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Effect of Biological Products on Yield, Production Economics and Soil Nutrient Status of Transplanted *kharif* Rice (*Oryza sativa* L.) in Gangetic Alluvial Soil of West Bengal, India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Field experiment was conducted during *kharif* season of 2017 and 2018 at Instructional Farm under Bidhan Chandra Krishi Viswavidyalaya, West Bengal in sandy loam soil to study the growth and yield of transplanted *kharif* rice variety Satabdi (cv. IET 4786) as influenced by biological products. The experiment was laid down in randomized complete block design (RCBD) with seven treatment combinations replicated thrice. Results revealed that RDF + soil applied Bolt GR @ 10 kg/ha produced higher growth attributes and yield of tested rice cultivar. The same treatment registered significantly higher total N and K uptake in tested cultivar; while the highest P uptake was recorded with RDF + Seed treatment with JumpStart2.0 @ 0.83 ml/kg seed. The treatment RDF + soil applied *Azospirillum* @ 2 kg/ha brought about significant positive changes of available N content in post-harvest soil over control situation (only RDF). However, significantly higher available P content was estimated in plots with RDF + soil applied PSB @ 2 kg/ha. Application of bio-products failed to exert any significant influence on residual soil K. The crop receiving RDF + soil applied Bolt GR @ 10 kg/ha gave highest gross return, net return and B:C ratio. Hence, application of RDF (60-30-30 kg N, P_2O_5 and K_2O/ha) along with Bolt GR @ 10 kg/ha or *Azospirillum* @ 2 kg/ha may be recommended to achieve higher grain yield of tested cultivar Satabdi (cv. IET 4786).

Keywords: Biological products; wet season rice; nutrient uptake; yield; economics.

1. INTRODUCTION

Almost every household in West Bengal depends heavily on rice (*Oryza sativa* L.) for food and livelihood security. Moreover, the demand for rice continues to increase owing to continued population growth. During 2015-16, rice production was to the tune of 159.5 lakh tones from 55.24 lakh hectare areas, with a productivity of 2.89 t/ha [1]. Presently, land is scarce and expansion is unlikely. The State's paddy fields are under pressure from increasing urbanization, climate change, and competition from other high-value agriculture, so rice yield will need to increase more quickly [2]. Rice yield growth of 1.0-1.2% annually beyond 2020 will be needed to meet the burgeoning demand without further soil degradation and environmental pollution [1].

Any enhancement to the agricultural system that raises productivity ought to lessen agriculture's detrimental effects on the environment and strengthen the system's sustainability. Using biological products to increase the efficacy of traditional mineral fertilizers is one such strategy. Biological products contain beneficial naturally occurring microorganisms or microbial derivatives as active ingredients that contribute to sustainable agriculture by increasing availability and uptake of mineral nutrients in the plant. The present study used different type of biological products namely Jump Start, Bolt GR, Ratchat, *Azospirillum* and PSB. JumpStart developed in Western Canada with a strain of *Penicillium bilaii* which improves P use efficiency in plants. The bio-stimulant product Bolt GR is a combination of humic acid, cold water extracts, ascorbic acid, amino acid, myo-inositol, thiamine and alpha-tocopherol. Humic acid, the primary ingredient in Bolt GR, acts on mechanisms involved in cell respiration, photosynthesis, protein synthesis, water and nutrient uptake, and enzyme activities to promote plant growth and, ultimately, yield. It has been shown that humic acid has a dose-dependent action that is especially potent at low concentrations. The main component of ratchat is lipo-chitooligo saccharides (LCOs), which are the essential signal molecules secreted by these microorganisms to start plant-microbe symbiotic relationships. The plant growth regulator LCOs exerts significant impact on plant biomass production, shoot and root growth, lateral root branching, cell cycle, embryogenesis, and seed germination [3]. Free-living bacteria called *Azospirillum* have the ability to influence the growth and yield of many different plant species, some of these bacteria are known to be plant-growth-promoting bacteria, or PGPBs [4]. Phosphate solubilizing bacteria (PSB) function as a bio-fertilizer, capable of solubilizing and mineralizing residual or fixed phosphorus, thereby enhancing its availability in the soil. It also produces growth substances like indole acetic acid, and gibberellins, ultimately increasing the overall phosphate use efficiency [5]. Taking due cognizance of above facts, the present experiment was planned to study the influence of biological products on rice production system during wet season in Gangetic alluvial soil of West Bengal.

2. MATERIALS AND METHODS

A field experiment was conducted during the wet seasons of 2017 and 2018 at the Instructional Farm of Bidhan Chandra Krishi Viswavidyalaya, Jaguli, Nadia, West Bengal ($22^0 93'$ N latitude, 88^0 $53'$ E longitude and at an elevation of 9.75m above MSL) under medium land situation to study the growth and yield of transplanted *kharif* rice as influenced by biological products. The experimental soil was sandy loam in texture (order *Inceptisol*), neutral in reaction (pH 7.1) and medium in total nitrogen (187.5 kg/ha), available phosphorus (38.6 kg/ha) and available potassium (201.8 kg/ha). The experimental site is characterized by a subtropical sub-humid climate, with an average annual rainfall of 1450 mm, 75% of which occurs between June and September. During crop growth period, the average maximum and minimum temperature fluctuated between 28.03ºC to 33.67ºC and 19.34 to 24.04ºC, respectively. The maximum and minimum relative humidity varied from 90 to 97.0% and 51.2 to 85.7%, respectively.

The experiment was laid down in randomized complete block design (RCBD) with seven treatment combinations namely T_1,100% RDF (60-30-30 kg N, P_2O_5 and K_2O/ha); T_2, 100% RDF + seed treatment with JumpStart 2.0 @ 0.83ml/kg seed; T_3, 100% RDF + soil application of Bolt GR @ 10 kg/ha; T_4, 100%RDF+ foliar application of Ratchet @ 300 ml/ha at 30 and 60 DAT; T_5, 100% RDF + foliar application of Ratchet @ 450 ml/ha at 30 and 60 DAT; T_6, 100% RDF + soil application of *Azospirillum*@ 2 kg/ha andT_7, 100% RDF + soil application of PSB @ 2 kg/ha and replicated thrice. One-fourth ($¼^{th}$) N along with full P_2O_5 and $¾^{th}$ K_2O of RDF were applied as basal (during final land preparation). Remaining ½ N was top-dressed at tillering stage, while $¼^{th}$ each of N and K_2O was given at panicle initiation stage. As advised for the area, all additional cultural and plant protection measures were also implemented. The test crop was rice cv. Satabdi (IET-4786). The individual plot size was 5m × 4m. In the main field, rice seedlings were transplanted@ 3 per hill with a spacing of 20cm × 15cm. The crop was harvested during 3^{rd} week of October when the plant become yellowish to brown and had around 14% grain moisture. Data on various yield components were collected at harvest. Harvested crops were kept in the field for 2-3 days for sun-drying and then threshing was done plot-wise separately. The grain and straw were properly sun-dried, weighed, and then converted into tons per hectare (t/ha).

Plant samples from each treatment were collected, oven-dried, and ground to analyze total recoveries of N, P and K at harvesting using standard procedures. Post-harvest soil samples were analyzed for total available N, P and K content using standard methods. Gross return, net return, and benefit-cost (B-C) ratios were calculated for wet season rice, utilizing market prices for inputs and the minimum support price established by the West Bengal government for outputs. Data obtained on measured growth and yield parameters were analyzed following the method of analysis for RCBD as described by Gomez and Gomez [6]. The significance of different sources of variation was tested at probability level of 0.05. The standard error of mean (S Em±) and critical difference (CD) value were considered for comparing treatment mean values.

3. RESULTS AND DISCUSSION

3.1 Growth Attributes

Tested biological products exerted significant impact on measured growth attributes namely plant height and DMA at 90 DAT while LAI at 60 DAT (Table 1). RDF along with soil applied Bolt GR @ 10 kg/ha along with produced plants with maximum height (102.7 cm), greater LAI (4.28) and DMA (852.2 g/m^2); being statistically at par with soil application of *Azospirillum*@ 2 kg/ha. The biological products supplied plant growth promoting substances such as hormones, organic acids, polysaccharides, amino acid, protein which in turn accelerated soil biological activities. They also enhanced the inherent plant capacity to express its full potential. Higher plant vigour, as observed with RDF + Bolt GR @ 10 kg/ha, might be attributed to the development of numerous root branching as well as root hairs and thereby increased nutrient uptake capacity. This effect on rice root system was enormous probably due to secretion of growth hormones and nitrogen fixation by bacteria. In addition, the humic acid being a component of Bolt GR is responsible for increasing the fresh and dry weight of the leaves, shoots, roots as well as number and plinth area of leaves [7]. In the present study, the observed greater LAI with the application of biological products was might due to better soil physico-chemical properties *vis-à-vis* better soil environment and increased crop growth. Previous studies also reported that *Azospirillum* inoculation resulted in crop growth enhancement in terms of height, number of leaf/plant, size of leaf and overall aerial biomass [8]. One of the main mechanisms proposed to explain plant growth promotion by *Azospirillum* sp. involves its ability to produce and metabolize various phytohormones and other plant growth-regulating molecules [9].

The crop growth rate of tested cultivar varied significantly (p≤0.05) with different treatments and showed a declining trend towards maturity. Similarly, biological products had a significant influence on length and dry weight of roots. The plants receiving RDF + Ratchet @ 450 ml/ha exhibited the maximum CGR during 30-60 DAT and it was statistically at par with plants receiving RDF + soil applied Bolt GR @ 10 kg/ha. The plants receiving RDF + JumpStart 2.0 @ 0.83ml/kg seed exhibited the highest root length (28.6cm) and dry weight (5.65g) at 60 DAT; being statistically at par with plants receiving RDF + soil applied Bolt GR @ 10 kg/ha and *Azospirillum*@ 2 kg/ha. In contrary, the lowest CGR, root length and dry weight was recorded in plants grown with RDF only. The strain *Penicillium bilaii*, main constituent of JumpStart 2.0, has been known to augment root length and root hair abundance, besides P solubilization [10]. The strategic application of biological products can enhance crop growth by increasing nutrient, moisture, and soil resource access, ultimately resulting in greater productivity and yield.

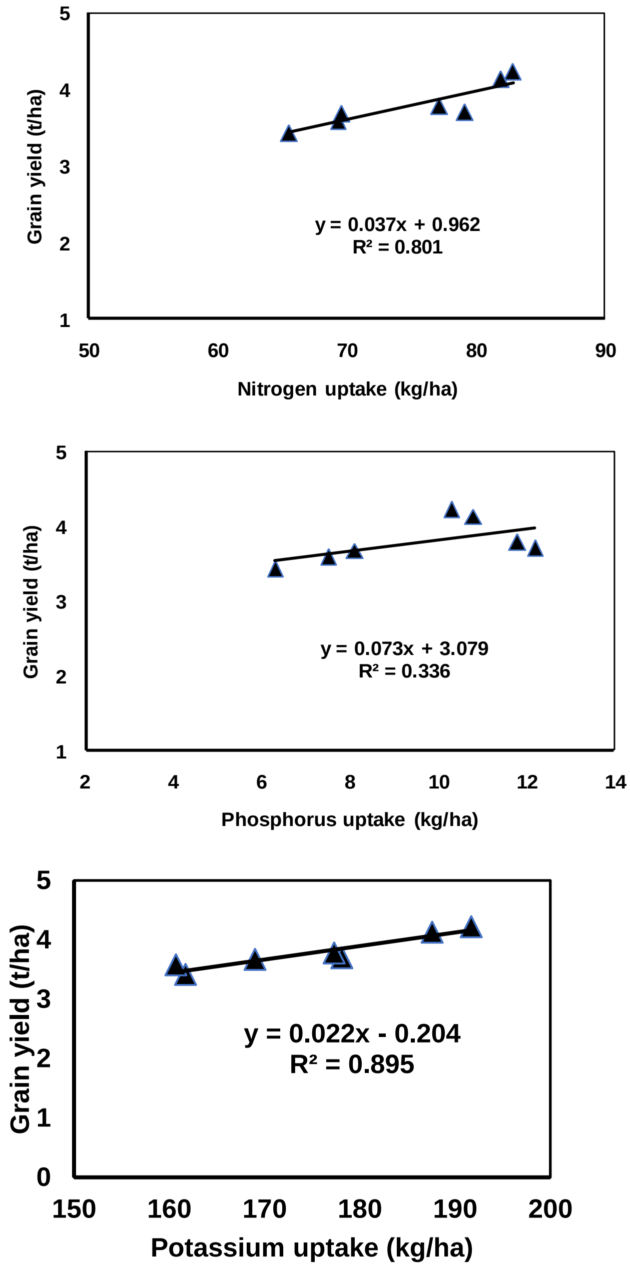
3.2 Panicle Length, Yield and Harvest Index

Measured panicle length varied significantly with the application of different bio-products in wet season (Table 2). The highest value of the parameter was recorded in plants fertilized with RDF + soil applied Bolt GR @ 10kg/ha, while the next best treatment was RDF + soil applied Jump Start @ 0.83ml/kg seed. This promising outcome may be attributed to the improved assimilation of growth resources, such as growth hormones, micronutrients, enzymes, proteins, vitamins, and other beneficial compounds, which were introduced to the plots receiving these biological products, so increased availability of these key nutrients and substances may have enhanced the overall growth and productivity of the crop. The loss of nitrogen is expected to be less in presence of humic acid, a component of Bolt GR, and thereby helped in better reproductive growth with greater panicle length and better grain filling [11].

The grain and straw yield of wet season rice was significantly improved on receiving different biological products (Table 2). The highest grain (4.22 t/ha) and straw yield (5.83 t/ha) was recorded in plots fertilized with RDF + soil application of Bolt GR @ 10 kg/ha; being statistically at par with grain yield obtained with RDF + soil applied *Azospirillum* @ 2 kg/ha. The strategic timing of biological product applications during critical phases of rice crop growth could account for the observed enhancement in growth characteristics and yield components. This synchronous deployment could optimize the utilization of these products by the plant, ultimately culminating in an increase in grain yield. The results are in agreement with findings of Osman et al. [12] who also opined that foliar spraying of humic and or fulvic acids, components of Bolt GR, influences grain yield and quality of rice cultivars. Incorporating Azospirillum into plant cultivation has been observed to yield impressive results, with increases in growth and yield rivaling the application of 15-20 kg of nitrogen per hectare. This remarkable finding highlights the efficacy of harnessing beneficial microorganisms for sustainable agriculture, reducing the need for excessive chemical fertilizer use [13]. Full NPK along with *Azospirillum* might have created the most convenient situation for better soil nutrient availability and higher nutrient accumulation [14], and hence the response in our study. Similarly, Govindan and Bagyaraj [15] observed that inoculation of *Azospirillum* sp. to wetland rice under acidic condition improved shoot growth, straw yield and N uptake. In the present study, bio-product application exerted significant influence on harvest index (HI), which ranged from 40.9 to 42.3%. However, the crop receiving RDF along with *Azospirillum* gave highest value of HI, which indicated greater translocation of photosynthates from source to sink and also better portioning towards reproductive growth [14]. In the present study, the lowest HI was recorded in plants fertilized with RDF only.

3.3 Nutrients Uptake

The nutrient uptake (N, P and K) by rice was significantly influenced by biological products (Table 3). The treatment RDF + soil applied Bolt GR @ 10 kg/ha registered significantly higher total N (82.9 kg/ha) and K (191.7 kg/ha) uptake in tested cultivar; being statistically at par with the treatment RDF + soil applied *Azospirillum* @ 2 kg/ha. Sivakumar et al. [16] also found that application of humic acid up to 20 kg/ha along with RDF resulted in highest total uptake of N, P and K in rice. Much earlier, Kannan and Ponmurugan [8] recorded significant increase in different plant parameters such as height, tiller number, dry matter yield and N uptake of rice plants with *Azospirillum* inoculation. Phonglosa et al. [14] also found highest recoveries of NPK on supplementation of chemical NPK with *Azospirillum*. In the present study, application of RDF + JumpStart 2.0 @ 0.83 ml/kg seed registered significantly highest P uptake in tested cultivar (Table 3), closely followed by those obtained with the treatment RDF + soil applied PSB @ 2 kg/ha. Results also indicated that PSB had a significant influence on grain yield, biological yield and total P uptake. Stimulation of plant growth by *P. bilaii* inoculation without a concurrent increase in the P content in plants had earlier been found in the study of Tripathy et al. [10]. In the present study, the total N, P and K uptake by plant were recorded lowest in control plot (RDF only). As expected, the relationship between nutrient uptake was linear and the grain yield of *kharif* rice was significantly correlated (R^2 = 0.801) in case of N, (R^2 = 0.336) in case of P and in case of K, (R^2 = 0.895) to the amount nutrient uptake (Fig. 1a, 1b and 1c).



[a]

[b]

[c]

Fig. 1. Correlation between grain yield and N uptake [a], grain yield and P uptake [b] and grain yield and K uptake [c]

Table 1. Effect of biological products on growth attributes of transplanted rice during wet season (mean data of 2 years)

Treatments	Plant height (cm) at 90 DAT	LAI at 60 DAT	DMA (g/m^2) at 90 DAT	CGR (g/m^2/day) 30-60 DAT	Root length (cm) at 60 DAT	Root dry weight (g/hill) at 60 DAT
T_1, RDF	93.9	3.83	773.8	11.72	19.3	3.98
T_2,RDF + JumpStart @ 0.83ml/kg seed	97.3	3.98	836.7	11.84	28.6	5.65
T_3, RDF + Bolt GR @ 10 kg/ha	102.7	4.28	852.2	12.51	27.9	5.42
T_4, RDF + Ratchet @ 300 ml/ha	95.2	4.05	786.9	12.11	22.4	4.27
T_5, RDF + Ratchet @ 450 ml/ha	96.2	4.12	798.3	12.72	23.8	4.53
T_6, RDF + *Azospirillum* @ 2 kg/ha	100.8	4.23	847.8	12.34	27.4	5.03
T_7, RDF+ PSB @ 2 kg/ha	99.8	4.14	822.1	12.11	28.2	5.52
S.Em (±)	0.65	0.05	3.52	0.08	1.48	0.24
CD (P=0.05)	1.98	0.16	10.8	0.27	4.61	0.78

RDF: Recommended N:P_2O_5: K_2O dose of 60:30:30 kg/ha
LAI, Leaf area index; DMA, Dry matter accumulation; CGR, Crop growth rate; DAT, Days after transplanting

Table 2. Effect of biological products on panicle length, grain yield, straw yield and harvest index of transplanted rice during wet season (mean data of 2 years)

Treatments	Panicle length (cm)	Grain yield (t/ha)	Straw yield (t/ha)	Harvest Index (%)
T_1, RDF	22.2	3.42	4.68	40.9
T_2,RDF + JumpStart @ 0.83ml/kg seed	24.3	3.70	5.26	41.2
T_3, RDF + Bolt GR @ 10 kg/ha	25.1	4.22	5.83	41.9
T_4, RDF + Ratchet @ 300 ml/ha	22.6	3.58	4.98	41.8
T_5, RDF + Ratchet @ 450 ml/ha	23.6	3.67	5.12	41.7
T_6, RDF + *Azospirillum* @ 2 kg/ha	24.2	4.13	5.64	42.3
T_7, RDF+ PSB @ 2 kg/ha	23.5	3.78	5.25	41.8
S.Em (±)	0.42	0.08	0.21	-
CD (P=0.05)	1.31	0.26	0.67	-

RDF: Recommended N: P_2O_5:K_2O dose of 60:30:30 kg/ha
NS, Non-significant

Table 3. Effect of biological products on total plant nutrient uptake,soil nutrient status and economics of transplanted rice during wet season (mean data of 2 years)

Treatments	Total (kg/ha)	Nutrient	Uptake	Residual soil nutrient status (kg/ha)			Gross return (Rs/ha)	Net return (Rs/ha)	B:C ratio
	N	P	K	Available N	Available P	Available K			
T_1, RDF	65.5	6.3	161.7	189.3	40.1	202.2	61,555	18,993	1.45
T_2, RDF + JumpStart @ 0.83ml/kg seed	79.2	12.2	178.1	193.1	45.9	209.3	72,110	29,240	1.68
T_3, RDF + Bolt GR @ 10 kg/ha	82.9	10.3	191.7	198.8	42.7	208.3	79,680	35,618	1.81
T_4, RDF + Ratchet @ 300 ml/ha	69.3	7.5	160.7	195.8	40.2	203.5	67,630	23,874	1.55
T_5, RDF + Ratchet @ 450 ml/ha	69.6	8.1	169.0	196.4	41.8	204.8	69,345	24,975	1.56
T_6, RDF + *Azospirillum* @ 2 kg/ha	82.0	10.8	187.6	203.1	44.1	210.3	77,915	34,703	1.80
T_7, RDF+ PSB @ 2 kg/ha	77.2	11.8	177.3	195.4	46.2	209.5	71,400	28,578	1.67
S.Em (±)	1.42	0.54	3.24	1.78	0.62	3.02	-	-	-
CD (P=0.05)	3.67	1.81	9.76	5.64	1.86	NS	-	-	-

RDF: Recommended N: P_2O_5:K_2O dose of 60:30:30 kg/ha
NS, Non-significant

3.4 Nutrient Status of Post-Harvest Soil

The treatment RDF + soil applied *Azospirillum* @ 2 kg/ha brought about greater positive changes of available N content in post-harvest soil over control situation (RDF only) (Table 3). However, it was statistically at par with RDF + soil applied Bolt GR @ 10 kg/ha. Significantly higher available P content was estimated in plots with RDF + soil applied PSB @ 2 kg /ha: being statistically at par with the treatment RDF + seed treatment JumpStart 2.0 @ 0.83ml/kg. Phosphate-solubilizing bacteria (PSB) are a unique class of bio-fertilizers that effectively enhance soil phosphorus availability. They accomplish this through their ability to solubilize and mineralize residual or fixed phosphorus, thereby increasing phosphorus uptake by plants. In addition to their vital role in soil fertility, PSB also produce essential growth substances such as indole acetic acid and gibberellins, which further contribute to greater phosphate use efficiency [5]. In the present study, application of bio-products failed to exert any significant influence on residual soil K. The overall status of N, P and K was marginally higher over initial values where only RDF was applied. This might be due to the less uptake of NPK leading to a substantial amount of left-over nutrients in post-harvest soil [17,18].

3.5 Economic Analysis

Combined application of RDF and biological products proved their superiority over sole RDF application (Table 3). In most cases, the observed yield gain were not huge (only 0.16 to 0.80 t/ha) but provided substantial income gains given the relatively low costs for all tested biological products. The crop receiving RDF + soil applied Bolt GR @ 10 kg/ha gave highest gross return, net return and B:C ratio. This might be due to the highest productivity realized at this application rate. In contrary, the lowest economic benefit was realized with control treatment (only RDF) due to poor grain yield [19,20].

4. CONCLUSION

Based on the findings, application of the recommended dose of fertilizer (RDF) at 60-30-30 kg N, P_2O_5, and K_2O per hectare, along with soil application of Bolt GR (10 kg/ha) or *Azospirillum* (2 kg/ha), is recommended to attain higher grain yields of *kharif* season rice (cv. IET 4786) in the Gangetic alluvial soil of West Bengal.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Banerjee H, Samanta S, Sarkar S, Garai S, Pal S, Bramhachari K. Growth, productivity and nutrient uptake of different rice cultivars under coastal eco-system of West Bengal. Journal of Indian Society of Coastal Agricultural Research. 2018;36(2): 115-121.
2. Mondal R, Goswami S, Mandi SK, Goswami SB. Quality Seed Production of Rice (*Oryza sativa* L.) as Influenced by Nutrient Management During Kharif Season in the Lower Indo-Gangetic Plains. Environment and Ecology. 2019;37 (1A): 274-280.
3. Maillet F, Poinsot V, Andre O, Puech-Pages V, Haouy A, Gueunier M, Cromer L, Giraudet D, Formey D, Niebel A, Martinez EA, Driguez H, Becard G and Denarie J. Fungal lipo chito oligo saccharide symbiotic signals in arbus cular mycorrhiza. Nature. 2011;469:58–63.
4. Sana M, Jana K, Mondal R, Mondal K, Banerjee H. Integration of chemical fertilizer with biological products on growth and production of rice during wet season. Oryza. 2020;57(3): 211-218
5. Chhonkar PK, Tilak KBR. Bioferilizers for sustainable agriculture: Research gaps and future needs. In Plant Nutrient Needs Supply, Efficiency and Policy Issues: 2000-2025 (Eds. JS. Kanwar and JC. Katyal). National Academy of Agricultural Sciences, New Delhi, pp. 52-66.
6. Gomez KA and Gomez AA 1984. Statistical Procedures for Agricultural Research.John Wiley and Sons, New York; 1997.
7. Vijoyakumari B, Yadav RH, Gowri P, Kandari LS. Effect of panchagavya, humic acid and micro herbal fertilizer on the yield and post harvest soil of soya bean (*Glycine*

max L.). Asian Journal of Plant Science. 2012;11(2):83-86.
8. Kannan T, Ponmurugan P. Response of paddy (*Oryza sativa* L.) varieties to Azospirillumbrasilense inoculation. Journal of Phytogy. 2010;2(6):08–13.
9. Salamone IEG de, Salvo LPD, Ortega JSE, Sorte PMFB, Urquiaga S, Teixeira RS. Field response of rice paddy crop to Azospirillum inoculation: physiology of rhizosphere bacterial communities and the genetic diversity of endophytic bacteria in different phases of plants. Plant and Soil. 2010;336:351-362.
10. Tripathy P, Kar M, Sahoo CR. Bio-fertilizer on nutrient acquisition, grain yield and grain quality of rice. Environment and Ecology. 2009;27(4A):1694- 1697.
11. Dhanasekaran K, Govindasamy R. Effect of urea coated with lignite derived humic substances on the performance of rice in a TypicChromustert soil. Advances in Plant Sciences. 2002;15(2): 505-509.
12. Osman EAM, EL-Masry AA, Khatab KA. Rice productivity and its inner quality as affected by anhydrous ammonia rates with foliar application of organic acids. Advances in Applied Science Research. 2013;4(4):174-183.
13. Rodrigues PE, Rodregues LS, Oliveira ALM de, Baldani VLD, Teixeira KR, Dos S, Urquiaga S, Reis VM. Azospirillum amazonense inoculation: effects on growth, yield and N_2-fixation of rice (*Oryza sativa* L.). Plant and Soil. 2008;302:249-361.
14. Phonglosa A, Bhattacharyya K, Ray K, Mandal J, Pari A, Banerjee H, Chattopadhyay A. Integrated nutrient management for okra in an inceptisol of eastern India and yield modeling through artificial neural network. Scientia Horticulturae. 2015;187:1-9.
15. Govindan M, Bagyaraj DJ. Field response of wetland rice to Azospirillum inoculation. Journal of Soil Biology and Ecology. 1995; 15:17-22.
16. Sivakumar K, Devarajan L, Dhanasekaran K, Venkatakrishnan D, Surendran U. Effect of humic acid on the yield and nutrient uptake of rice. Oryza. 2007;44(3):277-280.
17. Kamble BM, Rajkumar Meena PN, Gajbhiye. Influence of Iron Nutrition on Soil Properties, Uptake and Yield of Soybean Grown on Iron Deficient Inceptisol. Journal of Experimental Agriculture International. 2022;44(11):131-42. Available:https://doi.org/10.9734/jeai/2022/v44i112059.
18. Singh NK, Kushal Sachan, Ranjitha G, Chandana S, Manoj BP, Narinder Panotra, and Drishty Katiyar. Building Soil Health and Fertility through Organic Amendments and Practices: A Review. Asian Journal of Soil Science and Plant Nutrition. 2024; 10(1):175-97. Available:https://doi.org/10.9734/ajsspn/2024/v10i1224.
19. Hossain MZ, Bahar MM, Sarkar B, Donne SW, Ok YS, Palansooriya KN, Kirkham MB, Chowdhury S, Bolan N. Biochar and its importance on nutrient dynamics in soil and plant. Biochar. 2020;2:379-420.
20. Mitra GN. Regulation of nutrient uptake by plants. New Delhi: Springer. 2015;10: 978-81.

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