Journal of the Indian Society of Soil Science, Vol. 69, No. 2, pp 179-186 (2021)
DOI: 10.5958/0974-0228.2021.00036.0

Effects of Bio-NPK Consortium on Growth, Yield and Nutrient Uptake by Rice under Clay Loam Textured Soil

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Field experiment was conducted to see the effects of bio-NPK consortium on growth, yield and nutrient uptake by rice during *kharif* season of 2018 at Research Station, Anand Agricultural University, Thasra. The experiment was laid out in a randomized block design, comprising of twelve treatment combinations of different levels of iron (Fe) and zinc (Zn) with or without bio-NPK consortium (*Azotobacter* sp., *Azospirillim* sp. and *Bacillus* sp.) with three replications. The soil of Thasra experimental field was clay loam texture, medium in organic carbon, available nitrogen (N) and phosphorus (P), high in available potassium (K) and medium in available Zn and Fe. Results revealed that application of RDF + 75% Zn + 75% Fe + Bio-NPK consortium (T_{12}) recorded significantly higher yield and uptake of N, P and S by rice grain and straw. The Fe content in straw and Zn content in grain increased significantly with application of RDF + 100% Zn + 100% Fe + Bio-NPK consortium (T_{10}). Significantly higher Fe and Zn uptake by grain and straw of rice was observed with application of RDF + 75% Zn + 75% Fe + Bio-NPK consortium (T_{12}). Maximum Cu uptake by rice straw was recorded with application of RDF + 100% Zn + 100% Fe + Bio-NPK consortium (T_{10}). The available N, P, K, S, Zn, Mn and Cu content in soil after harvest of rice failed to show any significant influence with different treatments. Significantly higher available Fe (7.10 mg kg^{-1}) in soil after harvest of rice was found in treatment with RDF + 75% Zn + 75% Fe (T_{11}). Maximum population of *Azotobacter*, *Azospirillum,* phosphate solubilizing bacteria and potassium mobilizing bacteria in soil was found in treatment T_{12} (RDF + 75% Zn + 75% Fe + Bio-NPK consortium) over control.

Key words: Rice, Bio-NPK consortium, micronutrient, content and uptake

The crucial role played by micronutrients in enhancing food grains production in India is now a well-recognized fact. Widespread micronutrient deficiencies in soil are now being recorded all over the country which resulted in severe losses in crop yield as well as in nutritional quality. It is estimated that nearly 50% of the agricultural soils are deficient in zinc (Zn), while 33% and 15% soils are deficient in boron (B) and iron (Fe), respectively (Anonymous 2018). In Gujarat, the deficiency of Zn and Fe is about 25% in different soils. In some light textured soils of Gujarat, multi-micronutrient deficiencies are also reported (Anonymous 2018). Extensive micronutrient deficiencies lead to decline in factor productivity even with balanced NPK fertilization. Although the crop response to micronutrients application varies with soil types, crops and genotype, agro-climatic conditions and severity of deficiency, an enormous responses to micronutrient fertilization have been reported in a wide variety of crops including horticultural crops across the country (Shukla *et al*. 2012).

In recent years, biofertilizers have been emerged as a supplement to mineral fertilizer and hold a promise to improve the yield of crops. Biofertilizers are found positive contribution to soil fertility, resulting in increase in crop yield without causing any environmental, water or soil hazards. Nitrogen (N) fixer, phosphate (P) solubilizing bacteria and potassium (K) mobilizing bacteria play an important role in plant nutrition. Further, the microbes are potential alternate that could cater plant Zn and Fe requirement by solubilizing the complex Zn in soil. Several bacteria living in plant rhizosphere promote plant growth directly or indirectly. Such bacteria are generally designated as plant growth promoting rhizobacteria (PGPR) or plant probiotics. Mechanisms of direct plant growth promotion of these rhizobacteria are bio-fertilization by nutrient acquisition, stimulation of root growth, rhizoremediation, and

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plant stress management under biotic and abiotic conditions. While, mechanisms of biological control by which rhizobacteria can promote plant growth indirectly are by reducing the level of diseases and pests which include antibiosis, induction of systemic resistance and competition for nutrients and niches (Ashrafuzzaman *et al*. 2009).

Rice is the most important staple food in several developing countries and chemical fertilizer is the most important input required for rice cultivation. The high yielding rice variety requires large amounts of chemical fertilizers, leading to health hazards and environmental pollution. Globally, rice is grown in 167.4 million hectare (Mha) area with a total production of 759.6 million tonnes (Mt) annually. Of this, Asia accounts for about 90% of the total production and consumption (Anonymous 2017). India is the largest rice growing country, covering an area of about 43.2 Mha with the production and productivity of 110.2 Mt and 2.55 t ha^{-1}, respectively during the year of 2016-2017 (Anonymous 2017). In Gujarat, rice is cultivated in an area of 0.836 Mha with total production of 1.79 Mt yr^{-1} and productivity of 2.14 t ha^{-1} during 2011-12 (Anonymous 2017). This crop is mainly grown during *kharif* and summer season in some districts of south Gujarat beside some districts of middle Gujarat where perennial canal irrigation facilities are available.

In order to make rice yield sustainable and less dependent on chemical fertilizers, it is important to know how to use bio-NPK consortium (PGPR) in rice crop that can biologically fix N, solubilize P and induce some growth promoting substances like indole acetic acid (IAA) that can contribute to the improvement of rice growth. Recently, there is a growing interest in PGPR due to their efficacy as biological control and growth promoting agents in many crops. In addition to improvement of plant growth, PGPR are directly involved in increased uptake of N, synthesis of phytohormones, solubilization of minerals such as P and production of siderophores that chelate Fe and make it available to the plant. It has also been reported that bio-NPK consortium is able to solubilize inorganic and/or organic P in soil. However, there is very little information regarding the use of bio-NPK consortium as biofertilizers in rice. The aim of this study was to see the effects of bio-NPK consortium comprising of *Azotobacter* sp., *Azospirillim* sp. and *Bacillus* sp. on growth, yield and nutrient uptake by rice in a clay loam textured soil.

Materials and Methods

For achieving the objective of present investigation, a field experiment was carried out at Research Station for Irrigated Crops, Anand Agricultural University, Thasra (22°42' N latitude, 73°54' E longitude) to see the effects of bio-NPK consortium on growth, yield and nutrient uptake by rice under clay loam textured soil (Typic Ustrochrepts) during *kharif* season of 2018. The experiment consisted of twelve treatments *i.e.* T_1: Control, T_2: Recommended dose of fertilizers (RDF) (NPK: 100:25:00 kg ha^{-1}) + 100% Zn, T_3: RDF + 100% Fe, T_4: RDF + Bio-NPK consortium (*Azotobacter* sp., *Azospirillim* sp. and *Bacillus* sp.), T_5: RDF + 100% Zn + Bio-NPK consortium, T_6: RDF + 75% Zn + Bio-NPK consortium, T_7: RDF + 100% Fe + Bio-NPK consortium, T_8: RDF + 75% Fe + Bio-NPK consortium, T_9: RDF + 100% Zn + 100% Fe, T_{10}: RDF + 100% Zn + 100% Fe + Bio-NPK consortium, T_{11}: RDF + 75% Zn + 75% Fe, T_{12}: RDF + 75% Zn + 75% Fe + Bio-NPK consortium.

The experimental field was ploughed and cross cultivated by tractor drawn cultivar and then leveled with the help of wooden plank. Field was allowed to water logged condition by excess irrigation and puddling was done using tractor drawn puddler. After maintaining constant levels of water height in the field, blocks were prepared perpendicular to fertility gradient and separate plots were formed by raising bunds on outer side of plots to avoid mixing of water and fertilizer. Transplanting was done using 25-days-old seedling of rice at specified spacing (20 cm × 15 cm) in each plots. The common application of RDF was applied on plot basis. For basal application, 50% of N in each plot *i.e.* 50 kg N ha^{-1} in the form of urea after transplanting was applied. The remaining 50% of N (50 kg N ha^{-1}) was applied after 30 days of transplanting (DAT). The nutrient content and uptake by rice was recorded after harvesting. Representative composite soil sample from 0-15 cm depth was collected initially from the entire experimental site and from each plot after the harvest of rice crop. For better representation, soil samples were prepared by mixing the soil collected from 5-6 spots from each plot randomly. The soil samples were air-dried and ground to pass through 2-mm sieve. The soil samples were labeled and stored in polythene lined cotton bags for further analysis. The soil of the experimental field was Typic Ustochrepts, clay loam in texture and had $pH_{1:2.5}$ 7.86, $EC_{1:2.5}$ 0.28 dS m^{-1}, organic carbon (OC) 0.58%, available N 282 kg ha^{-1}, available P_2O_5 38 kg ha^{-1}, available K_2O 312 kg ha^{-1}, available sulphur (S)

Table 1. Methods used for initial soil, after harvest of soil and plant analysis

Parameters	Reference
Soil analysis	
pH (1:2.5 soil: water)	Jackson (1973)
EC (1:2.5 soil: water)	Jackson (1973)
Organic carbon (Wet oxidation)	Walkley and Black (1934)
Available N (Alkaline $KMnO_4$-N)	Subbiah and Asija (1956)
Available P (0.5 *M* $NaHCO_3$ extractable)	Olsen *et al*. (1954)
Available K (1 *N* NH_4OAc extractable)	Jackson (1973)
Available S ($CaCl_2$ extractable)	Williams and Steinbergs (1959)
Available micronutrients (DTPA extractable Fe, Mn, Zn, Cu)	Lindsay and Norvell (1978)
Plant analysis	
Total N (%)	Jackson (1973)
Total P (%)	Jackson (1973)
Total K (%)	Jackson (1973)
Total S (%)	Chesnin and Yien (1951)
Total Fe, Mn, Zn and Cu (mg kg^{-1})	Jackson (1973)

10.6 mg kg^{-1}, and available Fe, Zn, Mn and Cu were 5.12, 0.78, 7.40 and 1.08 mg kg^{-1}, respectively (Table 1). Rice grain and straw yields were recorded for each plot and nutrient contents in grain and straw were analyzed for N, P, K, S, Fe, Mn, Zn and Cu as per the standard procedures. All the data recorded during the study period were statistically analyzed using standard methods as suggested by Steel and Torrie (1982).

Results and Discussion

Yield of rice

The different treatments significantly influenced the grain (5.82 t ha^{-1}) and straw (6.63 t ha^{-1}) yield of rice (Table 2). The maximum grain and straw yield recorded under T_{12} (RDF + 75% Zn + 75% Fe + Bio-NPK consortium) was on par with the treatments T_5, T_6, T_7, T_8 and T_9 in grain yield. In case of straw yield it was statistically similar with all the treatments except T_2. The results indicated that the application of either Zn or Fe along with bio-NPK consortium or combined application of 100% Zn and Fe in absence of bio-NPK consortium found equally effective with 75% each of Zn and Fe along with bio-NPK consortium. Thus, application of 75% dose of either Zn or Fe along with bio-NPK consortium or only 100% dose of both Zn and Fe found beneficial. Similar findings have been reported by Kaz Ali *et al.* (2017) who found that *Azospirillum lipoferum* inoculation increased rice tiller numbers and

Table 2. Effect of different treatments on grain and straw yield of rice

Treatments	Yield of rice (t ha^{-1})	
	Grain	Straw
T_1: Control	4.89^{d}	5.48^{c}
T_2: RDF + 100% Zn	5.00^{cd}	5.91^{bc}
T_3: RDF + 100% Fe	5.26^{abcd}	6.06^{ab}
T_4: RDF + Bio-NPK consortium	5.13^{bcd}	6.05^{ab}
T_5: RDF + 100% Zn + Bio-NPK consortium	5.67^{ab}	6.25^{ab}
T_6: RDF + 75% Zn + Bio-NPK consortium	5.52^{abc}	6.39^{ab}
T_7: RDF + 100% Fe + Bio-NPK consortium	5.71^{ab}	6.40^{ab}
T_8: RDF + 75% Fe + Bio-NPK consortium	5.66^{ab}	6.42^{ab}
T_9: RDF + 100% Zn + 100% Fe	5.49^{abc}	6.44^{ab}
T_{10}: RDF + 100% Zn + 100% Fe + Bio-NPK consortium	5.33^{abcd}	6.52^{ab}
T_{11}: RDF + 75% Zn + 75% Fe	5.38^{abcd}	6.51^{ab}
T_{12}: RDF + 75% Zn + 75% Fe + Bio-NPK consortium	5.82^{a}	6.63^{a}
S.Em.±	0.17	0.18
CD (P=0.05)	Sig.	Sig.
CV (%)	5.48	4.99

Note: Treatments means with the letter/letters in common are not significant by Duncan's Multiple Range Test at 5% level of significance

subsequently the grain yield. Co-coinoculation of microorganisms and their synergistic effect on plant growth by increased nutrients uptake led to the yield increase compared to control. Similar result was obtained by Ahmed *et al.* (2013) and Vaid *et al.* (2014) in their experiments. The yield attributes like grain and straw yield of rice increased significantly due to application of RDF + 75% Zn + 75% Fe + Bio-NPK consortium. Significant increase in grain and straw yield of rice might be due to positive effect of treatments on growth parameters and yield attributes during growth period. This might be due to the inoculation of N fixer, P solubilizer and organisms that produces plant growth promoting substances and their role in the increased availability of nutrients to the crop plants. Similar results were reported by Ashrafuzzaman *et al.* (2009), Ahmed *et al.* (2013) and Sadaghiani *et al.* (2014).

Nutrient Content and Uptake

Application of different treatments did not show significantly effect on N, P, K, S, Fe, Zn, Mn and Cu content in rice grain and straw (Table 3 and 4). Treatment T_{12} (RDF + 75% Zn + 75% Fe + Bio-NPK

Table 3. Effect of different treatments on nutrient content of rice grain and straw

Treatments	Nutrient content (%) of rice							
	Nitrogen		Phosphorus		Potassium		Sulphur	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
T_1: Control	1.82^a	0.68^a	0.249^a	0.159^a	0.54^a	1.30^a	0.426^a	0.358^a
T_2: RDF + 100% Zn	1.84^a	0.73^a	0.277^a	0.173^a	0.61^a	1.46^a	0.430^a	0.384^a
T_3: RDF + 100% Fe	1.88^a	0.69^a	0.283^a	0.179^a	0.59^a	1.42^a	0.428^a	0.390^a
T_4: RDF + Bio-NPK consortium	1.89^a	0.73^a	0.278^a	0.170^a	0.60^a	1.45^a	0.434^a	0.390^a
T_5: RDF + 100% Zn + Bio-NPK consortium	1.96^a	0.78^a	0.288^a	0.163^a	0.57^a	1.36^a	0.432^a	0.376^a
T_6: RDF + 75% Zn + Bio-NPK consortium	2.00^a	0.76^a	0.322^a	0.187^a	0.56^a	1.37^a	0.441^a	0.381^a
T_7: RDF + 100% Fe + Bio-NPK consortium	1.94^a	0.78^a	0.300^a	0.169^a	0.60^a	1.45^a	0.435^a	0.403^a
T_8: RDF + 75% Fe + Bio-NPK consortium	1.97^a	0.72^a	0.316^a	0.167^a	0.58^a	1.40^a	0.443^a	0.413^a
T_9: RDF + 100% Zn + 100% Fe	1.91^a	0.76^a	0.321^a	0.190^a	0.55^a	1.33^a	0.444^a	0.402^a
T_{10}: RDF + 100% Zn + 100% Fe + Bio-NPK consortium	1.96^a	0.77^a	0.329^a	0.181^a	0.64^a	1.54^a	0.453^a	0.403^a
T_{11}: RDF + 75% Zn + 75% Fe	1.89^a	0.78^a	0.290^a	0.193^a	0.60^a	1.45^a	0.445^a	0.389^a
T_{12}: RDF + 75% Zn + 75% Fe + Bio-NPK consortium	2.00^a	0.79^a	0.286^a	0.191^a	0.63^a	1.51^a	0.467^a	0.412^a
S.Em.±	0.05	0.03	0.02	0.01	0.03	0.07	0.009	0.011
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	4.7	6.0	9.9	7.7	9.5	8.9	3.4	4.9

Table 4. Effect of different treatments on micronutrient content (mg kg^{-1}) of rice

Treatments	Micronutrient content (mg kg^{-1}) of rice							
	Fe		Zn		Mn		Cu	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
T_1: Control	39.1^a	176.1^d	27.2^e	36.4^d	7.08^a	26.6^a	2.75^a	5.68^a
T_2: RDF + 100% Zn	45.8^a	213.3^b	32.2^{abcd}	41.9^{ab}	8.52^a	31.9^a	3.05^a	6.38^a
T_3: RDF + 100% Fe	45.6^a	222.5^{ab}	30.6^{bcd}	39.2^{bc}	7.82^a	30.3^a	3.00^a	7.02^a
T_4: RDF + Bio-NPK consortium	46.9^a	216.9^{ab}	30.4^{cd}	38.7^c	8.37^a	31.4^a	3.03^a	5.95^a
T_5: RDF + 100% Zn + Bio-NPK consortium	45.7^a	218.2^{ab}	32.9^{abc}	43.8^{ab}	8.72^a	32.7^a	3.00^a	6.78^a
T_6: RDF + 75% Zn + Bio-NPK consortium	45.0^a	217.3^{ab}	33.2^{ab}	43.5^{ab}	9.10^a	30.1^a	2.93^a	7.22^a
T_7: RDF + 100% Fe + Bio-NPK consortium	48.9^a	226.6^{ab}	30.0^d	37.4^c	8.10^a	30.4^a	3.18^a	6.02^a
T_8: RDF + 75% Fe + Bio-NPK consortium	49.5^a	228.4^{ab}	30.9^{bcd}	38.3^c	8.43^a	31.6^a	3.17^a	6.72^a
T_9: RDF + 100% Zn + 100% Fe	46.5^a	226.3^{ab}	33.1^{abc}	41.9^{ab}	8.85^a	33.2^a	3.22^a	7.02^a
T_{10}: RDF + 100% Zn + 100% Fe + Bio-NPK consortium	46.9^a	228.7^a	33.7^a	44.7^a	7.97^a	29.9^a	3.35^a	7.28^a
T_{11}: RDF + 75% Zn + 75% Fe	45.2^a	227.7^{ab}	32.6^{abcd}	42.0^{ab}	7.82^a	29.3^a	3.27^a	6.55^a
T_{12}: RDF + 75% Zn + 75% Fe + Bio-NPK consortium	47.8^a	227.5^{ab}	32.3^{abcd}	44.5^{ab}	8.02^a	34.1^a	3.42^a	6.65^a
S.Em.±	2.57	3.47	0.81	0.95	0.49	1.58	0.20	0.41
CD (P=0.05)	NS	Sig.	Sig.	Sig.	NS	NS	NS	NS
CV (%)	9.7	2.7	4.1	4.0	10.3	8.8	10.9	10.8

Note: Treatments means with the letter/letters in common are not significant by Duncan's Multiple Range Test at 5% level of significance

consortium resulted in significantly higher N uptake by grain (111.6 kg ha^{-1}) and straw (52.5 kg ha^{-1}) (Table 5). However, it remained at par with T_3, T_5, T_6, T_7, T_8, T_9, T_{10} and T_{11}. In addition to enhancement plant growth and yield, bio-NPK consortium are directly involved in increased concentration and uptake of N and synthesis of phytohormones. This may be correlated with their ability to fulfill the N requirement of the rice crop, while application of single species may have failed to meet N requirement (Vaid *et al*. 2014; Sharma *et al.* 2014). Significantly higher P uptake by grain (18.0 kg ha^{-1}) and straw (12.6 kg ha^{-1}) by rice was observed in T_{12} (RDF + 75% Zn + 75% Fe + Bio-NPK consortium). However, it remained at par with treatment T_6, T_7, T_8, T_9 and T_{10} in grain but in case of straw it was statistically similar with T_6, T_9, T_{10} and T_{11}. Its might be due to increased availability of P which was added in the soil through resources by *Azotobacter* and phosphate solubilizing bacteria. Similar results were found by Yadav *et al.* (2014) and Gooma *et al.* (2015). Whereas, in case of K uptake (100.3 kg ha^{-1}) by straw was significantly higher with application of RDF + 75% Zn + 75% Fe + Bio-NPK consortium (T_{12}) and remained on par with all the treatments except control. Its might be due to the application of Bio-NPK consortium which helps in mobilization of K in plant. Similar results were found by Mathews *et al.* (2006) and Biari *et al.* (2008). The maximum S uptake by grain (27.2 kg ha^{-1}) and straw (27.3 kg ha^{-1}) of rice was observed with application of RDF + 75% Zn + 75% Fe + Bio-NPK consortium (T_{12}) remained statistically at par with T_5, T_7 and T_8 in grain but in case of straw it was statistically at par with the treatment T_6 to T_{11} (Table 6). The reason could be due to combined application Zn and Fe with bio-NPK consortium which ultimately enhanced its absorption by plants because of fair availability of S in the soil resulting in increased uptake of S by rice. These findings all in accordance with Kalhapure *et al*. (2014).

Treatment T_{10} (RDF + 100% Zn + 100% Fe + Bio-NPK consortium) recorded significantly higher Fe content in straw (228.7 mg kg^{-1}) (Table 4). However, it remained at par with all the treatment except T_1 and T_2. While, significantly higher Fe uptake by grain (279.0 g ha^{-1}) and straw (1507.9 g ha^{-1}) of rice was recorded with application of RDF + 75% Zn + 75% Fe + Bio-NPK consortium (T_{12}) but it was statistically similar with all the treatments except T_1 and T_2 in grain, but in case of straw it was on par with T_6, T_7, T_8, T_9, T_{10} and T_{11} (Table 6). It might be due to the application of bio-NPK consortium which might have mobilized Fe in root zone and thus increased Fe availability. Similar result was found by Lal and Sharma (2013). Significantly higher Zn content in rice grain (33.7 mg kg^{-1}) and straw (44.7 mg kg^{-1}) were registered with application of RDF + 100% Zn + 100% Fe + Bio-NPK consortium (T_{10}). However, it remained at par with T_2, T_5, T_6, T_9, T_{11} and T_{12} (Table 6). Significantly higher Zn uptake by rice grain (188.1

Table 5. Effect of different treatments on nutrient uptake (kg ha^{-1}) by rice

Treatments	Nutrient uptake (kg ha^{-1}) by rice							
	Nitrogen		Phosphorus		Potassium		Sulphur	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
T_1: Control	88.7^{d}	36.9^{d}	12.2^{d}	8.74^{d}	26.2^{a}	71.0^{c}	20.8^{e}	19.6^{d}
T_2: RDF + 100% Zn	92.0^{bc}	43.3^{bcd}	13.8^{bcd}	10.2^{cd}	30.5^{a}	86.5^{ab}	21.5^{cd}	22.7^{cd}
T_3: RDF + 100% Fe	98.5^{abc}	41.8^{bcd}	14.8^{bc}	10.9^{bc}	31.2^{a}	86.2^{ab}	22.5^{bcd}	23.6^{bcd}
T_4: RDF + Bio-NPK consortium	97.0^{bc}	44.1^{cd}	14.2^{bc}	10.3^{bcd}	30.9^{a}	87.6^{ab}	22.3^{cd}	23.6^{bcd}
T_5: RDF + 100% Zn + Bio-NPK consortium	110.4^{ab}	48.6^{abc}	16.3^{abcd}	10.2^{bcd}	32.2^{a}	84.4^{bc}	24.6^{abc}	23.4^{cd}
T_6: RDF + 75% Zn + Bio-NPK consortium	110.4^{ab}	48.7^{abc}	17.8^{ab}	11.9^{abc}	30.8^{a}	87.3^{ab}	24.3^{bc}	24.3^{abc}
T_7: RDF + 100% Fe + Bio-NPK consortium	110.5^{ab}	49.6^{ab}	17.0^{ab}	10.9^{bc}	34.4^{a}	93.2^{ab}	24.8^{abc}	25.8^{abc}
T_8: RDF + 75% Fe + Bio-NPK consortium	104.4^{abc}	45.9^{bcd}	17.9^{ab}	10.7^{bc}	32.9^{a}	89.6^{ab}	25.1^{ab}	26.6^{ab}
T_9: RDF + 100% Zn + 100% Fe	109.9^{ab}	48.9^{abc}	17.1^{ab}	12.3^{abc}	30.4^{a}	86.6^{ab}	24.4^{bc}	25.9^{abc}
T_{10}: RDF + 100% Zn + 100% Fe + Bio-NPK consortium	111.5^{ab}	50.2^{ab}	16.7^{abc}	11.8^{abc}	34.2^{a}	100.3^{ab}	24.2^{bc}	26.3^{abc}
T_{11}: RDF + 75% Zn + 75% Fe	101.9^{abc}	50.9^{ab}	15.5^{abcd}	12.6^{ab}	32.5^{a}	94.3^{ab}	23.9^{bcd}	25.3^{abcd}
T_{12}: RDF + 75% Zn + 75% Fe + Bio-NPK consortium	111.6^{a}	52.5^{a}	18.0^{a}	12.6^{a}	36.7^{a}	100.3^{a}	27.2^{a}	27.3^{a}
S.Em.±	4.44	1.83	0.95	0.60	1.93	4.94	0.90	1.03
CD (P=0.05)	Sig.	Sig.	Sig.	Sig.	NS	Sig.	Sig.	Sig.
CV (%)	7.4	6.8	10.3	9.3	10.5	9.6	6.6	7.3

Note: Treatments means with the letter/letters in common are not significant by Duncan's Multiple Range Test at 5% level of significance

Table 6. Effect of different treatments on micronutrient uptake (g ha^{-1}) by rice

Treatments	Micronutrient uptake (g ha^{-1}) by rice							
	Fe		Zn		Mn		Cu	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
T_1: Control	188.7^{d}	964.2^{d}	132.7^{d}	199.2^{d}	34.13^{a}	145.5^{a}	13.51^{a}	31.16^{d}
T_2: RDF + 100% Zn	229.1^{bc}	1261.0^{cd}	160.9^{bc}	247.4^{bcd}	42.56^{a}	188.8^{a}	15.25^{a}	37.78^{bcd}
T_3: RDF + 100% Fe	240.3^{abc}	1349.4^{bc}	160.8^{bc}	237.4^{bcd}	41.08^{a}	183.8^{a}	15.76^{a}	42.59^{abc}
T_4: RDF + Bio-NPK consortium	242.2^{abcd}	1309.3^{bcd}	155.9^{c}	233.5^{bc}	42.50^{a}	190.5^{a}	15.63^{a}	35.96^{cd}
T_5: RDF + 100% Zn + Bio-NPK consortium	258.8^{abc}	1365.0^{bc}	186.4^{ab}	274.1^{ab}	49.52^{a}	205.1^{a}	17.01^{a}	42.24^{abc}
T_6: RDF + 75% Zn + Bio-NPK consortium	247.9^{abc}	1388.3^{abc}	183.4^{ab}	278.0^{ab}	50.31^{a}	192.9^{a}	16.18^{a}	46.12^{ab}
T_7: RDF + 100% Fe + Bio-NPK consortium	279.1^{ab}	1448.6^{abc}	171.6^{abcd}	239.1^{c}	46.12^{a}	196.1^{a}	18.13^{a}	38.76^{bcd}
T_8: RDF + 75% Fe + Bio-NPK consortium	280.4^{ab}	1466.5^{abc}	175.1^{abc}	245.6^{bc}	47.85^{a}	203.1^{a}	17.92^{a}	43.17^{abc}
T_9: RDF + 100% Zn + 100% Fe	254.7^{abc}	1457.9^{abc}	181.4^{ab}	269.8^{abc}	48.64^{a}	213.8^{a}	17.63^{a}	45.21^{ab}
T_{10}: RDF + 100% Zn + 100% Fe + Bio-NPK consortium	250.9^{abc}	1491.6^{ab}	179.6^{ab}	291.3^{ab}	42.54^{a}	195.4^{a}	18.01^{a}	47.53^{a}
T_{11}: RDF + 75% Zn + 75% Fe	243.5^{abc}	1482.7^{ab}	175.2^{abc}	273.6^{ab}	42.31^{a}	190.9^{a}	18.42^{a}	42.64^{abc}
T_{12}: RDF + 75% Zn + 75% Fe + Bio-NPK consortium	279.0^{a}	1507.9^{a}	188.1^{a}	294.2^{a}	47.07^{a}	225.0^{a}	18.97^{a}	43.84^{abc}
S.Em.±	15.3	43.3	6.5	8.4	3.15	13.8	1.23	2.93
CD (P=0.05)	Sig.	Sig.	Sig.	Sig.	NS	NS	NS	Sig.
CV (%)	10.6	5.5	6.6	5.7	12.2	12.3	12.7	12.2

Note: Treatments means with the letter/letters in common are not significant by Duncan's Multiple Range Test at 5% level of significance

g ha^{-1}) and straw (294.2 g ha^{-1}) were observed with application of RDF + 75% Zn + 75% Fe + Bio-NPK consortium (T_{12}). It could be due to increase in growth and yield parameters which influences and increase water and nutrition absorption causing better plant growth. Similar results were also reported by Biari *et al.* (2008). Application of Fe and Zn fertilizers either to soil or foliar application considerably increased Fe and Zn content in rice grain and straw. These findings are in line with those reported by Yadav *et al.* (2011) and Patel *et al.* (2015). Maximum Cu uptake by straw (47.5 g ha^{-1}) was obtained with application of RDF + 100% Zn + 100% Fe + Bio-NPK consortium (T_{10}) but it was statistically similar with T_3, T_5, T_6, T_8, T_9, T_{11} and T_{12}. Similar results were also reported by Mathews *et al.* (2006) and Biari *et al.* (2008).

Post-harvest Available Nutrients

The soil available N, P, K, S, Zn, Mn and Cu after harvest of rice failed to show any significant

Table 7. Effect of different treatments on available nutrient in soil after harvest of rice

Treatments	Available macronutrients (kg ha^{-1})				Available micronutrients (mg kg^{-1})			
	N	P	K	S	Fe	Zn	Mn	Cu
T_1: Control	196.0^{a}	31.1^{a}	325.5^{a}	6.62^{a}	5.16^{d}	1.11^{a}	7.09^{a}	2.69^{a}
T_2: RDF + 100% Zn	206.5^{a}	33.5^{a}	328.5^{a}	6.91^{a}	6.50^{abc}	1.16^{a}	7.74^{a}	3.03^{a}
T_3: RDF + 100% Fe	201.2^{a}	31.9^{a}	343.5^{a}	6.79^{a}	6.78^{abc}	1.13^{a}	7.75^{a}	2.94^{a}
T_4: RDF + Bio-NPK consortium	185.5^{a}	32.2^{a}	332.3^{a}	6.68^{a}	5.56^{bc}	1.14^{a}	7.91^{a}	2.91^{a}
T_5: RDF + 100% Zn + Bio-NPK consortium	196.0^{a}	33.2^{a}	345.7^{a}	6.90^{a}	6.04^{bc}	1.33^{a}	7.61^{a}	3.39^{a}
T_6: RDF + 75% Zn + Bio-NPK consortium	201.2^{a}	33.3^{a}	353.9^{a}	6.69^{a}	5.96^{bc}	1.26^{a}	8.15^{a}	3.08^{a}
T_7: RDF + 100% Fe + Bio-NPK consortium	196.0^{a}	33.1^{a}	346.5^{a}	7.91^{a}	5.97^{bc}	1.23^{a}	7.98^{a}	2.98^{a}
T_8: RDF + 75% Fe + Bio-NPK consortium	206.5^{a}	32.7^{a}	348.7^{a}	8.43^{a}	6.54^{abc}	1.27^{a}	9.34^{a}	3.05^{a}
T_9: RDF + 100% Zn + 100% Fe	211.7^{a}	33.1^{a}	339.7^{a}	8.43^{a}	6.99^{ab}	1.21^{a}	8.77^{a}	3.04^{a}
T_{10}: RDF + 100% Zn + 100% Fe + Bio-NPK consortium	211.7^{a}	33.4^{a}	339.7^{a}	8.39^{a}	6.97^{ab}	1.17^{a}	7.70^{a}	3.10^{a}
T_{11}: RDF + 75% Zn + 75% Fe	206.5^{a}	32.5^{a}	350.9^{a}	6.94^{a}	7.10^{a}	1.25^{a}	7.60^{a}	2.82^{a}
T_{12}: RDF + 75% Zn + 75% Fe + Bio-NPK consortium	215.0^{a}	33.8^{a}	357.7^{a}	8.34^{a}	6.53^{abc}	1.29^{a}	8.07^{a}	3.04^{a}
S.Em.±	14.84	0.82	15.6	0.60	0.32	0.09	0.60	0.12
CD (P=0.05)	NS	NS	NS	NS	Sig.	NS	NS	NS
CV (%)	12.7	4.3	7.9	14.0	8.7	12.8	13.0	7.2

Note: Treatments means with the letter/letters in common are not significant by Duncan's Multiple Range Test at 5% level of significance

Table 8. Effect of different treatments on micronutrient content (mg kg^{-1}) of rice

Treatments	*Azotobacter* (×10^6 cfu g^{-1})	*Azospirillum* (×10^6 cfu g^{-1})	PSB (×10^7 cfu g^{-1})	KMB (×10^7 cfu g^{-1})
T_1: Control	6.61^d	6.69^e	7.68^e	7.74^d
T_2: RDF + 100% Zn	6.64^{bc}	6.72^{bcd}	7.72^d	8.01^{bc}
T_3: RDF + 100% Fe	6.77^{bc}	6.73^{bcd}	7.74^d	8.00^{bc}
T_4: RDF + Bio-NPK consortium	8.89^{abc}	8.97^{abc}	9.92^{ab}	9.98^{ab}
T_5: RDF + 100% Zn + Bio-NPK consortium	8.89^{abc}	8.95^{abc}	9.91^{ab}	9.97^{ab}
T_6: RDF + 75% Zn + Bio-NPK consortium	8.86^{abc}	8.94^{abc}	9.85^{ab}	9.85^{ab}
T_7: RDF + 100% Fe + Bio-NPK consortium	8.84^{abc}	8.92^{abc}	9.98^{ab}	9.96^{ab}
T_8: RDF + 75% Fe + Bio-NPK consortium	8.88^{abc}	9.04^{ab}	9.87^{ab}	9.91^{ab}
T_9: RDF + 100% Zn + 100% Fe	6.70^{bc}	6.83^{bcd}	7.77^d	8.02^{bc}
T_{10}: RDF + 100% Zn + 100% Fe + Bio-NPK consortium	9.03^{ab}	9.02^{ab}	10.00^{ab}	9.95^{ab}
T_{11}: RDF + 75% Zn + 75% Fe	6.76^{bc}	6.76^{de}	7.78^c	8.02^{bc}
T_{12}: RDF + 75% Zn + 75% Fe + Bio-NPK consortium	9.05^a	9.05^a	10.01^a	9.99^a
S.Em.±	0.08	0.05	0.04	0.02
CD (P=0.05)	Sig.	Sig.	Sig.	Sig.
CV (%)	1.80	1.10	0.69	0.45

Note: Treatments means with the letter/letters in common are not significant by Duncan's Multiple Range Test at 5% level of significance

influence of different treatments (Table 7). Maximum available Fe (7.10 mg kg^{-1}) in soil was recorded with application of RDF + 75% Zn + 75% Fe (T_{11}), but it was statistically at par with T_2, T_3, T_8, T_9, T_{10} and T_{12}. This might be due to combined inoculation of N_2 fixers, P solubilizer and K solubilizer which helped in benefitting the plant growth than their sole application. Dual inoculation might have contributed towards enhanced plant growth and increased the soluble micronutrients (Vaid *et al.* 2014).

Microbial Population

Data revealed that all the treatments were found superior over control at both the locations as well as on pooled basis (Table 8). Maximum population of *Azotobacter* (9.05×10^6 cfu g^{-1} soil), *Azospirillum* (9.05×10^6 cfu g^{-1} soil), phosphate solubilizing bacteria (10.01×10^7 cfu g^{-1} soil) and potassium mobilizing bacteria (9.99×10^7 cfu g^{-1} of soil) were found in soils treated with T_{12} (RDF + 75% Zn + 75% Fe + Bio-NPK consortium), which were statistically at par with T_4, T_5, T_6, T_7, T_8, T_{10} and T_{11}. This may be due to the availability of higher root exudates and nutrients in rhizospheric soil of rice (Abdullahi *et al*. 2014; Sharma *et al*. 2014).

Conclusions

It may be concluded that the agronomic approach for optimum rice yield and enhancement of micronutrients concentration could be better accomplished with the supplementation of 75% Fe and Zn along with Bio-NPK consortium which was found comparable with 100% dose of Fe and Zn.

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Received 27 November 2019; Accepted 4 June 2021