Eco. Env. & Cons. 29 (November Suppl. Issue) : 2023; pp. (S353-S358)
ISSN 0971–765X

DOI No.: http://doi.org/10.53550/EEC.2023.v29i06s.053

Effect of nutrient management practices on nitrogen, phosphorus and yield of lowland rice in Eastern Himalayan region

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(Received 24 May, 2023; Accepted 31 July, 2023)

ABSTRACT

An experiment was conducted on paddy crop (Shahsarang 1 variety) for the estimation of nitrogen and phosphorus uptake in grain and straw when applied through different treatments of chemical and biofertilizers. The experiment was conducted in Kharif season of the year 2016, at ICAR complex for NEH, Meghalaya, in a split-plot design comprising 3 main plot treatments *viz.* 1. 100% organic, 2. 100% inorganic (recommended dose of fertilizer) and 3. INM (75% RDF with 25% FYM) and 4 subplot treatments *viz.* Control, *Azospirillum*, *Azospirillum* with PSB and *Azospirillum* with PSB and ZnSB in sub plots. Each treatment was replicated thrice. The results showed that highest concentration of N and P in both grains and straw were observed in inorganic followed by INM management practices when combined with *Azotobacter* + PSB + ZnSB and highest grain yield obtained with inorganic.

Key words: *Nitrogen, Phosphorus, Azotobacter, PSB, ZnSB*

Introduction

The most essential staple food crop in majority of developing countries is rice (*Oryza sativa*). Asia is where rice is predominantly cultivated, with China producing most of it. In terms of output, India comes in second place to China (Rathna *et al.*, 2019). The area under rice crop is approximately 45 million hectares and production are 177.65 million tonnes (MoA and FW, 2022). According to (Maclean *et al.*, 2002), Rice provides around 21% of the world's energy requirements. To fulfil the demands of ever-increasing population, food production must increase. Our aim in future must be to enhance input use efficiency to make the agriculture more sustainable, like integrated sources of nutrients due to the high prices of energy and the scarcity of resources. Large amounts of nitrogen (N) and phosphorus (P) are administered to agricultural systems, and deficiencies in either component result in output losses. Therefore, a holistic strategy should be used to generate rice that is nutrient-efficient, combining an in-

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tegrated source of nutrients with better nutrient content and uptake via a strong root system, increasing grain filling and production (Vinod *et al.,* 2012). In light of this, the present experiment was conducted to determine how nutrient management techniques and microbial inoculants affect lowland rice's ability to absorb Nitrogen, Phosphorus and affects yield in the eastern Himalayas.

Materials and Methods

The experiment was undertaken into a split-plot design with 12 treatment combinations having 3 replications with 3 main plot treatments *viz.* 1. 100% organic, 2. 100% inorganic (recommended dose of fertilizer) and 3. INM (75% RDF+ 25% FYM) and 4 subplot treatments comprising of different microbial inoculation *viz.* 1. control, 2. *Azospirillum*, 3. *Azospirillum* with PSB, 4. *Azospirillum* with PSB and ZnSB in subplots. In the organic treatment, nutrient supplementation was provided using farmyard manure (FYM) applications. For the inorganic nutrient management approach, Urea, SSP, and MOP were used in the ratios of 80: 60: 40 kg/ha each to apply nitrogen (N), phosphorus (P), and potassium (K). In the organic plot, the nutrient requirement was fulfilled by farm yard manure and rock phosphate. However, in the INM plots, the nutrient application consisted of a 75% RDF (recommended dose of fertilizer) combined with 25% FYM. The seedlings' roots were submerged in the solution after the biofertilizers had been dissolved in water at the required concentration. The experiment was done on a popular local rice variety known as 'Shahsarang 1'.

Fertilizer application

- **Organic main plot:** 102 kg FYM+ rock phosphate
- **Inorganic main plot treatment: -**NPK was applied in the ratio of (80:60:40).
- **Integrated nutrient management: -** For integrated nutrient management 75% of nutrient requirement was fulfilled through recommended dose of fertilizers and the remaining 25% requirement was fulfilled through FYM 25.5 kg @0.3 kg/m^2.

Urea was applied in three split applications (50% as basal + 25% at tillering + 25% at panicle initiation)

- **Biofertilizers application:** Following biofertilizers were inoculated at their recommended rate i.e., 200 g/ acre or 500 g/ ha for carrier based and 125 ml/ha for liquid formulation:

Azospirillum @ 1.0 g/plot

Phosphate solubilizing bacteria (PSB) @ 1.0 g/plot

Zinc solubilizing bacteria (ZnSB) @ 2.0 ml/plot

For biofertilizer inoculation treatment above mentioned quantities of biofertilizer were dissolved in water and seedling roots were dipped for one hour before transplanting.

Statistical analysis

The analysis of variance (ANOVA) method was used to investigate the acquired data, and the "F" test was used to determine its significance (Gomez and Gomez, 1984). The following formula was used to determine critical difference (CD) when the F test showed a substantial difference between the means:

CD = SEm × $\sqrt{2}$ × t (0.05) at error degree of freedom

$$\text{SEm}\pm = \sqrt{\frac{\text{Error mean sum of squre}}{\text{Number of replications}}}$$

Results and Discussion

Nitrogen (N) contents in grains and straw were significantly affected by nutrient management practices (Table 1). Both inorganic and INM recorded significantly higher N concentrations over organic management, however, it was statistically at par among the inorganic and INM practices. The higher most N concentrations in grain (1.32%) and straw (0.55%) were recorded with inorganic nutrient management practice, respectively and these were followed by N concentrations under INM and organic management. Among the microbial inoculants, a higher N concentration (1.30%) in the grain was observed with *Azospirillum*+ PSB+ ZnSB inoculation and it was significantly more than control and sole inoculation with *Azospirillum*. The differences in N concentrations between sole *Azospirillum* and *Azospirillum*+ PSB and *Azospirillum*+ PSB and *Azospirillum*+ PSB + ZnSB were at par. In straw also, a similar trend was observed in the nutrient management practices of microbial inoculation. The highest (0.55%) and lowest (0.52%) N concentrations were recorded in *Azospirillum*+ PSB+ ZnSB and control, respectively. Due to nitrogen fixing nature of bacteria, responsible for higher concentration of N in grain under this treatment (Bakulin *et al.*, 2007). The interaction effect due to nutrient management practices and microbial inoculation was also found to be nonsignificant.

N uptake in grains and straw

Nitrogen in grains, straw and total uptake by paddy is presented in Table 3. Among the nutrient management practices both inorganic and INM were found to be significantly higher over the organic system, however, difference between inorganic and INM were *at par* in both grain, straw, and overall consumption of N also. On the contrary difference between organic and inorganic management was statistically significant. The highest N uptake observed was 55.43, 33.55 and 89.32 kg/ha, (grains, straw and total uptake respectively). Among the microbial inoculants, the highest N uptake was recorded in *Azospirillum* + PSB + ZnSB and it was significantly higher than in control and sole inoculation of *Azospirillum*. All the treatments having inoculants showed significant differences in N uptake in grains, straw and their total. The highest value on N uptake were recorded to be 55.43 kg/ha, 34.78 kg/ha and 90.22 kg/ha (in grains, straw and total respectively) with the combined inoculation of *Azospirillum*+ PSB+ ZnSB treatment. The interaction effect due to nutrient management and microbial inoculants was significant only in the case of total N uptake. *Azospirillum* along with their nitrogen fixing value of about 20-40 kg/ha N, are also known for the production of growth-regulating substances (Rao *et al.*, 1998). The greater concentration and absorption of N in grain under this treatment is caused by nitrogen-fixing bacteria, which convert inert air N to organic molecules (Rao *et al.*, 1998). According to (Afzal *et al.*, 2005), dual inoculum of microorganisms without Phosphorus increased grain production by 20% whereas PSB with P fertilizer increased yield of wheat (*Triticum aestivum*) by 30–40%.

P content in grains and straw

Table 4 contains information on the phosphorus (P) content of rice grains and straws. The highest concentrations of Phosphorus in grain (1428.27 ppm) and in straw (949.55 ppm) were recorded with mineral fertilization at RDF (inorganic) nutrient management practice and those were followed by INM and organic treatment. All three nutrient management practices showed significant variation in the P-concentration of grains. But in straw inorganic and INM practices had statistically *at par* P-concentration while all other combinations differences were significant. Among microbial inoculants highest concentration of P grain (1409.13 ppm) and straw (940.39 ppm) were observed in the combined inoculation of *Azospirillum with* PSB and ZnSB. All the microbial inoculants including *Azospirillum* showed significantly higher Phosphorus concentration in grain over the control. Whereas in straw only the combined application of *Azospirillum* and PSB and *Azospirillum* with PSB and ZnSB showed signifi-

Table 1. Nitrogen concentration and uptake in paddy as affected by nutrient mangament practices

Treatment	N concentration in Grain (%)	N concentration in Straw (%)	N uptake in (kg/ha)		
			Grain	Straw	Total nitrogen uptake
Nutrient management practices					
Organic	1.23	0.52	43.42	29.50	72.93
Inorganic	1.32	0.55	53.94	33.50	87.43
INM	1.30	0.53	55.77	33.55	89.32
S Em±	0.017	0.003	1.07	0.52	1.35
CD (P=0.05)	0.050	0.012	4.24	2.04	5.31
Microbial inoculants					
Control	1.26	0.52	45.88	29.24	75.12
Azospirillum	1.28	0.53	50.24	31.27	81.50
Azospirillum + PSB	1.29	0.54	52.62	33.44	86.06
Azospirillum + PSB + ZnSB	1.30	0.55	55.43	34.78	90.22
S Em±	0.014	0.003	0.87	0.57	1.01
CD (P=0.05)	0.03	0.01	2.58	1.70	3.01
Interaction	NS	NS	NS	NS	S

N content in grains and straw

cantly higher P concentration over control. Treatments with sole *Azospirillum* recorded statistically lower P concentration compared to *Azospirillum*+ PSB+ ZnSB treatments however it was *at par* with *Azospirillum* + PSB. The interaction effect due to the nutrient management practices and microbial inoculants was not significant in both grains and straw. *Bacillus subtilis* is capable of maintaining stable contact with plant roots and promoting plant growth (Charest *et al.*, 2005). Chen *et al.* (2006) also reported a higher level of P uptake by plants due to the inoculation with PSB.

P uptake in grains and straw

P uptake by grains, straw and total uptake by rice is presented in (Table 4). In nutrient management practices, both inorganic and INM resulted in higher P uptake over organic whereas the difference between inorganic and INM was *at par*. The highest value of P uptake in grain (5.95 kg/ha), straw (5.83 kg/ha) and total (11.78 kg/ha) were recorded in INM and those were followed by inorganic and organic treatments. Among the microbial inoculants, the higher most values of P uptake were recorded in *Azospirillum*+ PSB+ ZnSB followed by *Azospirillum*+ PSB, *Azospirillum* + PSB+ ZnSB and control. For P uptake in grain, except for *Azospirillum*+ PSB and *Azospirillum* + PSB+ ZnSB treatment, all other combinations recorded significant differences. The total uptake of P was significantly higher with microbial inoculation over the control. The highest value of P uptake was (6.00 kg/ha), (5.96 kg/ha) and (11.96 kg/ha) (grain, straw and total respectively) was recorded with *Azospirillum* + PSB+ ZnSB treatment. Qurban *et al.* (2013) conducted an experiment to study the effect of organic acids and PSB on phosphate solubilization from rock phosphate on the growth of aerobic rice. The results of that study showed significantly higher phosphorus solubilization through phosphate-solubilizing bacteria (PSB) along with organic acid treatments. By secreting organic acids, certain soil bacteria may convert the insoluble phosphate in the soil into soluble forms (Gupta, 2004).

Table 3. Grain, straw and biological yield at different stage in rice crop under different nutrient application practices

Treatment	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)
Nutrient management practices			
Organic	3.65	5.69	9.34
Inorganic	4.08	6.06	10.15
INM	4.27	6.28	10.55
S Em±	0.08	0.09	0.16
CD (P=0.05)	0.34	0.36	0.63
Microbial inoculants			
Control	3.72	5.62	9.34
Azospirillum	3.94	5.94	9.89
Azospirillum+ PSB	4.10	6.17	10.27
Azospirillum+ PSB+ ZnSB	4.25	6.31	10.56
S Em±	0.05	0.10	0.11
CD (P=0.05)	0.17	0.31	0.33
Interaction	S	S	S

Grain yield

Both main and subplot treatments had a substantial impact on the rice crop's grain yield (Table 4). INM had the grain yield (4.27 t/ha) that was significantly higher over inorganic (4.08 t/ha) and organic (3.65 t/ha) treatments. INM and inorganic management differed significantly from organic management in terms of yield. However, the difference between INM and inorganic was not significant. Inorganic and INM management had a yield advantage over organic management of 12% and 17%, respectively. In the microbial inoculation treatments, combined inoculation with *Azospirillum* + PSB+ ZnSB, *Azospirillum* + PSB and sole inoculation with *Azospirillum* gave significantly higher grains yield over control. The difference between *Azospirillum* alone and *Azospirillum* + PSB + ZnSB was also found to be significant. The Azospirillum+ PSB+ ZnSB yielded highest (4.25 t/ha) and control yielded the lowest (3.72 t/ha) grain yields treatments. When compared to the control treatment, the inoculation with Azospirillum alone, Azospirillum+ PSB, and Azospirillum + PSB+ ZnSB had yield advantages of 5.91%, 10.21%, and 14.24%. The interaction effect due to the nutrient management practices and inoculation of microbial inoculants was found to be significant. Shah and Kumar (2014) also reported, application of either 50% RDF with 50% RDN through MOC (mustard oil cake) or 75% RDF with 25% RDN through MOC and biofertilizer exhibited better grain yields of 20.2% to 33.8% and higher straw yields of 11.0% to 33.3%. Rao *et al.* (2014) reported that yield obtained under organic farming was 14-51% lower than inorganic and integrated nutrient management in rice even after seven years across the country.

Table 4. Phosphorus concentration and uptake in paddy as affected by nutrient management practices

Treatment	P concentration (ppm)		P uptake (kg/ha)		
	Grain	Straw	Grain	Straw	Total
Nutrient management practices					
Organic	1340.00	857.31	4.90	4.88	9.78
Inorganic	1428.27	949.55	5.84	5.78	11.62
INM	1391.20	926.42	5.95	5.83	11.78
S Em±	8.77	8.78	0.12	0.13	0.23
CD (P=0.05)	34.32	34.41	0.49	0.51	0.91
Microbial inoculants					
Control	1364.49	888.30	5.08	4.94	10.03
Azospirillum	1368.50	890.20	5.42	5.38	10.80
Azospirillum+ PSB	1399.56	921.32	5.75	5.70	11.45
Azospirillum+ PSB+ ZnSB	1409.13	940.39	6.00	5.96	11.96
S Em±	10.01	7.31	0.10	0.12	0.15
CD (P=0.05)	29.72	21.77	0.29	0.35	0.46
Interaction	NS	NS	NS	NS	S

Straw yield

The use of microbial inoculants and practices for nutrient management had a considerable impact on rice straw yield, just like they had on grain yield (Table 3). INM had the highest straw yield (6.28 t/ha), followed by inorganic (6.06 t/ha), and organic (5.09 t/ha). There was a substantial difference between INM and inorganic management compared to organic management. But the differences between INM and inorganic were not significant. The lowest straw yield (5.69 t/ha) was recorded in organic treatment. Among the microbial inoculants, combined inoculation with *Azospirillum*+ PSB+ ZnSB, *Azospirillum*+ PSB and sole inoculation with *Azospirillum* gave significantly higher straw yield over the control. Azospirillum alone and Azospirillum+ PSB+ ZnSB were observed to differ significantly from each other. Straw yields were highest in the *Azospirillum* + PSB+ ZnSB treatments (6.31 t/ha) and lowest in the control treatments (5.62 t/ha). Comparing the inoculation with *Azospirillum* alone, *Azospirillum* with PSB, and *Azospirillum* with PSB and ZnSB to the control treatment, there was a yield advantage of 5.69%, 9.78%, and 12.27%. On straw yield, it was discovered that there was a strong interaction impact caused by the nutrient management practices and the inoculation of microbial inoculants. Shah and Kumar (2014) in an experiment observed higher straw yield of 83.3 and 85.6 q/ha during 2009 and 2010, respectively under INM practice including bio-fertilizers. The higher yield under INM practice might be due to its greater availability and uptake of macro as well as micronutrients and active participation in photosynthesis, starch formation, entry of water into plants roots and translocation of protein. It also enhanced the process of tissue differentiation from somatic to reproductive phase, thus lead to higher grain and straw yield (Hossaen *et al.*, 2011). Sharma *et al.* (2010) also found highest grain and straw yield and harvest index when RP was combined with the inoculation of PSB.

Biological yield

Nutrient management techniques and microbial inoculants also had a big impact on rice's biological yield, which included grain and straw yields (Table 3). In nutrient management practices both inorganic and INM gave significantly higher biological yield over organic treatment. The highest (10.55 t/ha) biological yields were recorded under INM and lowest (9.34 t/ha) with organic plots. In terms of the microbial inoculants, sole inoculation with Azospirillum and mixed inoculation with Azospirillum+ PSB+ ZnSB and Azospirillum+ PSB considerably increased the biological yield compared to the control. The treatments sole *Azospirillum* and *Azospirillum*+ PSB, as well as Azospirillum and Azospirillum+ PSB+ ZnSB, also showed significant differences in biological yields. The interaction effect due to the nutrient management practices and inoculation of microbial inoculants on straw yield was found to be significant. Prasad *et al.* (1995) observed that INM sustain high level of production as well as productivity of rice crop.

Conclusion

With inorganic nutrient management practices, the highest N contents in grain (1.32%) and straw (0.55%) were found. The highest values of N uptake in grain, straw and total uptake were recorded at 55.43, 33.55 and 89.32 kg/ha, respectively in INM which were *at par* with inorganic treatment. The highest concentrations of P in grain (1428.27 ppm) and straw (949.55 ppm) were recorded with mineral fertilization at RDF (inorganic) nutrient management practice and those were followed by INM and organic treatment. The maximum grain yield (4.27 t/ha), followed by inorganic (4.08 t/ha), and organic (3.65 t/ha), was seen in INM. Inorganic and INM management had a yield advantage over organic management of 12% and 17%, respectively. It is possible to draw the conclusion that farmers can use INM, which consists of 75% mineral fertiliser and 25% organic inputs, to increase low land rice production, profitability, and grain quality in the eastern Himalayas. However, soil quality was the best under organic management.

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