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Long-term effect of integrated nutrient management on yield and nutrients uptake by rice (O*ryza sativa*) in acid soil

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ABSTRACT

Long-term field experiment on rice commenced in *kharif* 2006 at Instructional-cum-Research farm of the Assam Agricultural University, Jorhat with integrated nutrient management practices for assessing its impact on yield and nutrient uptake by rice in acid soil. The treatments consisted of T_1, absolute control; T_2,100% recommended doses (RD) of inorganic NPK; T_3, 50% RD of inorganic NP + 100% K + biofertilizers; T_4, 50% RD of inorganic NP + 100% K + enriched compost @ 1 tonne/ha; and T_5, 25% RD of inorganic NP + 100% K + enriched compost @ 2 tonnes/ha. Results revealed that after 10 years of experiment, grain yield of rice (4.43 t/ha) increased significantly with 100% NPK by 10.8 and 78.6 % over 50% NP+100% K+ bio-fertilizers and control, respectively and it was at par with 25% NP + 100% K+ enriched compost @ 2 t/ha (4.38 t/ha). Whereas, the maximum straw yield (5.18 t/ha) was recorded with 25% NP + 100% K+ enriched compost @ 2 t/ha which was higher significantly over 50% NP and 100% K+ bio-fertilizers (4.63 t/ha) and control (3.08 t/ha), respectively and total nutrient uptake, i.e. N, P, K, Zn, Cu and Ni by rice was significantly higher in 25% RD of inorganic NP + 100% K + enriched compost @ 2 tonnes/ha treatment as compared to recommended dose of fertilizer (100% NPK) in acid soil but total aluminium uptake by rice significantly decreased with the application of reduced doses of NP along with higher dose of enriched compost (2 t/ha). Therefore, aluminium toxicity level in rice plant under acidic condition could be reduced through enriched compost application.

Key words: Acid soil, Aluminium, INM, Nutrients uptake, Rice, Yield

Rice (*Oryza sativa* L.) is the staple food for more than half of the world population and it provides 21% and 15% per capita of dietary energy and protein, respectively (Maclean *et al.* 2002). Rice is one of the most important cereal food crops of India in terms of area, production and consumer preference. India is also the second largest producer and consumer of rice in the world. In India, rice accounts for more than 40% of food-grain production, providing direct employment to 70% people in rural areas. Our national food security hinges on the growth and stability of rice production. Rice is grown in 44.6 million ha under 4 major ecosystems: irrigated, rainfed lowland, rainfed upland and flood prone. More than half of rice area (55%) is rainfed and distribution-wise 80% of rainfed rice area is in eastern India, making its cultivation vulnerable to vagaries of monsoon. At present, lowland rice occupies about 39% of the total cropped area of Asom (Adhya *et al.* 2008). Integrated nutrient management is one of the most important components of the production technology to sustain soil fertility and crop productivity. The combined use of organic and inorganic sources of plant nutrients not only pushed the production and profitability of field crops but also helped in maintaining the fertility status of the soil (Chandrasoorian *et al*. 1994). The advantage of combined use of organic and inorganic sources of nutrients as integrated nutrient management has been proved superior to the use of each component separately (Palaniappan and Annadurai 2007). Though, the fertilizers have played a prominent role in increasing the productivity of crops in the country, but continuous imbalanced use of fertilizers caused deterioration of soil health. Organic manures improve soil physical, chemical and biological properties and thus enhance crop productivity *vis-à-vis* maintain soil health. In addition to this, the organic manures help in improving the use efficiency of inorganic fertilizers (Singh and Biswas 2000). The supply of essential micronutrients through organic manures also improved plant metabolic activities especially in the early vigorous growth of plant (Anburani and Manivannan 2002). So, long term field experiments are crucially important for understanding dynamic interactions

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between soil, nutrient and crop management practices and provide one of the few means for evaluating sustainable agricultural management systems and better prediction of the sustainable future (Poulton 1995, Rasmussen *et al*. 1998 and Girma *et al*. 2007). Therefore, this study was conducted with an objective to find out the impact of enriched compost and bio-fertilizers along with inorganic fertilizer on yield and nutrients uptake by rice in acidic soil.

MATERIALS AND METHODS

The experiment was initiated during rainy season since, 2006 using rice as test crop under the long-term integrated nutrient management at Instructional-cum-Research (ICR) farm of the Assam Agricultural University, Jorhat, located at latitude 26°43'N and longitude 94°11'E. Experiment was conducted in a randomised block design with five fertiliser treatments and four replicates (plot size 8 m × 5 m, with 1 m buffer zone between treatments). Based on the package of practices recommended by Assam Agricultural University and State Agriculture Department, Asom, India (2006), inorganic fertilisers @ 40 kg N/ha, 20 kg P/ha and 20 kg K/ha for rice fields, considered to be 100% of the recommended doses (RD) were applied. The different treatments were as T_1, absolute control; T_2, 100% RD of inorganic NPK; T_3, 50% RD of inorganic NP + 100% K + bio-fertilizers; T_4, 50% RD of inorganic NP + 100% K + 1 tonne enriched compost/ha; and T_5, 25% RD of inorganic NP + 100% K + 2 tonnes enriched compost/ha. The research farm has a typical subtropical climate. Experimental soil was Inceptisol with clay loam in texture (28.6% clay) and is classified as an Aeric Endoaquept (Dutta and Karmakar 1995), with dominant Kaolintic minerals. The variety Ranjit rice was transplanted on the second week of July with a row spacing of 20 × 20 cm.

Crops were harvested at maturity and grain and straw yields were recorded. The grain and straw samples were dried in oven at 65± 2°C for 72 h. The oven dried plant samples were then ground in a Wiley mill. Nitrogen content in grain and straw samples was determined by micro-Kjeldahl method (Jackson 1973). For estimation of P content, ground grain and straw samples were digested with di-acid mixture (HNO_3:$HClO_4$ in 3:1 ratio) and P content in the acid digest was estimated by vanadomolybdo yellow colour method (Jackson 1973) by a spectrophotometer. Potassium, Zn, Cu, Fe and Mn, Ni and Al in acid digest were determined using ICP-MS (Jackson 1967). The uptake of nutrients was obtained as product of their concentrations and yield.

RESULTS AND DISCUSSION

Yield

Grain, straw and biological yields of rice responded significantly to integrated nutrient management practices (Table 1). Maximum grain, straw and biological yields of rice were recorded (4.38, 5.18 and 9.55 t/ha, respectively) with the application of 25% NP + 100% K+ enriched compost @ 2 t/ha. Application of enriched compost @ 2 t/ha along with 25% NP + 100% K increased the grain, straw and biological yields by 76.6%, 68.2% and 71.8%, respectively over control. Grain yield of rice (4.0 t/ha) was recorded with application of bio-fertilizer along with 50% RD of inorganic NP + 100% K, which was statistically at par with other integrated nutrient management practices. Whereas application of enriched compost (2 t/ha) + 25% RD of inorganic NP + 100% K and enriched compost @ 1 t/ha + 50% RD of inorganic NP + 100% K were recorded statistically at par in respect of grain, straw and biological yields of rice, which was statistically at par with 100% RDF. Singhal *et al.* (2012) reported that inoculation of bio-fertilizers in combination with limited dose of phosphorus produced higher and sustainable yields of maize and wheat crops and maintained soil health. In another study, Sharma *et al.* (2015) and Sharma *et al.*(2016) also recorded significantly higher grain yields of pearl-millet and wheat under balanced integrated nutrient management based on STCR fertilizer recommendations using fertilizer adjustment equations. The possible reason behind the higher yield of rice in acid soil might be due to positive effects of organic matter added through enriched compost on soil health, irrespective of supplying the macronutrients, microbial activity and higher supply of secondary and micronutrients as compared to control.

Table 1 Effect of manuring and fertilization on grain, straw and biological yields (t/ha) of rice

Treatment	Grain yield	Straw yield	Biological yield
Control	2.48^{C}	3.08^{C}	5.56^{C}
100% RDF of NPK	4.43^{A}	5.03^{AB}	9.46^{AB}
50% RDF of NP + 100% K + Bio-fertilizers	4.00^{B}	4.63^{B}	8.63^{B}
50% RDF of NP + 100% K + Enriched compost @ 1 t/ha	4.30^{AB}	5.10^{A}	9.40^{AB}
25% RDF of NP + 100% K + Enriched compost @ 2 t/ha	4.38^{AB}	5.18^{A}	9.55^{A}
SEm (±)	0.19	0.22	0.40
CD (P=0.05)	0.41	0.47	0.88

Uptake of nutrients

Major nutrients: Uptake of N, P and K by rice crops influenced by integrated use of organic sources and chemical fertilizer (Table 2). The N uptake by grain and straw by rice ranged from 48.6 to 95.0 kg/ha and 20.7 to 47.2 kg/ha, respectively. It was significantly higher with 25% NP + 100% K + enriched compost @ 2 t/ha and the increase was 95.5% and 128% in grain and straw, respectively over control. Total nitrogen uptake (142 kg/ha) by rice crop was recorded significantly higher with 25% RD of inorganic NP + 100% K + 2 tonnes enriched compost/ha over rest of the treatment except 50% RD of inorganic NP + 100% K + enriched compost @ 1 tonne/ha (T_4). Increase in total nitrogen uptake by rice might be due

Table 2 Effect of manuring and fertilization on major nutrients uptake (kg/ha) in grain and straw of rice

Treatment	Nitrogen			Phosphorus			Potassium		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
Control	48.6^{C}	20.7^{D}	69.3^{D}	5.70^{C}	1.11^{C}	6.80^{C}	6.73^{B}	48.9^{C}	55.6^{C}
100% NPK	89.3^{A}	40.2^{B}	130^{B}	17.5^{B}	2.88^{B}	20.4^{B}	13.8^{A}	94.1^{AB}	108^{AB}
50% NP + 100% K + bio-fertilizers	79.4^{B}	35.0^{C}	114^{C}	16.6^{B}	3.58^{B}	20.2^{B}	13.9^{A}	84.1^{B}	98.0^{B}
50% NP + 100% K + enriched compost @ 1 t/ha	89.5^{A}	43.0^{AB}	133^{AB}	18.8^{AB}	3.16^{B}	21.9^{B}	14.9^{A}	99.5^{AB}	114^{AB}
25% NP + 100% K + enriched compost @ 2 t/ha	95.0^{A}	47.2^{A}	142^{A}	21.8^{A}	5.39^{A}	27.2^{A}	15.7^{A}	105^{A}	121^{A}
SEm (±)	2.00	1.10	2.87	0.82	0.27	0.93	0.90	4.14	4.37
CD (P=0.05)	6.17	3.40	8.83	2.53	0.84	2.86	2.78	12.8	13.5

Table 3 Effect of manuring and fertilization on Zn, Fe and Cu uptake (g/ha) in grain and straw of rice

Treatment	Zn			Fe			Cu		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
Control	61.7^{B}	93.3^{C}	155^{C}	25.3^{B}	1088^{B}	1114^{B}	4.48^{B}	12.5^{C}	17.0^{C}
100% NPK	121^{A}	191^{B}	311^{B}	63.2^{A}	1835^{A}	1898^{A}	9.68^{A}	26.0^{B}	35.7^{B}
50% NP + 100% K + bio-fertilizers	105^{AB}	197^{B}	302^{B}	61.8^{A}	1719^{A}	1781^{A}	9.03^{A}	27.4^{B}	36.4^{B}
50% NP + 100% K + enriched compost @ 1 t/ha	125^{A}	237^{AB}	362^{AB}	68.8^{A}	1912^{A}	1981^{A}	10.1^{A}	32.5^{A}	42.6^{A}
25% NP + 100% K + enriched compost @ 2 t/ha	136^{A}	276^{A}	412^{A}	72.6^{A}	1992^{A}	2065^{A}	10.9^{A}	36.2^{A}	47.1^{A}
SEm (±)	10.3	16.1	15.7	2.98	101	103	0.48	1.18	1.25
CD (P=0.05)	31.6	49.7	48.2	9.18	312	318	1.46	3.65	3.86

Table 4 Effect of manuring and fertilization on Mn, Ni and Al uptake (g/ha) in gain and straw of rice

Treatment	Mn			Ni			Al		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
Control	33.3^{C}	318^{C}	351^{C}	0.63^{C}	3.13^{B}	3.76^{C}	13.1^{B}	190^{B}	203^{B}
100% NPK	71.6^{B}	613^{AB}	684^{AB}	1.40^{B}	5.59^{A}	6.9^{9B}	20.5^{A}	264^{A}	285^{A}
50% NP + 100% K + bio-fertilizers	69.1^{B}	584^{B}	653^{B}	1.39^{B}	5.41^{A}	6.81^{B}	15.7^{AB}	213^{AB}	229^{AB}
50% NP + 100% K + enriched compost @ 1 t/ha	79.2^{AB}	669^{AB}	748^{AB}	1.68^{AB}	6.18^{A}	7.86^{AB}	13.7^{B}	210^{AB}	224^{AB}
25% NP + 100% K + enriched compost @ 2 t/ha	84.7^{A}	720^{A}	805^{A}	1.92^{A}	6.55^{A}	8.47^{A}	10.4^{B}	201^{B}	212^{B}
SEm (±)	3.02	28.4	30.4	0.09	0.29	0.30	1.43	14.3	14.9
CD (P=0.05)	9.32	87.6	93.8	0.28	0.88	0.95	4.39	44.0	46.1

to positive inter-relationship between nutrients with enriched compost which exerted beneficial effects in the release of ammonical and nitrate nitrogen. Similar result was recorded with the addition of nitrogenous fertilizer along with FYM which helps in narrowing of C:N ratio and thus, increased mineralization resulting in rapid conversion of organically bound N to inorganic forms and increase N uptake by plant (Singh *et al*. 2006). Phosphorus uptake by grain and straw of rice ranged between 5.70 to 21.8 kg/ha and 1.11 to 5.39 kg/ha, respectively. Phosphorus uptake by rice also followed the similar trend as of N. Phosphorus uptake by rice plant increased by 282% in grain and 386% in straw over control as a result of 2 tonnes enriched compost/ha with 75% reduced doses of NP (25% NP + 100% K). This might be due to the formation of various organic acids during decomposition of organic matter which increased the solubility of inert rock phosphate and ultimately release of inorganic P in soil (Babana and Antoun 2006). Chelation of H^{+} or Al^{3+} ions by organic acids is the main reason behind releasing of P (Reyes *et al*. 2006). Total K uptake by rice ranged from 55.6 kg/ha in control to 121 kg/ha in 25% NP + 100% K + enriched compost @ 2 t/ha treatment. The total K uptake by rice was significantly higher with 25% RD of inorganic NP + 100% K + 2 tonnes enriched compost/ha as compared to bio-fertilizer along with reduced dose of NP treatment and control but it was statistically at par with 100% recommended dose of NPK and enriched compost @1 t/ha along with 50% reduced dose of NP treatments. Potassium uptake by rice grain was observed statistically at par when recommended dose of fertilizer alone or reduced dose of NP along with enriched compost.

Micronutrients: Application of 25% NP + 100% K + enriched compost @ 2 t/ha increased, Zn uptake by rice grain and straw ranged from 61.7 to 136 g/ha in grain and 93.3 to

276 g/ha in straw, which were 120% and 196% higher over control respectively. All the integrated nutrient management practices considerably increased Zn uptake by grain and straw. Maximum iron uptake by rice grain (72.6 g/ha) was recorded with 25% NP + 100% K + enriched compost @ 2 t/ha treatment which was higher by 181% over control and 14.8% over 100% NPK treatment. Iron uptake by straw increased significantly with all the organic amendment treatments and the increase ranged from 83.1% (25% NP + 100% K + enriched compost @ 2 t/ha) to 58.0% (50% NP + 100% K + bio-fertilizers). Application of enriched compost @ 2 t/ha with 25% NP + 100% K noticed maximum Cu uptake in grain (10.9 g/ha) and straw (36.2 g/ha) which were 143% and 190% higher, respectively over control. Application of any kind of fertilizer and manure did not make any difference in Cu uptake by rice grain. Manganese and nickel uptake by rice grain and straw increased effectively due to enriched compost @1 tonne or 2 tonnes/ha along with reduced dose of NP over recommended dose of fertilizer. Application of 25% NP + 100% K + enriched compost @ 2 t/ha increased Mn uptake by 154% and 126% in grain and straw, respectively over control. Whereas 50% NP + 100% K + enriched compost @ 1 t/ha application increased Mn uptake by 138% and 110% by grain and straw, respectively over control. Singhal *et al.* (2012) also reported the higher uptake of micronutrients, i.e. Zn, Fe, Mn and Cu by maize grain with the application of enriched compost with reduced dose of nitrogen. The highest uptake of micronutrients due to application of enriched compost @ 2 t/ha with 75% reduced dose of nitrogen might be attributed to production of various organic acids of low molecular weight such as succinic, citric, malic, oxalic and acetic acids in addition to the release of N and micronutrient cations. These organic acids form complexes with micronutrient cations and remain in soluble form thus prevent these elements from precipitation, fixation, oxidation and leaching (Kumar *et al.* 1993). Nickel uptake by rice grain increased by 205% and 167% with 25% NP + 100% K + enriched compost @ 2 t/ha and 50% NP + 100% K + enriched compost @ 1 t/ha treatment, respectively. In straw, Ni uptake increased by 109% and 97.4% with 2 t/ha and 1 t/ha enriched compost, respectively, with reduced doses of NP over control. Aluminium uptake by grain and straw of rice reduced effectively due to the application of enriched compost and bio-fertilizer along with reduced dose of NP. Aluminium uptake decreased by 97.1% and 31.3% in grain and straw, respectively under 25% NP + 100% K + enriched compost @ 2 t/ha treatment over 100% NPK recommended dose. Besides, the compost being the rich source of macronutrient and micronutrients are also capable of producing ligands which increase micronutrient availability to plants by reducing sorption to the clay minerals (Madrid 1999). Furthermore, addition of organic matter to soil alters the soil reactions which in turn increase the metal solubility and availability. Aluminium content in plant decreases due to decreasing the chelation of exchangeable aluminium with organic matter in integrated nutrient management treatments.

From the present study, it can be concluded that application of enriched compost @ 2 t/ha and bio-fertilizers along with reduced dose of NP had significant beneficial impact on yield and nutrients uptake by rice grown in acid soils of Asom.

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