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Short Communication

Influence of varieties and nutrient management practices on productivity, nutrient acquisition and resource-use efficiency of rice (*Oryza sativa*) in North-eastern hill region of India

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Rice (*Oryza sativa* L.) plays a vital role in food and nutritional security of India especially in north-eastern hill region (NEHR) where ~80% of the total cultivated area is occupied by rice (Das *et al*. 2010). Average rice productivity is relatively low in NEHR due to non-adoption of high yielding varieties (HYVs'), low fertilizer/manure use and poor crop management practices besides poor socio-agro-economic situation of the north-eastern hill farmers who ill-afford recommended agricultural inputs for better crop management (Das *et al*. 2010, Harish *et al*. 2017). Under such situations, use of promising HYVs' and organic matter addition may prove as noble intervention for sustainability of rice production systems in the region. Use of organic manures improves the soil, physico-chemical and microbiological as it has all essential plant nutrients enriching soil fertility (Choudhary and Suri 2009, 2014; Paul *et al*. 2014, 2016, Choudhary and Rahi 2018). Keeping in view above facts, a field experiment was conducted to assess the relative performance of promising rice varieties of NEHR under different nutrient management practices in terms of crop productivity, plant nutrient acquisition and resource-use efficiency in NEHR, India.

The field experiment was conducted during *kharif* 2016 at the Lowland Rice Research Block of the Experimental Farm of ICAR–RC–NEHR, Barapani, Meghalaya, India [Latitude 25°30′ N; Longitude 91°51′ E; Altitude 950 m] in Eastern Himalayas. Meghalaya falls under high rainfall zone with subtropical type of climate. Total rainfall during the growing season i.e. June to November, 2016 was 1622.6 mm. The soil of the experimental site was acidic (pH 4.8), with sandy–clay loam texture, Walkley–Black C (oxidizable–SOC) 2.45%, alkaline $KMnO_4$ oxidizable–N 236 kg/ha, 0.5 M $NaHCO_3$ extractable–P 6.3 kg/ha and 1 N NH_4OAc extractable–K 293.4 kg/ha. Thus, the soil was high in soil organic carbon (SOC), low in available–N and available–P_2O_5 but high in available–K_2O.The experiment consisting of 12 treatment combinations was laid out in split–plot design with 3 replications. The treatments consisted of 4 main–plot treatments, viz. 100% organic through FYM, 100% inorganic [100% recommended dose of fertilizers (RDF)], integrated nutrient management (INM) (50% RDF+ 50% FYM) and absolute control (no fertilizer/FYM). While in sub–plots, three varieties, viz. Shahsarang–1, Lumpnah and Megha SA–2 were transplanted in puddled soil using 30 days old rice seedlings with spacing of 20 cm × 20 cm using 2 seedlings per hill. Mineral N, P and K were applied through urea, single super phosphate and muriate of potash @ 80:60:40 kg N:P_2O_5:K_2O/ha, respectively for inorganic nutrient management. Urea was applied in three split applications (50% as basal + 25% at tillering + 25% at panicle initiation). In organic plots, plant nutrients were applied through FYM using 16 tonnes FYM/ha on oven dry weight basis which supplied 80 kg N/ha and 32 kg P_2O_5/ha because it contained 0.5% N and 0.2% P_2O_5 content on oven dry weight basis while the remaining phosphorus (28 kg) was supplied through rock phosphate (20% P_2O_5) using 140 kg rock phosphate/ha. In integrated nutrient management (INM) plots, plant nutrients were applied through 50% RDF and 50% FYM (8 t FYM/ha) and remaining through rock phosphate using 70 kg rock phosphate/ha. Under INM, urea was again applied in three splits as per the N requirement. The observations on grain yield, NPK nutrient content (%) in rice grains, their uptake (kg/ha) were assessed using standard procedures (Rana

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et al. 2014). An optimal irrigation practice was followed besides rainfall. Continuous submergence of 2-5 cm was maintained from transplanting to maturity in the crop. Two hand–weedings at 20 and 55 days after transplanting (DAT) and one cono–weeding at 35 DAT; were done to manage weeds. The other crop management practices were as per recommendations. After harvesting, threshing, cleaning and drying, the grain yield was recorded at 14% moisture content. Straw yield and harvest index were also worked-out using standard procedures (Rana *et al.* 2014). Production efficiency (PE) in kg/ha/day and monetary efficiency (ME) in ₹/ha/day of each treatment were also computed using standard procedures (Kumar *et al.* 2015). Partial factor productivity (PFP) of applied nutrients, viz. N, P and K through inorganic fertilizers and/or FYM in rice crop was calculated after precise estimations following standard procedures (Rana *et al*. 2014).

The results revealed that rice grain and straw yield were significantly higher in INM practice (4.18 and 6.36 t/ha) followed by inorganic (4.02 and 6.29 t/ha) and organic practice (3.74 and 6.05 t/ha) and least in control treatment (2.26 and 3.90 t/ha), (Table 1). Among rice varieties, the Shahsarang–1 was the highest yielder in terms of grain and straw yield (3.86 and 5.73 t/ha) followed by Lumpnah (3.60 and 5.66 t/ha) and Megha SA–2 (3.19 and 5.56 t/ha), which may be attributed to varietal yield potential (Dass and Chandra 2013). No interaction effect was found for grain and straw yield between different nutrient management practices and rice varieties (Table 1). Better performance of rice varieties under INM practice was probably because of good crop establishment and better anchorage of roots (Choudhary and Suri 2009; Paul *et al*. 2014). Generally, neither sole use of organic manures nor sole use of chemical fertilizers can achieve the crop yield sustainability, thus, their integrated use might have maintained the higher yield levels by supplying primary and secondary micronutrients, and might have enhanced the efficiency of applied nutrients by maintaining favorable soil physico–chemical and microbiological parameters (Choudhary and Suri 2009, 2014; Paul *et al*. 2014, Choudhary and Rahi 2018). the INM practice exhibited higher grain yield over their respective counterparts.

Regarding plant nutrient acquisition, the INM practice exhibited highest NPK concentrations in rice grains and straw followed by inorganic, organic practice and control treatment owing to better crop nutrition (Choudhary and Suri 2009, 2014, Paul *et al*. 2014). The N uptake in rice grains, straw and total N uptake were significantly higher in INM practice followed by inorganic, organic and control treatment. This may be attributed to balanced and continuous N supply to rice crop under INM (Choudhary and Suri 2009, 2014). In case of P and K uptake in rice grains, straw and total uptake, the INM practice again exhibited significantly higher values, and it was followed by organic practice, inorganic practice, and control treatment. Under INM and organic practice, the added organic matter on decomposition and mineralization released P on one hand and also produced

Table 1 Effect of different nutrient management practices and rice varieties on crop productivity and nutrient acquisition in rice crop

Treatment	Grain yield (t/ha)	Straw yield (t/ha)	Nutrient concentrations (%)						Nutrient uptake (kg/ha)								
			N		P		K		N			P			K		
			Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
Nutrient management practices																	
Organic	3.74	6.05	1.24	0.63	0.176	0.109	0.33	0.77	46.5	38.1	84.7	6.5	6.6	13.1	15.6	46.8	62.7
INM*	4.18	6.36	1.32	0.67	0.212	0.124	0.36	0.85	55.3	42.8	98.1	8.9	7.9	16.8	20.7	53.9	74.6
Inorganic	4.02	6.29	1.28	0.65	0.194	0.106	0.34	0.81	51.4	40.8	92.2	4.6	6.6	11.2	14.0	50.8	64.7
Control	2.26	3.90	1.15	0.60	0.092	0.081	0.30	0.70	26.0	23.6	49.6	2.1	3.2	5.3	6.5	27.2	33.7
SEm ±	0.06	0.05	0.03	0.01	0.005	0.004	0.015	0.002	1.3	0.6	1.4	0.2	0.2	0.2	2.7	0.5	2.6
CD (P=0.05)	0.21	0.18	0.08	0.02	0.018	0.015	0.019	0.009	4.6	2.2	4.8	0.5	0.8	0.8	9.2	1.6	9.0
Rice varieties																	
Shahsarang–1	3.86	5.73	1.28	0.65	0.146	0.12	0.34	0.80	50.0	37.5	87.5	5.9	6.8	12.7	15.6	46.1	61.7
Lumpnah	3.60	5.66	1.25	0.64	0.145	0.10	0.33	0.78	45.6	36.5	82.1	5.5	6.0	11.5	14.3	45.2	59.5
Megha SA2	3.19	5.56	1.21	0.62	0.155	0.09	0.33	0.76	38.8	35.1	73.9	5.2	5.5	10.6	12.8	42.7	55.5
SEm ±	0.05	0.02	0.02	0.004	0.008	0.005	0.003	0.004	1.1	0.2	1.2	0.3	0.3	0.5	0.8	0.4	1.0
CD (P=0.05)	0.15	0.06	NS	0.011	NS	0.015	0.009	0.014	3.2	0.7	3.5	NS	1.0	1.4	NS	1.1	2.9

*INM: Integrated nutrient management.

Table 2 Effect of different nutrient management practices and rice varieties on production efficiency and monetary efficiency and partial factor productivity of applied nutrients (NPK) in rice crop

Treatment	Production efficiency (kg/ha/day)	Monetary efficiency (₹/ha/day)	Partial factor productivity (kg/ha/kg of applied nutrients)		
			PFP_N	PFP_P	PFP_K
Nutrient management practices					
Organic	24.7	221.5	46.8	62.4	46.8
INM	27.6	305.2	52.2	69.6	69.6
Inorganic	26.4	337.6	50.3	67.0	100.5
Control	14.9	160.9	–	–	–
SEm ±	0.40	5.9	0.66	0.88	0.83
CD (P=0.05)	1.40	20.4	2.67	3.57	3.36
Rice varieties					
Shahsarang–1	25.2	284.9	54.0	72.0	78.2
Lumpnah	25.0	275.3	50.7	67.7	73.8
Megha SA2	20.0	208.7	44.5	59.4	64.9
SEm ±	0.33	5.0	0.64	0.85	1.16
CD (P=0.05)	0.98	15.0	1.99	2.65	3.61

organic acids on the other which by chelation/complexation released soil P under the acidic soils of NEHR (Kumar *et al.* 2014). Likewise, the proton generated and phosphatases produced by the action of P solubilizing organisms also mobilized the soil–P leading to higher P uptake in present study under INM or organic practice (Choudhary and Suri 2009, Kumar *et al*. 2014). Again, the added organic matter under INM and organic practice is responsible for higher K supplies besides holding positively charged potassium (K^+) ions (Olk *et al.* 1996, Choudhary and Suri 2009); leading to higher K acquisition and uptake in the study (Table 1). Overall, the NPK acquisition behaviour again proved that better plant nutrition leads to higher crop productivity which resulted in higher NPK uptake in rice grains, straw and total uptake in current study (Choudhary and Suri 2014, 2018a; Paul *et al*. 2014, 2016). Among rice varieties, Shahsarang–1 reported highest N and K concentrations in grains and straw followed by Lumpnah and Megha SA–2 owing to better crop nutrition and crop productivity (Dass and Chandra 2013, Paul *et al*. 2014). Shahsarang–1 again reported highest P concentrations in straw (0.12%); whereas, Megha SA2 reported highest grain–P (0.155%) content, however, the differences for grain–N and P concentrations among the rice varieties were non–significant. The NPK uptake in rice grains, straw and total NPK uptake were significantly higher in Shahsarang–1 followed by Lumpnah and Megha SA–2 owing to higher productivity in Shahsarang–1 and genetic ability of these rice genotypes as well (Dass and Chandra 2013; Choudhary and Suri 2018a, 2018b). No significant interaction effect was found for NPK concentrations and uptake in rice grains and straw for different nutrient management practices and rice varieties.

The INM practice also had highest production efficiency (27.6 kg/ha/day) followed by inorganic practice, organic practice and control, respectively. This production efficiency pattern may be attributed to better crop yields governed by higher shoot and root growth, better solar harvest and enhanced nutrient acquisition under respective nutrient management practices (Choudhary and Suri 2018a, 2018b). However, the inorganic practice exhibited highest monetary efficiency (337.6 ₹/ha/ day) followed by INM, organic practice and control, respectively. Since, cost of cultivation under inorganic practice was less due to non-use of bulky organic manures compared to INM and organic practice; it ultimately leads to comparatively higher net returns and monetary efficiency under inorganic practice (Kumar *et al*. 2015, Paul *et al*. 2016). Among rice varieties, production, efficiency (25.2 kg/ha/day) and monetary efficiency (284.9 ₹/ha/day) were highest in Shahsarang–1 followed by Lumpnah and Megha SA–2, respectively which may be the resultant of genetic ability of these rice genotypes (Dass and Chandra 2013). No interaction effect was found between different nutrient management practices and rice varieties for both production and monetary efficiency (Table 2). Data pertaining to partial factor productivity of applied nutrients ($PFP_{N/P/K}$) indicated that INM practice had highest PFP_N (52.3 kg/ha/kg) and PFP_P (69.6 kg/ha/kg) followed by inorganic practice while organic practice recorded lowest PFP_N (46.8 kg/ha/kg) and PFP_P (62.4 kg/ha/kg). The PFP_K was highest for inorganic practice (100.5 kg/ha/kg) followed by INM and least for organic practice (Table 2). The higher $PFP_{N/P/K}$ of applied nutrients under INM and inorganic practice compared to the organic practice may be attributed to quite balanced and continuous nutrient availability and nutrient acquisition from applied mineral sources as compared to organic sources (Choudhary and Suri 2018a,b). This phenomenon might have resulted in better crop establishment and anchorage of roots resulting in better nutrient acquisition, plant growth and photosynthetic efficiency with better yield performance and $PFP_{N/P/K}$ as well under INM and inorganic practice as compared to organic practice in the current study (Dass and Chandra 2013, Paul *et al*. 2014, Choudhary and Rahi 2018). Among rice varieties, the respective PFP_N, PFP_P and PFP_K were highest in Shahsarang–1 (54, 72 and 78.2 kg/ha/kg) followed by Lumpnah and Megha SA–2, respectively. No interaction effect was found for PFP_N, PFP_P and PFP_K between different nutrient management practices and rice varieties in current study.

SUMMARY

It is concluded that the INM practice and rice variety Shahsarang 1 showed their superiority over their respective counterparts, i.e. other nutrient management practices and rice varieties w.r.t. crop productivity, NPK acquisition behavior in rice grains and straw vis–à–vis NPK uptake, and resource–use efficiency in current study. Thus, INM practice and rice variety Shahsarang 1 can be recommended to the resource-poor hill farmers for enhancing rice productivity, plant nutrient acquisition and resource–use efficiency in north-eastern hill region of eastern Himalayas.

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