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Response of INM in rice in rice–wheat cropping system

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ABSTRACT

A field experiment was carried out at the research farm of C.S. Azad University of Agriculture & Technology, Kanpur, UP during *kharif* of 2013–14 & 2014–15, to study the effect of INM on yield, nutrient contents and uptake of rice. The experiment was conducted with 11 treatments, viz. control, 100% NPK (RDF 120:60:40 kg/ha), 100% NPK + FYM 5 t/ha, 100% NPK + blue green algae (BGA), 100% NPK + FYM + BGA, 100% NPK + 40 kg S/ha, 100% NPK + 5 kg Zn/ha, 100% NPK + 40 kg S/ha + 5 kg Zn/ha, 100% NPK + 40 kg S/ha + 5 kg Zn/ha + 10 kg Fe/ha, 100% NPK + FYM + BGA + 40 kg S/ha + 5 kg Zn/ha + 10 kg Fe/ha and 125% NPK in RBD replicated thrice. Results of this study revealed that among the different INM options significantly highest grain (5.27 t/ha), straw (6.23 t/ha) and biological yield (11.5 t/ha) with harvest index (45.8%) were recorded with 100% NPK + FYM + BGA + 40 kg S/ha + 5 kg Zn/ha + 10 kg Fe/ha. Application of 100% NPK increased grain yield by 100% over control and further addition of FYM at the rate of 5 t/ha increased the yield by 2.75% compared to 100% RDF. The highest protein content, starch content and head rice recovery was recorded with application of 100% NPK + FYM + BGA + 40 kg S/ha + 5 kg Zn/ha + 10 kg Fe/ha.

Key words: Integrated nutrient management, Nutrient uptake, Head rice recovery, Rice quality

The major concerns with the sustainability of rice (*Oryza sativa* L.) under rice–wheat cropping system is yield stagnation (Verma *et al*. 2017), rapidly declining underground water table (Humphreys *et al.* 2010), soil health degradation and environmental pollution. Excessive and indiscriminate use of nitrogenous fertilizers resulted into leaching of nitrates which is responsible for the eutrophication and pollution of ground water. In India rice is being cultivated on an area of 44 million ha with total production of 109.7 million tonnes and average productivity of 2.49 tonnes/ha (FAI, Fertiliser Statistics 2017–18). The rice–wheat cropping system is very critical for food security in South Asia, which occupies approximately 13.5 million ha (m ha) of land, extending across Indo-Gangetic Plains. During last five decades, great emphasis has been given on upgrading the protein content and quantity in these two cereals through genetic manipulations (Saika *et al*. 2011). Besides genetic improvements, agronomic means like adequate plant nutrition management can also achieve these goals to a greater extent by improving the protein content and productivity (Sharma *et al*. 2016).

Integrated nutrient management (INM) system plays a pivotal role in balancing soil fertility and plant nutrient supply to an optimum level through the judicious and efficient use of chemical fertilizers, farmyard manure (FYM), biofertilizers and micronutrients leading to an ecofriendly approach and economically viable solution for this problem (Kumar and Shivay 2010, Yadav *et al.* 2013). Continuous integrated use of organic manures with chemical fertilizers would be quite promising in assessing the sustainability of a cropping system vis-à-vis monitoring the soil properties. In the recent year, concept of integrated plant nutrient supply (IPNS) involving combined used of organic fertilizer and bio-inoculants have been developed. However, so far no research work has been done on IPNS in rice under rice–wheat cropping system in Central Uttar Pradesh, India. Hence, an attempt was made to carry out an experiment to evaluate the effect of INM options on productivity, quality and nutrient uptake of rice under rice–wheat cropping system.

MATERIALS AND METHODS

The field experiment was conducted at crop research farm of C.S. Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh during 2013–14 and 2014–15 rainy season (*kharif*). The soil of experimental field was sandy loam with slightly alkaline having 0.39% of organic carbon (OC), EC of 0.4 dS/m and *p*H of 7.8. It was low in available N (165 kg/ha), P (6.0 kg/ha), S (9.9 kg/ha) and Zn (0.54 mg/kg) and medium in K (191 kg/ha) and Fe (4.7 g/ha). The experiment was conducted consisting of 11 treatments of nutrient management options, viz. control, 100% NPK

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(RDF 120:60:40 kg/ha), 100% NPK + farmyard manure (FYM, 5 t/ha), 100% NPK + blue green algae (BGA), 100% NPK + FYM + BGA, 100% NPK + 40 kg S/ha, 100% NPK + 5 kg Zn/ha, 100% NPK + 40 kg S/ha + 5 kg Zn/ha, 100% NPK + 40 kg S/ha + 5 kg Zn/ha + 10 kg Fe/ha, 100% NPK + FYM + BGA + 40 kg S/ha + 5 kg Zn/ha + 10 kg Fe/ha and 125% NPK in randomized block design replicated thrice. Farmyard manure was applied at the rate of 5 t/ha as per treatments by incorporation into the soil before puddling for transplanting of rice seedlings. Full dose of P_2O_5, K_2O, Zn, S and Fe as per treatment were applied as broadcasting and mixing into soil through di-ammonium phosphate, muriate of potash, zinc sulphate, elemental sulphur, ferrous sulphate, respectively before transplanting at the time of field preparation. The rice crop was transplanted in the month of July during both years. Nitrogen was applied through di-ammonium phosphate and prilled urea. Half of the recommended dose of nitrogen was applied before transplanting and remaining half was top dressed in the two equal splits at tillering and panicle emergence stages through urea. Biofertilizer *Nostoc* species of blue green algae (BGA) was applied @ 16 kg/ha 7 days after rice transplanting in standing water condition through uniform broadcasting as per the treatments. The grain yield was converted into tones/ha at 14% moisture in the grains. Nutrient contents at harvest in the plant samples of rice grain and straw was determined by drying the samples in hot air oven at 60°C±2°C till a constant dry weight was obtained. The total NPK and S, Zn, Fe contents in the rice grain and straw samples were determined as per the standard procedures described by Prasad *et al.* (2006). The total N, P, K, Zn and Fe uptake was computed by multiplying the nutrient contents with the respective plant biomass.

Quality parameters, viz. crude protein content, starch content and head rice recovery were estimated. The crude protein content in the rice grain as influenced by different nutrient management options were estimated by multiplying the nitrogen contents of the respective treatment with a coefficient of 5.95 (Prasad *et al.* 2006). The starch content in grain was estimated as described by McCready and Hassid (1943). The head rice recovery was determined by the technique given by Halick and Kelly (1959) as:

$$\text{Head rice recovery (\%)} = \frac{\text{Weight of whole rice grain}}{\text{Weight of raw rice}} \times 100$$

RESULTS AND DISCUSSION

Productivity of rice: Among different integrated nutrient management options, application of 100% NPK + FYM + BGA + 40 kg S/ha + 5 kg Zn/ha + 10 kg Fe/ha recorded significantly the highest rice grain (5.27 t/ha), straw (6.23 t/ha) and biological yields (11.50 t/ha) with harvest index of 45.8%. The lowest yield and harvest index were recorded with control. Application of 100% NPK almost doubled the grain yield (100.5%) compared to control. Further, by addition of 10 t FYM/ha increased the yield by 6% compared to RDF (120:60:40 kg/ha). However, addition of BGA did not increase the yield significantly compared to 100% NPK and 100% NPK + FYM. Application of 100% NPK + FYM + BGA increased 6.6% higher grain yield compared to RDF (120:60:40 kg/ha). The straw and biological yields of rice varied from 3.05–6.23 and 5.23–11.50 t/ha, respectively (Table 1). All the integrated nutrient management options

Table 1 Effect of integrated nutrient management options on yields, harvest index and quality parameters of rice (mean data of 2 years)

Treatment	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (/ha)	Harvest index (%)	Protein content (%)	Starch content (%)	Head rice recovery (%)
Control	2.18	3.05	5.23	41.6	6.81	67.5	61.0
100% NPK (RDF, 120:60:40 kg NPK/ha)	4.36	5.52	9.88	44.1	7.20	68.5	62.5
100% NPK + FYM (5 t/ha)	4.48	5.70	10.18	44.0	7.70	68.0	62.5
100% NPK + BGA	4.42	5.53	9.95	44.4	7.65	67.5	63.5
100% NPK + FYM + BGA	4.65	5.84	10.49	44.3	7.69	68.5	63.5
100% NPK + 40 kg S/ha	4.42	5.62	10.04	44.0	7.71	67.5	64.5
100% NPK + 5 kg Zn/ha	4.45	5.65	10.10	44.1	7.75	68.5	66.0
100% NPK + 40 kg S/ha + 5 kg Zn/ha	4.49	5.70	10.19	44.1	7.78	68.5	67.5
100% NPK + 40 kg S/ha + 5 kg Zn/ha + 10 kg iron (Fe)/ha	4.48	5.73	10.21	43.9	7.84	69.0	67.5
100% NPK + FYM + BGA + 40 kg S/ha + 5 kg Zn/ha + 10 kg Fe/ha	5.27	6.23	11.50	45.8	8.03	71.0	69.5
125% NPK	4.63	5.85	10.48	44.2	7.99	69.0	68.0
SE(d)	0.21	0.12	0.33	0.01	0.10	0.83	1.20
CD (P=0.05)	0.44	0.25	0.69	0.03	0.24	1.73	2.50

RDF, Recommended dose of fertilizers; FYM, Farmyard manure; BGA, Blue green algae were significantly superior to control. Application of 100% NPK + FYM + BGA increased significantly grain and straw yields as compared to application of 100% NPK, 100% NPK + FYM and 100% NPK + BGA alone. Application of 100% NPK + FYM + BGA + 40 kg S/ha + 5 kg Zn/ha + 10 kg Fe/ha resulted in significant increase in straw yield compared with 100% NPK. Application of 100% NPK + FYM + BGA + 40 kg S/ha + 5 kg Zn/ha + 10 kg Fe/ha and 125% NPK increased two times higher straw and biological yield than control. Application of 100% NPK + FYM + BGA + 40 kg S/ha + 5 kg Zn/ha + 10 kg Fe/ha increased 20.9% grain yield than 100% NPK.

The significant increase in rice grain, straw and biological yields due to the different integrated nutrient management options might be due to balance and synchronized supply of macro and micro nutrients. Application of FYM in conjunction with recommended dose of NPK added a significant amount of NPK in the soil, besides supplying other essential micronutrients to the soil. In association with soil microorganisms, organic manures are known to help in synthesis of certain phytohormones and vitamins which promote the growth and development of crops. Similar results were obtained by Sharma *et al.* (2015) and Verma *et al.* (2017). Addition of FYM, besides its nutritional role might have played significant role in improving the physico-chemical properties of soil specially the moisture retention, aggregate formation, soil aeration and enhanced microbial activity. Since the soil under study was having low in organic carbon, FYM and BGA which might stand as safe guard to this condition. Addition of sulphur and micro nutrients like zinc and iron might have balancing effect besides there important role in metabolic function of plant (Reddy *et al.* 2010).

Quality attributes: Quality analysis of paddy grain revealed that application of 100% NPK + FYM + BGA + 40 kg S/ha + 5 kg Zn/ha + 10 kg Fe/ha gave the highest crude protein content, i.e. 8.03%, starch content 71.0% and head rice recovery 69.5% (Table 1) and it remained statistically on par with 125% NPK. The minimum protein, starch and head rice recovery content were recorded with control. Different nutrient management options showed the possibility of augmented metabolisable nitrogen from organic source and as well as applied chemical nitrogen in the form of fertilizer for its assimilation into amino acids and crude protein. Several investigators have reported the similar results (Premi *et al.* 2003) and it was evident that improvement can be brought out in the food value of the crop due to balance nutrition through organic and inorganic sources of nutrient, which increases the kernel plumpness and reduced husk content thereby increasing the food value of the crop.

NPK and S contents and their uptake by rice: NPK contents in rice grain and straw increased significantly with increased nutrients added through chemical fertilizers in conjunction with FYM and BGA. The highest NPK contents of rice grain and straw was recorded with application 100% NPK + FYM + BGA + 40 kg S/ha + 5 kg Zn/ha + 10 kg Fe/ha followed by 125% NPK (Table 2). The lowest values of NPK contents were recorded in control. K content in straw unlike other nutrients, i.e. N and P was roughly four times higher than that of grain. Further, it was evident that application of FYM, BGA, sulphur, zinc and their combination showed significant increase in NPK concentrations. Total NPK uptake of rice varied from 31.2–88.0, 6.14–23.54 and 37.13–109.2 kg/ha, respectively (Fig 1). Among all integrated nutrient management options application of 100% NPK + FYM + BGA + 40 kg S/ha + 5 kg Zn/ha + 10 kg Fe/ha recorded the highest uptake of NPK followed by 125% NPK. The lowest NPK uptake was observed in control. The total K uptake in grain was observed in the range of 4.23 to 32.9 kg/ha and 19.0 to 90.2 kg/ha in straw and the later (straw) was 4.5 times higher than former (grain).

Partitioning of nitrogen in rice grain and straw was about 76.0% and 24.0% irrespective of different treatments. Hence, it seems that rice grain was the major sink of nitrogen. In general the P uptake in rice grain was 2.5–3.0 times higher compared to straw. These results can be explained on the basis of the fact that grain tissues have much higher protein than that of straw and phosphorus is a component of protein besides its key role in photophosphorylation and energy metabolism. Higher concentration and uptake of potassium was recorded in straw than grain. This might be due to fact that potassium is not known to be constituent of biochemical but is the activator of about 60 enzymes and is

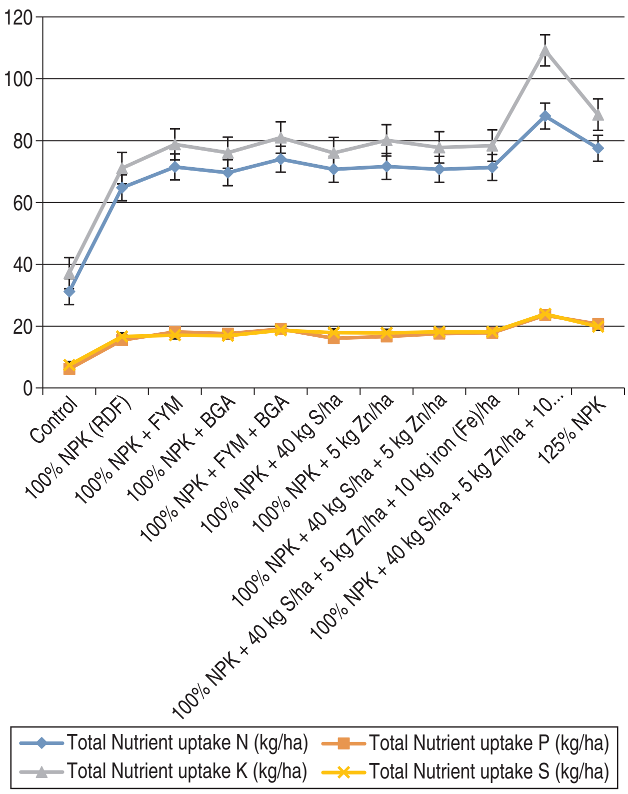

Fig 1 Effect of integrated nutrient management options on total uptake of N, P, K and S by rice crop.

Table 2 Effect of integrated nutrient management options on nutrient contents in rice grain, straw and their uptake (mean data of 2 years)

Treatment	Nutrient content (%)								Nutrient uptake (kg/ha)							
	N		P		K		S		N		P		K		S	
	Grain	Straw	Grain	Grain	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
Control	1.09	0.25	0.20	0.21	0.21	1.08	0.21	0.10	23.7	7.5	4.3	1.8	4.2	32.9	4.33	3.05
100% NPK (RDF, 120:60:40 kg NPK/ha)	1.16	0.26	0.27	0.22	0.22	1.13	0.22	0.11	50.3	14.5	11.6	3.8	12.3	58.8	10.56	6.07
100% NPK + FYM (5 t/ha)	1.24	0.29	0.31	0.22	0.22	1.13	0.22	0.11	55.1	16.4	13.9	4.2	14.5	64.3	11.05	6.00
100% NPK + BGA	1.23	0.28	0.31	0.21	0.21	1.13	0.21	0.11	54.1	15.5	13.6	4.0	14.2	61.9	11.13	5.80
100% NPK + FYM + BGA	1.23	0.29	0.31	0.23	0.23	1.13	0.23	0.11	57.3	16.7	14.6	4.5	15.2	65.8	12.25	6.43
100% NPK + 40 kg S/ha	1.24	0.29	0.27	0.24	0.24	1.13	0.24	0.12	54.6	16.2	12.1	4.0	13.0	63.0	11.20	6.73
100% NPK + 5 kg Zn/ha	1.24	0.29	0.28	0.24	0.24	1.13	0.24	0.12	55.2	16.5	12.4	4.2	13.2	66.9	11.35	6.50
100% NPK + 40 kg S/ha + 5 kg Zn/ha	1.25	0.30	0.29	0.24	0.24	1.13	0.24	0.12	55.9	14.8	13.2	4.4	13.6	64.2	11.35	6.84
100% NPK + 40 kg S/ha + 5 kg Zn/ha + 10 kg Fe/ha	1.25	0.30	0.30	0.24	0.24	1.13	0.24	0.12	56.3	15.0	13.3	4.5	13.7	64.7	11.60	6.59
100% NPK + FYM + BGA + 40 kg S/ha + 5 kg Zn/ha + 10 kg Fe/ha	1.29	0.33	0.34	0.26	0.26	1.15	0.26	0.14	67.9	20.1	17.9	5.6	19.0	90.2	15.50	8.41
125% NPK	1.28	0.32	0.33	0.24	0.24	1.14	0.24	0.12	59.2	18.4	15.5	5.2	16.4	72.0	13.10	6.72
SE(d)	0.53	0.01	0.01	0.01	0.01	0.01	0.01	0.01	2.7	1.26	0.9	0.38	1.1	4.0	0.54	0.51
CD (P=0.05)	0.06	0.02	0.02	0.02	0.02	0.02	0.02	0.02	5.7	2.62	1.8	0.80	2.3	8.4	1.13	1.07

RDF, Recommended dose of fertilizers; FYM, Farmyard manure; BGA, Blue green algae keenly involved in the humification of stem tissues (Pandey *et al.* 2004, Sharma and Vishvakarma 2006). The highest uptake of NPK with application of 100% NPK + FYM + BGA + 40 kg S/ha + 5 kg Zn/ha + 10 kg Fe/ha might be due to the more availability of different types of nutrients, which encouraged the crop growth and finally higher yields. The results of present study are in agreement with those of Reddy *et al.* (2010).

As per the data (Table 2) the concentration of sulphur in rice grain was estimated higher in rice grain than straw under all treatments. Application of 100% NPK + FYM + BGA + 40 kg S/ha + 5 kg Zn/ha + 10 kg Fe/ha recorded significantly the highest sulphur content in rice grain and straw and lowest was recorded with control. The highest sulphur uptake by rice grain and straw was recorded with application of 100% NPK + FYM + BGA + 40 kg S/ha + 5 kg Zn/ha + 10 kg Fe/ha which significantly differed with other treatments. Sulphur content and as well as total uptake was higher in rice grain than straw indicating that rice grains are better sink for sulphur and grain yield can be increased by addition of sulphur. These results are in agreement with those reported by Singh and Ram (2012) and Das *et al.* (2012). Increases in rice biomass due to addition of zinc might be due to its deficiency in experimental soil and also the key role of zinc in the regulation of metabolic functions in chlorophyll synthesis, auxin production and protein metabolism. The above results are corroborated by the report of Das *et al.* (2012) and Singh *et al.* (2011). There was a linear increase in the uptake value of all nutrients with increase fertilizer doses.

From the above study, it can be inferred that INM options through organics and chemical fertilizers not only improved the crop productivity but their judicious use also resulted in enhancement of nutrient contents and their uptake by rice under rice–wheat crop sequence in central Uttar Pradesh. Integrated use of FYM @ 5 t/ha in combination with other organic sources, viz. BGA @ 16 kg/ha in conjunction with 100% recommended dose of N, P, K, S, Zn and Fe in rice exhibited significantly higher yields, nutrient content and their uptake by rice.

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