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Effect of biofertilizer and organic manure on the growth and yield of rice (*Oryza sativa* L.)

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Abstract

The field experiment was carried out during the kharif season of 2024 at the crop research farm of the Department of Agronomy, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj (U.P.), India. The experiment was entitled “Effect of Biofertilizer and Organic Manure on the Growth and Yield of Rice (*Oryza sativa* L.)”. It was laid out in a randomized block design (RBD) consisting of nine treatments replicated thrice, viz., T₁: Azotobacter 6 kg/ha with FYM 12 t/ha, T₂: Azotobacter 6 kg/ha with vermicompost (VC) 5 t/ha, T₃: Azotobacter with poultry manure (PM) 4 t/ha, T₄: Azolla 500 kg/ha with FYM 12 t/ha, T₅: Azolla 500 kg/ha with VC 5 t/ha, T₆: Azolla 500 kg/ha with PM 4 t/ha, T₇: Azotobacter 3 kg/ha with Azolla 500 kg/ha and FYM 12 t/ha, T₈: Azotobacter 6 kg/ha with Azolla 500 kg/ha and VC 5 t/ha, and T₉: Azotobacter 6 kg/ha with Azolla 500 kg/ha and PM 4 t/ha. The results of the experiment showed that growth parameters such as plant height (58.52 cm), number of tillers per plant (11.94), and plant dry weight (42.44 g) were significantly increased with higher levels of Azotobacter, Azolla, and PM, with the maximum observed under the application of Azotobacter 6 kg/ha, Azolla 500 kg/ha, and PM 5 t/ha. Significantly highest number of effective tillers per m² (421.67), number of grains per panicle (187.27), grain yield (3.49 t/ha), and straw yield (6.92 t/ha) were also recorded under this treatment. Additionally, gross return (INR 2,86,447.00/ha), net return (INR 1,89,647.50/ha), and benefit: cost ratio (2.40) were highest with the application of Azotobacter 6 kg/ha, Azolla 500 kg/ha, and PM 5 t/ha.

Keywords: Biofertilizer, organic manure, growth, yield, economic, rice (Pusa basmati1718)

Introduction

Rice (*Oryza sativa* L.) is one of the world's most vital staple food crops, serving as a primary source of sustenance for nearly two-thirds of the global population. India plays a key role in rice cultivation and production. As a staple, rice is rich in carbohydrates—mainly in the form of starch—which makes it a quick source of energy. It contributes approximately 27% to the global dietary energy intake, 20% to dietary protein, and around 3% to dietary fat. In addition to macronutrients, rice also offers notable nutritional benefits by supplying essential micronutrients such as thiamine, riboflavin, niacin, and zinc, though it contains only smaller quantities of other vitamins and minerals. According to the U.S. Department of Agriculture (USDA), India's paddy production for 2024-2025 is estimated at 220.52 million metric tons (rough rice), with a milled rice output of 147 million metric tons. This marks a significant increase from the previous year's production of 206.76 million metric tons of rough rice and 137.83 million metric tons of milled rice. The Food and Agriculture Organization (FAO) also forecasts India's paddy production at a record 214.2 million metric tons, attributing the rise to favourable monsoon rains and expanded planting areas. The Indian government's second advance estimates report a combined Kharif and Rabi rice production of approximately 1,364.37 lakh metric tons (136.44 million metric tons), with Kharif rice at 1,206.79 lakh metric tons and Rabi rice at 157.58 lakh metric ton. more than 90% of the world's rice is both grown and consumed in Asia, particularly in six countries: China, India, Indonesia, Bangladesh, Vietnam, and Japan (Kumar *et al.*, 2017) [5]. Globally, In the 2024-25 Kharif season, Uttar Pradesh (UP) is projected to produce approximately 265.54 lakh metric tonnes of paddy, cultivated over an area of 61.24 lakh hectares, with an average yield of 43.36 quintals per hectare.

Azotobacter is a nitrogen-fixing bacterium capable of contributing up to 20 kg of nitrogen per hectare in non-leguminous crops. It transforms atmospheric nitrogen into an ammoniacal form (NH_4^+), which plants can readily absorb and utilize. Beyond nitrogen fixation, *Azotobacter* also produces auxins, vitamins, growth-promoting substances, and antifungal compounds, which enhance its effectiveness. The nitrogen it fixes in the rhizosphere—the soil surrounding plant roots—is readily taken up by the roots, potentially leading to improved growth and development of the crop (Rathore and Gautham, 2003; Kumar *et al.*, 2012) [8, 4]. Historically, Indian agriculture has relied on natural manure, as the addition of FYM influences nutrient absorption, crop production, and soil health, leading to a synergistic impact (Yadav and Kumar, 2002) [18]. The application of vermicompost, wheat residue, and farm yard manure in a favorable environment may have led to balanced nutrition by enhancing the release of macro and micro nutrients, facilitating greater nutrient uptake. This hastened the formation of new tissues and the emergence of new shoots, which have ultimately enhanced the plants' height, dry matter accumulation, chlorophyll levels, and total tillers per meter of row length (Togas *et al.*, 2007) [16]. Vermicompost is the compost produced using earthworms, and the method of employing nearby earthworm species for composting or sustaining life is referred to as vermi tech. Vermicompost typically has a finely textured, peat-like consistency that boasts excellent structure, porosity, aeration, drainage, and moisture retention capabilities. Vermicompost enhances the physical, chemical, and biological properties of soil. There is strong evidence that vermicompost enhances plant growth and positively impacts all yield metrics of crops such as wheat, rice, and sugarcane. The addition of Azolla in rice paddies enhanced the weight of grains, length of panicles, percentage of grain filling, and overall grain yield. This finding shows that adding Azolla boosts rice yield by 5-42% compared to the control; Azolla can serve as green manure prior to rice transplanting. Azolla is cultivated 15-20 days before rice transplanting in a properly prepared field using 500 kg to 1 ton of fresh inoculum per hectare. Biofertilizers, containing helpful microorganisms, provide an environmentally friendly and affordable substitute. They enhance plant growth by facilitating nutrient availability (such as nitrogen, phosphorus, and potassium) and promoting the production of phytohormones. These microbial inputs establish symbiotic relationships with plants, improving soil fertility and crop productivity. This study investigates the influence of various biofertilizers such as *Azolla*, *Azotobacter*, on the growth and yield of rice variety Uma under field conditions. The research aims to evaluate whether integrating biofertilizers with recommended agricultural practices can sustainably enhance rice production and reduce dependence on chemical inputs.

Materials and Methods

A field experiment took place during the Kharif season of 2024 at the Crop Research Farm (CRF), Department of Agronomy, Naini Agricultural Institute, SHUATS, Prayagraj (U.P.), to investigate the "Impact of biofertilizer and organic manure on the growth and yield of rice (*Oryza sativa* L.)." The experimental field's soil had a sandy loam texture, with a pH of 7.1, a low organic carbon content (0.452%), available nitrogen (178.48 kg/ha), available phosphorus (23.6 kg/ha), and available potassium (231.4 kg/ha). The study was designed using a Randomized Block Design featuring nine treatments and three replications. The treatment combinations are as follows: T1: *Azotobacter* 6 kg/ha with FYM 12 t/ha, T2: *Azotobacter* 6 kg/ha

with vermicompost (VC) 5 t/ha, T3: *Azotobacter* with poultry manure (PM) 4 t/ha, T4: *Azolla* 500 kg/ha with FYM 12 t/ha, T5: *Azolla* 500 kg/ha with VC 5 t/ha, T6: *Azolla* 500 kg/ha with PM 4 t/ha, T7: *Azotobacter* 3 kg/ha combined with *Azolla* 500 kg/ha and FYM 12 t/ha, T8: *Azotobacter* 6 kg/ha combined with *Azolla* 500 kg/ha and VC 5 t/ha, and T9: *Azotobacter* 6 kg/ha combined with *Azolla* 500 kg/ha and PM 4 t/ha.

Chemical analysis of soil: A composite soil sample was collected before laying out the experiment to determine the initial soil characteristics. The soil sample was taken from a depth of 0-15 cm, air-dried in the shade, ground with a wooden pestle and mortar, filtered through a 2 mm sieve, and used for analysis. Organic carbon availability and the black technique were according to Jackson (1973) [3]; available nitrogen was determined by the alkaline permanganate method by Subbiah and Asija (1956) [13], and phosphorus availability was measured using Olsen's colorimeter method as described by Olsen *et al.*

Statistical analysis: The experimental data gathered underwent a statistical analysis of variance (ANOVA) as described by Gamez and Gomez (2010). Critical Difference (CD) values were computed, and the 'F' test was significant at the 5% level.

Result and Discussion

Growth and Yield attributes

1. Plant height (cm)

Significant differences were recorded among the treatments. However, significantly higher plant height (57.07 cm) was recorded with the application of *Azotobacter* 6 kg/ha along with *Azolla* 500 kg/ha and PM 4 t/ha. Whereas, the application of *Azotobacter* 6 kg/ha along with *Azolla* 500 kg/ha and VC 5 t/ha (56.46 cm), and *Azotobacter* 6 kg/ha along with *Azolla* 500 kg/ha and FYM 12 t/ha (53.80 cm) were statistically at par with the application of *Azotobacter* 6 kg/ha along with *Azolla* 500 kg/ha and PM 4 t/ha. According to Daveri *et al.* (2012), applying Farm Yard Manure significantly increased plant height in both 2006-07 and 2007-08. Singh *et al.* (2002) [11] emphasized the importance of using organic sources like Farm Yard Manure, Poultry Manure, and full doses of mineral fertilizers for improved crop growth. The highest plant height was observed with the cumulative application of organic manures and biofertilizers, followed by their direct and residual effects. Applications to both rice and preceding wheat crops were more effective than applications to rice alone. While Dwivedi and Thakur (2000) also noted stronger cumulative than direct effects, differences among cumulative, direct, and residual effects were not statistically significant. Interaction effects between organic manures, biofertilizers, and their application modes significantly influenced rice plant height in both years.

2. Number of tillers/hills

The significantly highest number of tillers per hill (11.94) was recorded under the treatment with *Azotobacter* at 6 kg/ha, *Azolla* at 500 kg/ha, and PM at 4 t/ha. This treatment was significantly superior to all others, except *Azotobacter* at 6 kg/ha, *Azolla* at 500 kg/ha, and VC at 5 t/ha (11.80), and *Azotobacter* at 6 kg/ha, *Azolla* at 500 kg/ha, and FYM at 12 t/ha (10.80), which were statistically at par. Tigangam and George (2017) [14] reported that the highest tillering occurred when farmyard manure (FYM) was combined with inorganic fertilizers. This was attributed to enhanced nitrogen availability, which promoted vegetative growth, and increased phosphorus solubility, which supported better root development and tiller

formation. According to Yuan *et al.*, (2010), the improved nutrient uptake facilitated by arbuscular mycorrhizal fungi (AMF) also stimulates the production of important biological metabolites and enzymes. These contribute to better water and nutrient balance within the plant, enhancing photosynthetic performance and the accumulation of assimilates—factors that ultimately support higher tiller production.

3. Plant dry weight (g)

Application of Azotobacter at 6 kg/ha, Azolla at 500 kg/ha, and PM at 4 t/ha the maximum plant dry weight (42.44 g) was recorded in which was significantly higher than all other treatments. However, the combinations of Azotobacter at 6 kg/ha, Azolla at 500 kg/ha, and VC at 5 t/ha (41.61 g), as well as Azotobacter at 6 kg/ha, Azolla at 500 kg/ha, and FYM at 12 t/ha (41.20 g), were statistically comparable to the PM-based treatment. As noted by Singh *et al.* (2013)^[12], bio-organic inputs greatly influenced yield characteristics, with the integration of FYM at 5 t/ha and BGA achieving the maximum effective tillers/m², filled grains per panicle, and 1000-grain weight, which were considerably superior to using either FYM at 5 t/ha or BGA alone. Upendra Rao *et al.*, (2014)^[17] reported that organic farming practices—comprising one-third of the recommended nitrogen dose (RDN) supplied through farmyard manure (FYM), vermicompost (VC), and neem cake, along with Azotobacter—led to significantly higher root dry weight and root volume in rice at the flowering stage.

4. Number of Effective Tillers per m²

The number of effective tillers per square meter showed a significant difference among all treatments. The maximum number of effective tillers (421.67/m²) was recorded with the application of Azotobacter at 6 kg/ha, Azolla at 500 kg/ha, and poultry manure (PM) at 4 t/ha. This was statistically at par with the treatment involving Azotobacter at 6 kg/ha, Azolla at 500 kg/ha, and vermicompost (VC) at 5 t/ha (410.33/m²), as well as Azotobacter at 6 kg/ha, Azolla at 500 kg/ha, and farmyard manure (FYM) at 12 t/ha (408.33/m²).

5. Number of Panicles per Spike

Significantly highest number of panicles per spike (17.47) was recorded with the application of Azotobacter at 6 kg/ha, Azolla at 500 kg/ha, and poultry manure at 4 t/ha. This was statistically at par with the treatments that received Azotobacter at 6 kg/ha, Azolla at 500 kg/ha, and VC at 5 t/ha (16.27), and Azotobacter at 6 kg/ha, Azolla at 500 kg/ha, and FYM at 12 t/ha (17.00).

6. Number of Grains per Panicle

The number of grains per panicle was found to be significantly higher (187.27) in the treatment with Azotobacter at 6 kg/ha, Azolla at 500 kg/ha, and poultry manure at 4 t/ha. This treatment was statistically at par with Azotobacter at 6 kg/ha, Azolla at 500 kg/ha, and FYM at 12 t/ha (186.00), and Azotobacter at 6 kg/ha, Azolla at 500 kg/ha, and VC at 5 t/ha (185.07).

7. Test Weight

The test weight was found to be non-significant among the treatments. However, the highest test weight (25.95 g) was

recorded with the application of Azotobacter at 6 kg/ha, Azolla at 500 kg/ha, and poultry manure at 4 t/ha.

8. Grain Yield

Significantly higher grain yield (3.39 t/ha) was recorded with the application of Azotobacter at 6 kg/ha, Azolla at 500 kg/ha, and poultry manure at 4 t/ha. This treatment was statistically at par with Azotobacter at 6 kg/ha, Azolla at 500 kg/ha, and VC at 5 t/ha (3.10 t/ha), and Azotobacter at 6 kg/ha, Azolla at 500 kg/ha, and FYM at 12 t/ha (2.93 t/ha).

9. Straw Yield

The Significantly maximum straw yield (6.92 t/ha) was recorded with the application of Azotobacter at 6 kg/ha, Azolla at 500 kg/ha, and poultry manure at 4 t/ha. This treatment was statistically at par with Azotobacter at 6 kg/ha, Azolla at 500 kg/ha, and VC at 5 t/ha (6.85 t/ha), and Azotobacter at 6 kg/ha, Azolla at 500 kg/ha, and FYM at 12 t/ha (6.80 t/ha).

10. Harvest Index

The harvest index was found to be significant. The highest harvest index (30.31%) was recorded with the treatment involving Azotobacter at 6 kg/ha, Azolla at 500 kg/ha, and poultry manure at 4 t/ha, as compared with other treatments. Shanmugan *et al.* (2003)^[9] reported beneficial effects of FYM and Mann *et al.* (1999)^[6] and Aulakh *et al.* (2000) reported beneficial effects of GM application on yield parameters and yield of rice. GM + FYM + Biofertilizer and GM + FYM were statistically at par and significantly increased grain yield over GM and FYM alone.

Economic Analysis

Analyzing the economic impact of treatments is essential for identifying the most cost-efficient choice that enhances revenue and is feasible for implementation. Information on cultivation expenses, total revenues, net profits, and benefit-cost (B:C) ratios is affected by various treatments. The cultivation expenses differed across treatments due to the application of various slow-release biofertilizers and organic manures, ranging from INR 96,800 to INR 1,06,800 per hectare. The treatment with Azotobacter at 6 kg/ha, Azolla at 500 kg/ha, and poultry manure (PM) at 4 t/ha resulted in the highest gross return (INR 2,86,447), net return (INR 1,89,647), and benefit-cost ratio (2.40). Similarly, the application of Azotobacter at 6 kg/ha, Azolla at 500 kg/ha, and farmyard manure (FYM) at 12 t/ha yielded a gross return of INR 2,34,893, a net return of INR 1,66,093, and a benefit-cost ratio of 2.32, which were relatively superior to the other treatments. Sharma *et al.* (2012)^[10] indicated that the greatest net return and benefit-cost ratio occurred with N90 P45 kg ha⁻¹. The rise in net return and B:C with the application of N90 P45 kg may result from superior yields in these treatments, leading to a greater return compared to the control. Banerjee and Pal (2012)^[1] showed that the net return and B:C ratio were 13,425 ha and 0.61, respectively, for 100% RDF. NPK at 80-40-40 kg ha was the highest compared to the other treatments. Shahbaz (2015) noted that Basmati 515 produced the greatest profit (48,951) and marginal rate of return (1.83) with fertilizer application of NPK 150-88-58 kg ha⁻¹.

Table 1: Effect of biofertilizer and organic manure on growth attributes of Rice.

S. No.	Treatment Combination	Pre Harvest Observation		
		Plant Height (cm)	Number of Tillers/hill	Plant dry Weight(g)
1.	Azotobacter 6kg/ha + Farm Yard Manure 12 t/ha	54.71	10.80	37.08
2.	Azotobacter 6kg/ha + Vermicompost 5 t/ha	57.61	10.13	38.72
3.	Azotobacter 6kg/ha + Poultry Manure 4t/ha	54.87	9.40	38.20
4.	Azolla 500kg/ha+ Farm Yard Manure 12t/ha	52.93	9.67	39.41
5.	Azolla 500kg/ha + Vermicompost 5 t/ha	57.00	10.40	39.86
6.	Azolla 500kg/ha + Poultry Manure 4 t/ha	57.53	10.93	39.04
7.	Azotobacter 6kg/ha + Azolla 500kg/ha + FYM 12 t/ha	55.80	10.80	41.20
8.	Azotobacter 6kg/ha + Azolla 500kg/ha + VC 5t/ha	58.42	11.80	41.61
9.	Azotobacter 6kg/ha+ Azolla 500kg/ha + PM 4t/ha	58.51	11.94	42.44
	F -Test	S	S	S
	S.Em ($\pm$)	2.62	0.57	1.28
	CD (p = 0.05)	8.96	1.71	3.84

Table 2: Effect of Bio-fertilize and Organic Manure on Yield Attributes of Rice.

S. No.	Treatment Combination	Post Harvest Observation						
		No. of Panicles/ Spike	Effective tillers/ m ²	Grains/ Panicle	Test Weight (g)	Seed Yield (t/ha)	Stover Yield (t/ha)	Harvest Index (%)
1.	Azotobacter 6kg/ha + Farm Yard Manure 12 t/ha	16.60	405.33	184.40	25.64	2.26	6.20	26.70
2.	Azotobacter 6kg/ha + Vermicompost 5 t/ha	16.87	406.00	185.60	25.91	2.28	6.22	26.91
3.	Azotobacter 6kg/ha + Poultry Manure 4t/ha	16.20	402.67	185.07	25.94	2.42	6.14	28.35
4.	Azolla 500kg/ha+ Farm Yard Manure 12t/ha	16.60	401.00	183.60	25.60	2.48	6.43	27.83
5.	Azolla 500kg/ha + Vermicompost 5 t/ha	16.67	409.00	184.20	25.54	2.41	6.56	26.88
6.	Azolla 500kg/ha + Poultry Manure 4 t/ha	16.67	405.00	184.47	25.92	2.44	6.65	26.85
7.	Azotobacter 6kg/ha + Azolla 500kg/ha + FYM 12 t/ha	17.00	408.33	186.00	25.95	2.93	6.80	30.10
8.	Azotobacter 6kg/ha + Azolla 500kg/ha + VC 5t/ha	17.47	405.00	185.07	25.74	3.10	6.85	30.03
9.	Azotobacter 6kg/ha+ Azolla 500kg/ha + PM 4t/ha	17.47	421.67	187.27	25.95	3.49	6.92	30.31
	F -Test	S	S	S	NS	S	S	S
	S.Em ($\pm$)	0.95	2.73	1.03	0.20	0.09	0.27	0.85
	CD (p = 0.05)	2.86	8.18	3.10	-	0.27	0.80	2.56

Table 3: Effect of biofertilizer and organic manure on economic of Rice.

S. No.	Treatment Combination	Cost of cultivation (INR/ha)	Gross returns (INR/ha)	Net returns (INR/ha)	BC Ratio (B:C)
1.	Azotobacter 6kg/ha + Farm Yard Manure 12 t/ha	58800	184027	125227	1.82
2.	Azotobacter 6kg/ha + Vermicompost 5 t/ha	96800	223080	126280	1.30
3.	Azotobacter 6kg/ha + Poultry Manure 4t/ha	86800	220253	133453	1.54
4.	Azolla 500kg/ha+ Farm Yard Manure 12t/ha	77600	214300	136700	1.76
5.	Azolla 500kg/ha + Vermicompost 5 t/ha	105600	239213	133613	1.27
6.	Azolla 500kg/ha + Poultry Manure 4 t/ha	95600	231073	135473	1.42
7.	Azotobacter 6kg/ha + Azolla 500kg/ha + FYM 12 t/ha	68800	228727	159927	2.32
8.	Azotobacter 6kg/ha + Azolla 500kg/ha + VC 5t/ha	106800	275493	168693	2.12
9.	Azotobacter 6kg/ha+ Azolla 500kg/ha + PM 4t/ha	96800	280307	183507	2.40

Conclusion

The use of Azotobacter at 6 kg/ha, Azolla at 500 kg/ha, and poultry manure at 4 t/ha resulted in improved growth parameters, yield attributes, and a higher benefit-cost ratio for rice.

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