic source								
15 kg N/ha through FYM	1.41	41.4	7.49	0.159	0.31	214.1	18.3	164.5
30 kg N/ha through FYM	1.40	42.0	7.44	0.183	0.33	226.0	21.3	168.4
45 kg N/ha through FYM	1.39	42.3	7.37	0.197	0.37	234.5	24.2	171.1
15 kg N/ha through VC	1.43	42.0	7.48	0.165	0.33	212.6	19.5	166.0
30 kg N/ha through VC	1.42	42.6	7.43	0.186	0.34	229.6	22.4	169.5
45 kg N/ha through VC	1.40	43.7	7.35	0.199	0.39	236.7	24.9	172.5
SEm±	0.011	0.48	0.02	0.001	0.003	1.8	0.23	0.9
CD (P=0.05)	NS	NS	0.08	0.004	0.009	5.1	0.68	2.5
Initial value of the I^{st} year	1.40	40.7	7.42	0.170	0.34	197.0	23.4	210.2
Initial value of the II^{nd} year	1.39	41.8	7.39	0.180	0.34	205.2	25.3	215.6

SRI, System of rice intensification; HI, harvest index; RDF, recommended dose of fertilizer; FYM, farmyard manure; VC, Vermicompost; EC, electrical conductivity

*100% RDF: 150 kg N, 75 kg P_2O_5 and 75 kg K_2O/ha

cation of both the organic sources (FYM and VC) at 45 kg N/ha. These results clearly indicate improved fertility status of soil owing to increased values of N, P and K with addition of 100% RDF accompanied by 45 kg N/ha through organic sources more particularly the VC. Application of organic manures in enough quantities improves the soil organic carbon and available N, P and K in soil (Maiti *et al.*, 2006; Kumari *et al*., 2013). Higher amount of nitrogen applied through the organic sources decomposes quickly producing more organic acids thus increase nitrogen in available form. This is also possible that FYM or VC applied at higher amount might have enhanced the microbial population and their activities in the decomposition, which could convert organically bound nitrogen to inorganic form without any adverse effect on available soil nitrogen. Kannan *et al*. (2005) reported in sandy-loam soil (udic haplustalf) that bacteria and fungi population were the highest under 75% recommended dose of N applied through VC with *Azospirillum*. Organic anions arising from decomposition of organic matter form stable complexes with Fe^{3+}, Al^{3+} and prevent their reaction with phosphates ions, and result in significantly higher available P due to organic sources. Soil exhibited significantly higher available K status under higher rates of organic sources as compared to medium and lower quantities. Most of the K in plants remains in organic form and also the decomposing organic matter may have solubilizing effect on native soil potassium. These findings are in done conformity with Kharub and Chander (2008).

Thus on the basis of economic analysis of 2 years of results, it is concluded that hybrid rice cv. 'PHB 71' treated by 100% recommended dose of fertilizer (150-75–75 kg NPK/ha) with 30 kg N/ha through vermicompost proved to be the most remunerative dose under SRI.

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