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Research Paper

Integrated nutrient management in rice (*Oryza sativa*)

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ABSTRACT

A field experiment was conducted during rainy season of 2010 and 2011 on a sandy loam soil at Banaras Hindu University, Varanasi, Uttar Pradesh to identify an appropriate integrated nutrient management practice in rice (*Oryza sativa* L.) for higher productivity, profitability and soil health. Rice grown with recommended dose of nitrogen through inorganic fertilizer (RDN) produced only 2% higher grain yield compared with the best integrated nutrient management treatment *i.e.* 75% RDN through inorganic fertilizer and 25% N through carpet waste + cow dung slurry + *Pleurotus sajor* + *Azotobacter* + PSB + *Trichoderma* + enriched with S and Zn. The uptake of N, P and K by rice grown with inorganic fertilizer was 3.08%, 5.92% and 2.79%, respectively higher than enriched carpet waste. Among the organic manures, higher gross and net returns were obtained under 75% RDN through inorganic fertilizer and 25% N through enriched carpet waste. The maximum organic carbon, available N, P and K were recorded from the plots receiving 50% RDN through inorganic fertilizer and 50% N through organic manure. The results indicated that 75% RDN through inorganic fertilizer and 25% nitrogen through carpet waste + cow dung slurry + *Pleurotus sajor* + *Azotobacter* + PSB + *Trichoderma* + Enrichment with S and Zn was the most appropriate organic nutrient management system for higher productivity and profitability with better soil health on long term basis.

Key words: Economics, Integrated nutrient management, Nutrient uptake, Rice, Yield,

In India, national food security system largely depends on the productivity of rice ecosystem. Management of organic waste in environment-friendly manner is becoming difficult due to rapid increase in population and urbanization. Organic waste materials are available in huge amounts in the form of farm and industrial wastes i.e. carpet wastes generated in huge amount from carpet industry. The continuous accumulation of these materials is becoming a potential source of land, water and air pollution. Composting is one of the biological processes for recycling of organic waste (Ahmad *et al;* 2007). It not only reduces the dependence on chemical fertilizers but also improves the bio-physico-chemical properties i.e. encourage the growth and activity of mycorrhizae and other beneficial organisms in the soil, increase fertilizer use efficiency, alleviate the deficiency of secondary and micronutrients, sustain higher productivity and improved soil health (Singh *et al;* 2006). It is very likely that the use of composted organic materials along with chemical fertilizers may be an effective alternate approach for further improving levels of the crop yields without deteriorating soil health. Hence, the present study was conducted to study the integrated nutrient management in rice.

MATERIALS AND METHODS

A field experiment was conducted for 2 consecutive years (2010 and 2011) during rainy season at the Research Farm, Department of Agronomy, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (Uttar Pradesh). The soil was sandy loam, with pH (1:2) 7.41, low in organic carbon (0.48%) and available N (190.50 kg/ha), medium in available phosphorus (19.85 kg/ha) and potassium (213.44 kg/ha) before starting the experiment. Nine treatments, viz. 100% recommended dose of nitrogen through chemical fertilizers (RDN, T_1), 75% RDN + 25% N through farm yard manure (T_2), 50% RDN + 50% N through farm yard manure (T_3), 75% RDN + 25% N through carpet waste + cow dung slurry + *Pleurotus sajor* (T_4), 50% RDN + 50% N through carpet waste + cow dung slurry + *Pleurotus sajor* (T_5), 75% RDN + 25% N through carpet waste + cow dung slurry + *Pleurotus sajor* + *Azotobacter* + PSB + *Trichoderma* (T_6), 50% RDN + 50% N through carpet waste + cow dung slurry + *Pleurotus sajor* + *Azotobacter* + PSB + *Trichoderma* (T_7), 75% RDN + 25% N through carpet waste + cow dung

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slurry + *Pleurotus sajor* + *Azotobacter* + PSB + *Trichoderma* + enriched with S and Zn (T_8) and 50% RDN + 50% N through carpet waste + cow dung slurry + *Pleurotus sajor* + *Azotobacter* + PSB + *Trichoderma* + enriched with S and Zn (T_9) were laid out in randomized block design replicated thrice, keeping the lay-out undisturbed throughout the field experimentation.

The enriched composts were prepared as per standard procedure. Microbial inoculant consisted of a combination of microbes, i.e., Phosphate solubilizing bacteria (*Bacillus polymyxa,*), cellulolytic fungus (*Trichoderma viride, Pleurotus sajor*) and free living N-fixer (*Azotobacter chroococcum*). Cellulolytic fungal cultures of *Trichoderma viride* was inoculated @ 300 g/tonne and *Bacillus polymyxa* @ 500 g/tonne of raw material. Carrier based inoculants of *Azotobacter* was applied to raise their number to 100 × 10^6/100 kg of organic material. The cellulolytic fungi were inoculated at the start of composting, whereas the nitrogen fixers and phosphate solubulizers were given after 28–30 days of initial composting to protect the microbes from direct exposure to excess heat generated from the materials. For improving the micronutrient content of compost, external spraying of salt solution was of gypsum @ 12 kg/tonne and zinc sulphate @ 200 g/tonne of compost was done at the final turning stage of composting mass. Fertilizers (120–60–60 kg N-P_2O_5-K_2O/ha) were applied through urea, di-ammonium phosphate and muriate of potash, respectively. Half of N and full dose of P and K were applied as basal before sowing in all the treatments. Remaining half dose of nitrogen was top dressed in two equal splits i.e. at active tillering and panicle initiation stages. Different organic manures like farm yard manure and carpet waste were also applied as basal before sowing in respective treatments. Twenty three day old seedlings of rice 'HUR 105' were transplanted at a spacing of 20 cm × 15 cm. All improved packages of practices were followed to raise the crop. Yield components and the grain and straw yields were recorded at harvest and the data were statistically analysed. The economic parameters like cost of cultivation and net returns were worked out by using prevailing market price of inputs and outputs. Plant NPK uptake were also estimated. The total N contents of plants was analysed by micro-Kjeldhal's method, P by vanadomolybdo phosphoric acid yellow-colour method and K was estimated by flame photometer method. The soil analysis before and end of the experiment was done by using standard methods. Since data followed the homogeneity test, data were pooled, analysed and presented.

RESULTS AND DISCUSSION

Yield and yield attributes

Different nutrient management had a significant effect on yield attributes, viz. effective tillers/m^2, spikelets/panicle, filled grains/panicle and test weight. Among the nutrient management treatments (Table 1), it was higher under 100% RDN through chemical fertilizer than the rest of the treatments but statistically on par treatments 75% RDN + 25% N through carpet waste + cow dung slurry + *Pleurotus sajor* + *Azotobacter* + PSB + *Trichoderma* (T_6), and 75% RDN + 25% N through carpet waste + cow dung slurry + *Pleurotus sajor* + *Azotobacter* + PSB + *Trichoderma* + enriched with S and Zn (T_8). The beneficial effect of organic compost on yield and attributes could be attrib-

Table 1. Yield attributes, grain, straw and harvest index as influenced by nitrogen substitution treatments (Pooled data of two years)

Treatment	Effective tillers/m^2 (no.)	Spikelets/ panicle (no.)	Panicles/ hill (no.)	Panicle length (cm)	Filled grains/ panicle (no.)	Test weight (g)	Grain yield (t/ha)	Straw yield (t/ha)	Harvest index (%)
100% recommended N through chemical fertilizers	288	70.8	16.1	22.7	136.8	27.7	5.72	6.64	45.8
75% RN + 25% N through FYM	246	59.4	14.8	21.8	114.3	25.6	5.13	5.85	46.7
50% RN + 50% N through FYM	243	53.8	14.15	21.4	102.9	24.4	4.67	5.28	47.0
75% RN + 25% N through C_1**	252	60.4	15.05	22.0	115.9	25.9	5.21	6.03	46.3
50% RN + 50% N through C_1	242	56.0	14.5	21.5	106.1	24.9	4.83	5.45	47.0
75% RN + 25% N through C_2	252	65.4	15.2	22.3	120.6	26.1	5.45	6.31	46.3
50% RN + 50% N through C_2	248	56.3	14.6	21.6	108.5	24.9	4.93	5.57	46.9
75% RN + 25% N through C_3**	270	71.4	15.6	22.5	132.2	26.7	5.61	6.46	46.2
50% RN + 50% N through C_3	262	58.8	14.7	21.7	111.9	25.2	5.04	5.75	46.7
SEm±	4.8	2.1	1.39	0.79	2.58	1.05	1.33	2.20	1.02
CD (P=0.05)	14.8	6.5	NS	NS	8.00	1.74	4.15	6.12	NS

*120 kg N/ha, Phosphorous @ 60 kg P_2O_5/ha and Potassium @ 60 kg K_2O/ha were commonly applied to all the treatments; ** C_1, C_2 and C_3 are the three best sources of compost (N) prepared through organic wastes *i.e.*; C_1: Carpet waste + cow dung slurry + *Pleurotus sajor*; C_2: Carpet waste + cow dung slurry + *Pleurotus sajor* + *Azotobacter* + PSB + *Trichoderma*; C_3: Carpet waste + cow dung slurry + *Pleurotus sajor* + *Azotobacter* + PSB + *Trichoderma* + Enriched with S and Zn uted to the fact that after proper decomposition and mineralization, the manures supplied available nutrients directly to the plant and also had solubilizing effect on fixed forms of nutrients in soil (Singh, 2006).

Yield is the manifestation of various yield components. Application of 100% RDN through chemical fertilizer produced maximum grian yields (5.72 t/ha), which was significantly higher grain than the rest of the INM treatments (Table 1), except treatments 75% RDN + 25% N through carpet waste + cow dung slurry + *Pleurotus sajor* + *Azotobacter* + PSB + *Trichoderma* and 75% RDN + 25% N through carpet waste + cow dung slurry + *Pleurotus sajor* + *Azotobacter* + PSB + *Trichoderma* + enriched with S and Zn. The highest grain yield under inorganic sources of nutrient (Kumari *et al;* 2010 and Chaudhary *et al;* 2011) might be due to immediate release and availability of nutrients compared with organic nutrient sources, which have relatively slow nutrient release and may achieve yield stability in the long run (Subhashini *et al;* 2007). The influence of treatments on harvest index was not significant (Dixit and Gupta, 2000).

Nutrient uptake

The highest N, P and K uptake by grain and straw (Table 2) was recorded with the 100% RDN through inorganic fertilizer, which was significantly better than the rest of the treatments except the treatment T_6 and T_8, Treatment receiving nitrogen application through inorganic fertilizer (T_1) had relatively faster release of nutrients, which resulted in higher grain and straw yield and thus had higher uptake of nutrients. Banik *et al;* (2006) also got similar result in respect of nutrient uptake.

S uptake by grain was maximum under the treatment T_8, where 75% RDN was applied through inorganic fertilizer and 25% N through carpet waste + cow dung slurry + *Pleurotus sajor* + *Azotobacter* + PSB + *Trichoderma* + enrichment with S and Zn, which was at par with treatments T_1, T_4 and T_6 and these were significantly higher than the rest of the treatments, which might be due to chelating action of organic compounds which prevents these cations from fixation, precipitation, oxidation and leaching (Gogoi *et al;* 2010).

Economics

Maximum gross and net returns and the lowest cost of cultivation were recorded under treatment, where 100% RDN was applied through inorganic fertilizer (Table 3). The net returns of 100% RDN treatment were on average higher by ₹5,425/ha over the best organic nutrition treatment *i.e.* 7% RDN was applied through inorganic fertilizer and 25% N through carpet waste + cow dung slurry + *Pleurotus sajor* + *Azotobacter* + PSB + *Trichoderma* + enrichment with S and Zn (Kumari *et al;* 2010).

Soil fertility

Organic carbon content of surface soil (Table 3) increased significantly with the application of organic manures along with fertilizers. Application of inorganic fertilizer only showed negative impact and reduced organic content of soil by 0.05% in two years. Higher organic carbon content was observed with the treatment, where 50% RDN was applied through organic manure followed by treatment with 25% RDN through organic manure (Nath *et al;* 2011 and Singh and Dhar, 2011). Application of

Table 2. Nutrient uptake of rice as influenced by nitrogen substitution treatments (Pooled data of two years)

Treatment	Nitrogen uptake (kg/ha)			Phosphorus uptake (kg/ha)			Potassium uptake (kg/ha)			Sulpher uptake (kg/ha)		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
100% recommended N through chemical fertilizers	61.5	29.8	91.3	13.4	8.04	21.5	14.6	69.8	84.5	7.9	2.9	10.9
75% RN + 25% N through FYM	56.0	27.6	83.6	12.0	6.37	18.4	13.9	63.1	77.1	7.4	2.7	10.1
50% RN + 50% N through FYM	51.8	26.5	78.3	11.3	5.22	16.5	13.1	58.5	71.6	7.1	2.5	9.6
75% RN + 25% N through C_1**	57.3	27.8	85.0	12.0	6.7	18.7	14.0	64.2	78.2	7.6	2.7	10.4
50% RN + 50% N through C_1	53.4	27.0	80.4	11.5	5.5	17.1	13.4	59.7	73.2	7.2	2.6	9.8
75% RN + 25% N through C_2	58.7	28.4	87.1	12.4	7.2	19.7	14.2	66.6	80.8	7.8	2.7	10.6
50% RN + 50% N through C_2	54.2	27.8	81.5	11.7	5.8	17.5	13.6	60.6	74.2	7.4	2.6	10.0
75% RN + 25% N through C_3**	59.6	28.9	88.5	12.6	7.6	20.2	14.3	67.7	82.1	7.9	2.8	10.8
50% RN + 50% N through C_3	55.5	27.6	83.0	11.8	6.2	18.1	13.7	61.9	75.7	7.5	2.6	10.1
SEm±	1.6	0.8	1.4	0.3	1.0	0.6	0.2	1.9	1.3	0.2	0.1	0.2
CD (P=0.05)	4.3	2.0	4.4	1.0	3.0	1.9	0.6	5.6	4.1	0.5	0.3	0.6

*120 kg N/ha, Phosphorous @ 60 kg P_2O_5/ha and Potassium @ 60 kg K_2O/ha were commonly applied to all the treatments; ** C_1, C_2 and C_3 are the three best sources of compost (N) prepared through organic wastes *i.e.*; C_1: Carpet waste + cow dung slurry + *Pleurotus sajor*; C_2: Carpet waste + cow dung slurry + *Pleurotus sajor* + *Azotobacter* + PSB + *Trichoderma*; C_3: Carpet waste + cow dung slurry + *Pleurotus sajor* + *Azotobacter* + PSB + *Trichoderma* + Enriched with S and Zn

Table 3. Economics and soil health status after two years as influenced by nitrogen substitution treatments

Treatment	Economics		EC	OC	Available nutrients (kg/ha)		
	Cost of cultivation (× 10^3 ₹/ha)	Net returns (₹/ha)	(dS/m)	(%)	N	P	K
100% recommended N through chemical fertilizers	26.8	55.2	0.34	0.43	190.7	22.0	214.6
75% RN + 25% N through FYM	29.4	43.9	0.33	0.49	194.1	22.2	218.1
50% RN + 50% N through FYM	32.1	34.5	0.31	0.52	197.7	22.3	221.4
75% RN + 25% N through C_1**	28.8	45.8	0.32	0.50	195.2	22.7	216.8
50% RN + 50% N through C_1	30.8	38.1	0.29	0.52	198.3	22.6	222.4
75% RN + 25% N through C_2	29.7	48.3	0.32	0.53	196.1	23.9	215.8
50% RN + 50% N through C_2	32.6	37.7	0.28	0.55	201.9	24.6	223.5
75% RN + 25% N through C_3**	30.5	49.7	0.31	0.54	197.6	24.6	215.7
50% RN + 50% N through C_3	34.2	37.7	0.27	0.57	202.9	25.8	223.9
SEm±		2.3	0.03	0.01	2.7	1.1	1.8
CD (P=0.05)		6.9	NS	0.02	8.5	3.7	5.8

Rates: Rice grain; ₹12,000/t and straw; ₹2,000/q; *120 kg N/ha, Phosphorous @ 60 kg P_2O_5/ha and Potassium @ 60 kg K_2O/ha were commonly applied to all the treatments; ** C_1, C_2 and C_3 are the three best sources of compost (N) prepared through organic wastes *i.e.*; C_1: Carpet waste + cow dung slurry + *Pleurotus sajor*; C_2: Carpet waste + cow dung slurry + *Pleurotus sajor* + *Azotobacter* + PSB + *Trichoderma;* C_3: Carpet waste + cow dung slurry + *Pleurotus sajor* + *Azotobacter* + PSB + *Trichoderma* + Enriched with S and Zna

manures along with inorganic fertilizer (T_2 to T_9) reduced the soil EC considerably as compared to sole application of inorganic fertilizer (Table 3). This could be ascribed to higher organic carbon content in these treatments, which had better soil aggregates and higher macropore space (Singh *et al;* 2006). The application of INM increased available N in the soil over the respective initial values and treatment T_1, where 100% nitrogen was supplied through inorganic fertilizer (Table 3). This might be due to the residual effect of applied fertilizers and to the mineralization of organic sources or through solubilization of nutrients from the native source during the process of decomposition of organic sources (Yadav and Kumar, 2009).

Available phosphorus content of surface soil (Table 3) increased significantly with the application of 50% organic manure along with 50% inorganic fertilizer. This might be due to CO_2 released and organic acid produced during decomposition, which helps in solubilizing native P. The organic matter (humus) may also reduce the fixation of phosphate by providing protective cover on sesqueoxides and chelating cations, which in turn enhanced the availability of P (Singh *et al;* 2008).

Available potassium content of soil increased considerably due to combined application of organic manures, biofertilizers and inorganic fertilizer compared to inorganic fertilizer alone (Table 3). This may be due to reduction of K-fixation, solubilization and release of K due to the interaction of organic matter with clay, besides the direct potassium addition to the potassium pool of the soil (Singh *et al;* 2008).

Rice receiving 75% RDN through inorganic fertilizer and 25% nitrogen through carpet waste + cow dung slurry + *Pleurotus sajor* + *Azotobacter* + PSB + *Trichoderma* + Enrichment with S and Zn was found to be the most appropriate organic nutrient management system for higher productivity and profitability with better soil health on long term basis. Inorganic crop receiving recommended dose of nitrogen gave the highest productivity and profits. However, use of enriched organic amendments and biofertilizer along with inorganic fertilizer enhanced the soil fertility after 2 years of study. Over years, it is expected to match or excel the fertilizer based production system.

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