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Growth, yield and nutrient use efficiency of rice (*Oryza sativa*) as affected by application of organics with fertilizers

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ABSTRACT

A field experiment was conducted at B.H.U. Varanasi during Kharif season 2013 to evaluate the effect of organics with chemical fertilizer on growth, yield, nutrient uptake and nutrient use efficiency in rice (Oryza sativa). The experiment was laid out in randomized block design with nine treatments and three replications. The results revealed that the substitution of 30% nitrogen through FYM and pressmud recorded tallest plants and maximum tillers m^{-1} row length at various growth stages, chlorophyll, grains/panicle and lowest values of these parameters in control. The maximum grain (4.79 t ha^{-1}) and straw (7.28 t ha^{-1}) yields were recorded under 70% RDF + 15% N as FYM + 15% N as pressmud treatment, which were 16.0 and 9.8% higher than 100% NPK alone, respectively. Application of 70% RDF + 15% N as FYM + 15% N as pressmud resulted in maximum uptake of N (58.9 and 37.9 kg ha^{-1}), P (16.4 and 16.9 kg ha^{-1}), K (16.0 and 86.9 kg ha^{-1}) and S (16.4 and 27.1 kg ha^{-1}) by grain and straw, respectively. The uptake of Fe (244.0 and 1566.6 g ha^{-1}), Cu (35.8 and 118.3 g ha^{-1}), Mn (71.4 and 388.4 g ha^{-1}) and Zn (137.0 and 181.5 g ha^{-1}) by grain and straw of rice were also higher with 70% RDF + 15% N as FYM + 15% as pressmud. On the other hand the lowest values of nutrient uptake were obtained from control treatment. Similar trend was also recorded in nutrient use efficiency of N (44.6%), P (36.4%), K (78.7%). The agronomic efficiencies of N, P and K were 17.0, 30.7, 36.5 kg grain kg^{-1} nutrient, respectively with 70% RDF + 15% N as FYM + 15% N as press mud.

Keywords: Nutrient uptake, yield, nutrient use efficiency, agronomic efficiency, organics

INTRODUCTION

Rice (*Oryza sativa* L.), the most important cereal crop in India; occupies nearly 35% of the total area under food grains and 15–20% of the cropped area of rice comes under *kharif* acreage. Cultivation of high yielding dwarf varieties responsive to fertilizer and excess use of inorganic fertilizers has depleted the inherent soil fertility. The decline or stagnation in yield has been attributed to nutrient mining and reduced use of organics (Baishya *et al.* 2015). Several long-term experiments conducted all over India indicated a decrease in rice productivity due to continuous use of chemical fertilizers (Kundu *et al.,* 2016).Integrated use of organic manure and chemical fertilizers would be quite promising not only in providing greater stability in production, but also in maintaining better soil fertility (Sharma and Subehiya, 2014). The application of organic manures influences the physical and chemical properties of soil and enhances the biological activities. Combined use of organics with fertilizer entails the maintenance of soil fertility to an optimum level for crop productivity to obtain the maximum benefit from all possible sources of plant nutrients. Organics as well as inorganic in an integrated manner is essential to address the twin concerns of nutrient excess and nutrient depletion. Integrated nutrient management (INM) aims to improve soil health and sustain high level of productivity and production. Organic supply of nutrients at the peak period of absorption also provide micro nutrients and modify soil-physical behaviour as well as increase the efficiency of applied nutrients. The combined use of organic and inorganic fertilizers has been reported not only to meet the nutrients need of the crop but also has been found to sustain large scale productivity goals. Limited studies have been conducted to work out the effect of combined use of inorganic fertilizers and organics (FYM, vermicompost and pressmud) on rice in eastern Uttar Pradesh. Therefore, the present investigation was conducted to evaluate the effect of chemical fertilizer and organics on crop growth, yield, nutrient uptake and efficiency of major nutrients by rice in alluvial soil of Varanasi.

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MATERIALS AND METHODS

The field experiment was conducted at Agricultural Research Farm, Banaras Hindu University, Varanasi (located between 25.14^0 to 25.33^0 N latitude and 82.56^0 to 83.03^0 E longitudes) during *kharif* season of 2013 using paddy as test crop. The mean ambient temperature and relative humidity during the experiment ranged from 17.3 ^{0}C to 34.8 ^{0}C and 75% to 86%, respectively. The soil of the experimental site was sandy clay loam in texture, moderately alkaline in reaction (pH 8.4) and had 3.9 g kg^{-1} organic carbon, nitrogen 205.7 kg ha^{-1}, phosphorus 29.4 kg ha^{-1} and potassium 184.7 kg ha^{-1}. The experiment was carried out in a randomized block design with three replications. The treatments consisted of *viz.,* T_1- control, T_2- 100% RDF (120:60:60), T_3- 70% RDF + 30% N as FYM, T_4- 70% RDF + 30% N as vermicompost (VC), T_5- 70% RDF + 30% N as pressmud (PM), T_6- 70% RDF + 15% N as FYM+15% as VC, T_7 - 70% RDF + 15% N as VC+15% as PM, T_8 - 70% RDF + 15% N as FYM+15% as PM, T_9 - 70% RDF + 10% N as FYM+10% as PM+10% as VC. The FYM (22.8% carbon, 0.78% N, 0.36% P, 0.50% K and 0.18% S with C:N ratio 29.2:1) vermicompost (31.3% carbon, 1.41% N, 0.43% P, 0.63% K and 0.42% S with C:N ratio 22.2:1 and press mud (35.0% carbon, 2.0% N, 1.78% P, 0.42% K and 2.28% S with C:N ratio 17.5:1) were applied before 15 days of transplanting. The urea, diammonium phosphate and muriate of potash were used as source of nitrogen, phosphorus and potassium, respectively. The rice (*var.* HUR 105) was transplanted in third week of July. Full dose of phosphorus and potassium and half dose of nitrogen were applied as basal at the time of sowing and the remaining half of nitrogen in two splits each at tillering and milking stage. Observations were recorded on plant height, tillers, chlorophyll content (SPAD value) at different growth stages and grains panicle^{-1}, test weight were recorded at maturity of crop. The grain and straw yields were recorded at harvest. The N content in grain and straw samples was determined by Kjeldahl method (Jackson, 1973). The grain and straw samples were wet digested with nitric acid and perchloric acid and P in digest was determined by vanadate phosphomolybdate yellow colour method, K by flame photometer, S by turbidimetric method and micronutrients by using atomic absorption spectrophotometer. The nutrient uptake was calculated by multiplying the nutrient concentration values with the grain and straw. Nutrient use efficiency and agronomic efficiency was calculated as described by Fageria *et al.* (2010).

RESULTS AND DISCUSSION

Growth and yield attributes

The growth and yield attributes of rice significantly influenced by the integrated N management modules (Table 1). At 30 days after transplanting (DAT) tallest plants (55.9 cm) and higher tillers/meter row (41.2) were recorded with 100% NPK fertilizers. This may be due to immediate nutrient releasing capacity of fertilizers as compared to organics.

Table 1: Effect of conjoint use of organics and fertilizers on growth and yield parameters of rice

Treatments	Plant height (cm)			Tillers m^{-1} row			Chlorophyll (SPAD value) 60 DAT	Grains panicle^{-1}	Yield (t ha^{-1})		Test weight (g)
	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT			Grain	Straw	
T_1	46.2c	68.1e	88.4e	35.6bcd	44.6f	50.7d	33.5b	84.4f	2.74d	5.13d	20.6c
T_2	55.9a	85.5c	111.8cd	41.2a	55.6de	60.5cd	40.0a	97.5de	4.13bc	6.63abc	21.3bc
T_3	48.4bc	77.7d	105.7d	34.3cd	51.2ef	55.7d	37.8a	91.9ef	3.83c	6.50bc	22.1bc
T_4	46.9c	85.1c	105.7d	33.5d	53.5e	58.1cd	37.9a	94.5def	3.98bc	6.48c	21.5b
T_5	52.3abc	91.7bc	119.6abc	38.6abcd	61.7bcd	70.6ab	38.8a	104.7cd	4.34abc	6.84abc	22.4a
T_6	51.1abc	88.7c	114.2bc	35.1cd	58.8cde	65.5bc	38.7a	100.0de	4.16bc	6.66abc	22.3a
T_7	55.3ab	97.8ab	120.9ab	39.6abc	67.8ab	74.9a	39.3a	117.8ab	4.69a	7.19ab	22.7a
T_8	55.3ab	102.9a	122.9a	40.6ab	72.9a	77.5a	39.7a	123.1a	4.79a	7.28a	23.0a
T_9	54.9ab	96.1b	120.5ab	39.3abc	66.1abc	74.1a	39.1a	111.6bc	4.42bc	6.92abc	22.4a

Means followed by same letter in each column are not significantly different by the Tukey HSD test (P<0.05). Abbreviation: DAT- days after transplanting

T_1- Control, T_2- 100% RDF, T_3- 70% RDF + 30% N as FYM, T_4- 70% RDF + 30% N as VC, T_5- 70% RDF + 30% N as PM, T_6- 70% RDF + 15% N as FYM+15% as VC, T_7 - 70% RDF + 15% N as VC+15% as PM, T_8 - 70% RDF + 15% N as FYM+15% as PM, T_9 - 70% RDF + 10% N as FYM+10% as PM+10% as VC.

The significantly higher chlorophyll (40 SPAD) content at 60 DAT was also recorded with 100% RDF. However, at 90 DAT maximum plant heights (122.9 cm), higher tillers (77.5 m^{-1} row) were recorded with 70% RDF + 15% N as FYM + 15% as pressmud. The maximum test weight (23.0 g), grains/panicle (123.1) were recorded with the 70% RDF + 15% N as FYM+15% as PM. Higher growth and yield attributes of rice obtained with the application of integrated nutrients was mainly due to their positive effect on various yield contributing characters (Sharma *et al.,* 2014). Sultana *et al.* (2015) also found significant and consistent increase in growth and yield attributes with combined application of organic and mineral fertilizers.

Yield

Highest grain (4.78 t ha^{-1}) and straw (7.28 t ha^{-1}) yields were recorded with the 70% RDF + 15% N as FYM+15% as PM. The application of 70% RDF + 30% N by pressmud recorded relatively higher grain (4.34 t ha^{-1}) and straw (6.84 t ha^{-1}) yield as compared to 70% RDF + 30% N as vermicompost (3.98 and 6.48 t ha^{-1}) and 70% RDF + 30% N as FYM (3.83 and 6.50 t ha^{-1}). It may be due to quickly release of nutrients from pressmud resulting higher yield of rice. The treatment 70% RDF + 15% N as FYM+15% as PM gave 16.0 and 9.8% higher grain and straw yield, respectively over 100% RDF. Application of FYM and pressmud alongwith 70% NPK resulted in maximum growth and yield that establishes the fact of synchrony between availability of nitrogen at critical stages of crop as well as other benefits derived from FYM and pressmud. Further, application of FYM adds and exploits the fixed nutrients of soil in available form and regulates its supply to the crop through mineralization and prevents them from leaching and other losses (Rasool *et al.,* 2015) on other hand pressmud is quick release nutrients as compared to FYM (Singh *et al.,* 2015) and combination of both with fertilizers provide adequate nutrients to crops during entire growth period and results higher grain yield. Also, oxidation of S present in pressmud was expected to affect an ameliorating action on soil to provide beneficial effect on releasing of native nutrients by shifting soil pH towards neutrality (Sultana *et al.,* 2015).

Table 2: Effect of conjoint use of organics and fertilizers on nutrients uptake (kg ha^{-1}) by rice

Treatments	Nitrogen		Phosphorus		Potassium		Sulphur	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
T_1	25.0f	18.2f	5.9e	5.6f	5.9e	49.7d	6.5e	10.2c
T_2	45.3cde	29.6de	12.1c	11.5d	12.1bcd	76.2abc	10.9d	16.1b
T_3	40.3e	28.0e	9.3d	9.5e	10.5d	70.7c	10.5d	16.2b
T_4	41.8de	27.8e	11.7cd	9.7e	11.8cd	72.7bc	12.1cd	18.2b
T_5	49.7bcd	32.8bcd	13.6abc	15.1b	12.0cd	75.0bc	15.5ab	27.0a
T_6	47.3bcde	31.5cd	12.6bc	12.6cd	14.9ab	82.3ab	12.7bcd	18.9b
T_7	55.2ab	35.7ab	15.2ab	15.8ab	15.0a	83.8ab	16.1a	27.1a
T_8	58.9a	37.9a	16.4a	16.9a	16.0a	86.9a	16.4a	27.1a
T_9	51.5abc	34.2bc	13.9abc	14.3bc	14.5abc	80.8abc	14.3bcd	24.5a

Means followed by same letter in each column are not significantly different by the Tukey HSD test (P<0.05)

Nutrient uptake

Application of 100% RDF recorded significantly higher nutrient uptake by rice over control. However, nutrients uptake further increased when organics (FYM, pressmud and vermicompost) were applied as 30% nitrogen basis. The N uptake by grain and straw (Table 2) was significantly affected by various treatments and varied between 25.9 and 58.9 kg ha^{-1} in grain and 18.2 and 37.9 kg ha^{-1} in straw. The significantly higher N uptake was noticed in 70% RDF + 15% N as FYM+15% as PM followed by 70% RDF + 15% N as VC + 15% as PM (55.2 and 35.7 kg ha^{-1} by grain and straw, respectively). Significantly highest plant accumulation of P (16.4 and 16.9 kg ha^{-1}), K (16.0 and 86.9 kg ha^{-1}) and S (16.4 and 27.1 kg ha^{-1}) in grain and straw were observed with application of 70% RDF + 15% N as FYM+15% as PM. Application of 100% RDF observed 26.2, 24.4 and 33.5% lesser P, K and S uptake by grain, respectively as compared to 70% RDF + 15% N as FYM+15% as PM. Chandel *et al.* (2014) reported that application of organic manure gave highest N, P, K and S uptake by wheat and maize. The Fe, Cu, Mn and Zn uptake by grain and straw (Table 3) also

significantly higher with application of 70% RDF + 15% N as FYM+15% as PM. The maximum uptake of Fe (244 and 1566.6 g ha^{-1}), Cu (35.8 and 118.3 g ha^{-1}) and Mn (71.4 and 388.4 g ha^{-1}) by grain and straw were recorded with 70% RDF + 15% N as FYM+15% as PM. The minimum value of Fe (84 and 786.6 g ha^{-1}), Cu (10 and 33.1g ha^{-1}), Mn (23.4 and 120.6 g ha^{-1}) and Zn (34.5 and 52.8 g ha^{-1}) were recorded with control. The 100% RDF removed significantly lower micronutrient as compared to 70% RDF + 15% N as FYM+15% as PM. As application of organics improve physical environment of soil and helped in nutrient translocation and absorption from the soil and organics itself have a good source of nutrients for the crop. Higher nutrient uptake by rice was observed with combined application of FYM or pressmud with the 100% recommended NP which helped the plants to synthesize maximum dry matter production and nutrients concentration in rice (Kumar *et al.,* 2012). Srivatsava *et al.* (2015) reported similar result for pearl millet and wheat under semi-arid *Inceptisols* and Shukla *et al.* (2016) for rice with combined application of FYM, pressmud and mineral fertilizers.

Table 3: Effect of conjoint use of organics and fertilizers on micronutrient uptake (g ha^{-1}) by rice

Treatments	Iron		Copper		Manganese		Zinc	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
T_1	84.0e	786.6e	10.0g	33.1e	23.4e	120.6f	34.5e	52.8f
T_2	131.4d	1152.6cd	16.3f	51.4d	39.3d	210.6e	68.0d	105.0e
T_3	217.0ab	1412.8ab	21.9de	59.6d	44.9d	261.0cde	113.8abc	177.7a
T_4	164.3cd	1145.1d	19.1ef	58.0d	38.1d	229.9de	119.7ab	183.9a
T_5	198.7bc	1242.6bcd	28.2bc	80.2bc	56.5bc	288.2bcd	94.0c	129.5d
T_6	202.0bc	1265.8bcd	25.0cd	62.6cd	49.2cd	277.9bcd	122.9ab	175.0ab
T_7	226.8ab	1345.3abcd	32.4ab	86.9b	61.7ab	311.8bc	118.1abc	157.6bc
T_8	244.0a	1566.6a	35.8a	118.3a	71.4a	388.4a	137.0a	181.5a
T_9	225.2ab	1389.3abc	32.3ab	111.0a	66.0ab	327.2b	103.1bc	139.4cd

Means followed by same letter in each column are not significantly different by the Tukey HSD test (P<0.05)

Efficiency indices

Nutrient supply through integration of both organic and chemical sources tended to increase the nutrient use efficiency and agronomic efficiency as compared to those of supplying nutrients through only chemical fertilizers. Nutrient use efficiency and agronomic efficiency of N, P and K were found higher with integrated use of organics with inorganic fertilizers (Table 4). Highest nitrogen use efficiency (44.6 %) was recorded in 70% RDF + 15% N as FYM + 15% as PM closely followed by 39.7% in 70% RDF + 15% N as VC + 15% as PM. The maximum values of P and K use efficiencies were 36.4 and 78.7% with 70% RDF + 15% N as FYM + 15% as PM. The sole application of 100% RDF recorded significantly lowest N (26.5%), P (20.3%) and K (54.5%) recovery. Similarly, the agronomic efficiency of nitrogen (17.0 kg kg^{-1}), phosphorus (30.7 kg kg^{-1}) and potassium (36.5 kg kg^{-1}) was recorded with 70% RDF + 15% N as FYM + 15% as PM amended plot followed by 16.2, 30.6 and 36.1 kg grain kg^{-1} application of NPK with 70% RDF + 15% N as FYM + 15% as PM. This might be due to balanced supply of plant nutrients through both organic manures and chemical sources.

Table 4: Effect of conjoint use of organics and fertilizers on nutrient use efficiency (%) and agronomic efficiency of nutrients (kg grain kg N^{-1}) in rice

Treatments	NUE	PUE	KUE	AE_N	AE_P	AE_K
T_1	-	-	-	-	-	-
T_2	26.5def	20.3de	54.5ab	9.1c	18.2c	18.2c
T_3	20.9f	12.3f	42.6b	11.6bc	23.8abc	21.4bc
T_4	22.0ef	16.5ef	48.0b	10.3bc	23.3abc	21.3bc
T_5	32.8bcd	28.7bc	52.2ab	13.3abc	21.6bc	32.3a
T_6	29.7cde	23.0cd	69.2ab	11.8bc	25.3abc	23.0bc
T_7	39.7ab	32.5ab	71.9ab	16.2a	30.6a	36.1a
T_8	44.6a	36.4a	78.7a	17.0a	30.7a	35.5a
T_9	35.4bc	27.9bc	66.0ab	14.0ab	27.2ab	29.2ab

Means followed by same letter in each column are not significantly different by the Tukey HSD test (P<0.05)

Application of organic manures stimulates nutrient uptake and ultimately influenced the nutrient efficiency and agronomic efficiency due to consistent supply of nutrients with better physical condition of soil (Salam *et al.,* 2014). Abbreviation: NUE, PUE and KUE is N, P and K use efficiency, respectively; AE_N, AE_P and AE_K agronomic efficiency of N, P and K, respectively (kg grain yield per kg nutrient application)

It may be concluded from the present study that application of 70% RDF + 15% N as FYM + 15% as PM is most contributive for improving the nutrients uptake and productivity of rice. Application of 70% RDF + 15% N as FYM + 15% as PM also helped in improving the nutrient use e□ciency and agronomic efficiency of rice. The results clearly indicated the need of integrated use of 70% RDF + 15% N as FYM + 15% as PM to meet the nutrient requirement of rice for sustaining the high productivity.

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