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Effect of azotobacter, bacillus, and pseudomonas-based biofertilizers on growth and yield of green gram

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Abstract
This study investigates the effects of Azotobacter, Bacillus, and Pseudomonas-based biofertilizers on the growth and yield of green gram (*Vigna radiata*). Conducted at SDMVMS College of Agricultural Biotechnology, Aurangabad, Maharashtra. the experiment involved eight treatments: control (no biofertilizer), and single or combined applications of Azotobacter, Bacillus, and Pseudomonas. Key growth parameters such as plant height, number of branches, and dry weight, as well as yield parameters including number of pods, pod length, number of seeds per pod, seed yield, and stover yield, were measured. Results indicated that the combination of all three biofertilizers (T8: Azotobacter + Bacillus + Pseudomonas) had the most significant impact on plant growth and yield. At 60 days after sowing (DAS), T8 produced the tallest plants (65 cm), the highest number of branches (10 branches per plant), and the greatest dry weight (4.0 g). In terms of yield, T8 also resulted in the highest number of pods per plant (15), longest pods (5.5 cm), highest seed yield (1200 kg/ha), and highest stover yield (1900 kg/ha). The control treatment (T1) showed the lowest values for all parameters, with plant height at 50 cm, 6 branches per plant, 2.0 g dry weight, 10 pods per plant, 4.5 cm pod length, 800 kg/ha seed yield, and 1300 kg/ha stover yield. These findings suggest that the use of combined Azotobacter, Bacillus, and Pseudomonas biofertilizers (T8) can significantly enhance the growth, yield, and overall productivity of green gram, offering a promising, sustainable alternative to chemical fertilizers.

Keywords: Azotobacter, bacillus, pseudomonas

Introduction

The increasing global demand for sustainable agricultural practices has led to a shift from reliance on chemical fertilizers to eco-friendly alternatives like biofertilizers. Biofertilizers, comprising beneficial microorganisms, have been widely recognized for their ability to enhance soil fertility, promote plant growth, and improve crop yields without causing environmental harm (Vessey, 2003) [1]. Among the most studied microbial groups, species of *Azotobacter*, *Bacillus*, and *Pseudomonas* have demonstrated remarkable efficacy in boosting plant productivity. *Azotobacter* is a free-living nitrogen-fixing bacterium first described by Beijerinck in 1901. It plays a vital role in nitrogen fixation, enriching the soil with biologically available nitrogen essential for plant growth. Studies by Wani *et al*. (1985) [2] highlighted the ability of *Azotobacter* species to enhance nitrogen availability, leading to improved plant growth and yield. On the other hand, *Bacillus* species, known for their phosphate-solubilizing capacity, were extensively studied by Rodriguez and Fraga (1999) [3], who demonstrated their pivotal role in increasing phosphorus availability and promoting plant health through the production of growth hormones and biocontrol agents. *Pseudomonas* species, particularly plant growth-promoting rhizobacteria (PGPR), have been a focus of research since the work of Kloepper *et al*. (1980) [4], who introduced the concept of PGPR and emphasized their multifaceted benefits. These include nutrient solubilization, production of phytohormones such as indole-3-acetic acid, and induced systemic resistance (ISR) against pathogens, as detailed by Zahir *et al*. (2004) [5]. Green gram (*Vigna radiata*), a vital legume crop, is widely grown for its nutritional value and role in improving soil fertility through nitrogen fixation. However, suboptimal yields due to nutrient deficiencies and declining soil health remain significant challenges.

The integration of biofertilizers into green gram cultivation could potentially address these issues by improving nutrient availability, enhancing soil microbial diversity, and reducing dependency on chemical fertilizers. This study aims to evaluate the effects of *Azotobacter*, *Bacillus*, and *Pseudomonas*-based biofertilizers on the growth and yield of green gram. By building on the foundational work of pioneering scientists and incorporating contemporary insights, this research seeks to advance the understanding of biofertilizer efficacy in sustainable agriculture.

Materials and Methods

The study titled *"Effect of Azotobacter, Bacillus, and Pseudomonas-Based Biofertilizers on Growth and Yield of Green Gram"* was conducted in the fields of SDMVMS College of Agricultural Biotechnology, Aurangabad (MH). The goal was to evaluate the agronomic performance of green gram. Before sowing, soil samples were collected from the top 15 cm of the field at random locations. These samples were mixed thoroughly, and the combined sample was analyzed for its physical and chemical properties at the soil testing laboratory of SDMVMS College. The experiment was designed using a randomized complete block design (RCBD) with 8 treatments and 3 replications. Certified seeds of green gram (*Vigna radiata*) were sourced from Krushi Seva Kendra, a local agricultural market in Aurangabad. To ensure contamination-free planting, the seeds were surface sterilized with a 0.1% sodium hypochlorite solution. The biofertilizers used in the study were prepared from strains of *Azotobacter*, *Bacillus*, and *Pseudomonas*. These biofertilizers were mixed with sterilized peat to create carrier-based inoculants, which were applied as seed treatments at a rate of 10 g per kilogram of seed before sowing.

The study included eight treatments:

- **T1:** Control (no biofertilizer)
- **T2:** *Azotobacter* alone
- **T3:** *Bacillus* alone
- **T4:** *Pseudomonas* alone
- **T5:** *Azotobacter* + *Bacillus*
- **T6:** *Azotobacter* + *Pseudomonas*
- **T7:** *Bacillus* + *Pseudomonas*
- **T8:** *Azotobacter* + *Bacillus* + *Pseudomonas*

The growth parameters recorded were plant height, the number of branches per plant, and dry weight at 20, 40, and 60 days after sowing (DAS). The yield parameters measured included the number of pods per plant, pod length, the number of seeds per pod, seed yield, and stover yield

Results and Discussion

Table 1: Growth parameters of green gram (*Vigna radiata*) as influenced by biofertilizers

Treatment	Plant height (cm)	Plant height (cm)	Plant height (cm)	No. of branches per Plant	No. of branches per Plant	No. of branches per Plant	Dry weight (g)	Dry weight (g)	Dry weight (g)
	20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS
T1: Control (No biofertilizer)	15	30.5	50	3.5	5	7	0.5	1	2
T2: Azotobacter alone	18.5	35	58	4	6	8	0.7	1.5	3
T3: Bacillus alone	17	34	56	4.5	6.5	8.5	0.6	1.3	2.8
T4: Pseudomonas alone	16.5	32.5	54.5	4	6	8	0.6	1.2	2.7
T5: Azotobacter + Bacillus	20	38	62	5	7	9	0.8	1.7	3.5
T6: Azotobacter + Pseudomonas	19	36	60	4.5	6.5	8.5	0.8	1.6	3.3
T7: Bacillus + Pseudomonas	18	35.5	57	4.5	6.5	8.5	0.7	1.4	3
T8: Azotobacter + Bacillus + Pseudomonas	21	40	65	5.5	7.5	10	1	2	4
CD (5%)	1.5	2	2.5	0.5	0.7	1	0.1	0.3	0.5
S.ED	0.5	0.7	1	0.2	0.3	0.5	0.05	0.1	0.2

Table 2: Yield Parameters of Green Gram *(Vigna radiata*) as Influenced by Biofertilizers

Treatment	No. of Pods per Plant	Pod Length (cm)	No. of Seeds per Pod	Seed Yield (kg/ha)	Stover Yield (kg/ha)
T1: Control (No biofertilizer)	10	4.5	7	800	1500
T2: Azotobacter alone	12.5	5	8	950	1700
T3: Bacillus alone	12	4.8	7.5	900	1600
T4: Pseudomonas alone	11.5	4.7	7.2	870	1550
T5: Azotobacter + Bacillus	14	5.2	8.5	1100	1800
T6: Azotobacter + Pseudomonas	13.5	5.1	8.2	1050	1750
T7: Bacillus + Pseudomonas	13	5	8	1000	1650
T8: Azotobacter + Bacillus + Pseudomonas	15	5.5	9	1200	1900
CD (5%)	1	0.2	0.5	50	100
S.ED	0.3	0.1	0.2	15	30

The application of biofertilizers had a significant impact on the growth parameters of green gram, with the combination of Azotobacter, Bacillus, and Pseudomonas (T8) showing the most significant results in terms of plant height, number of branches per plant, and dry weight at all growth stages. At 20 days after sowing (DAS), T8 had the tallest plants (21 cm), followed by T5 (Azotobacter + Bacillus) with 20 cm. The control (T1) showed the shortest plants at 15 cm. By 60 DAS, T8 maintained its superiority with a height of 65 cm, significantly outperforming the control, which measured 50 cm. These results are consistent with findings from Sharma and Kumar (2021) [6], who reported that combined biofertilizer treatments significantly increase plant height compared to controls. The number of branches per plant was highest in T8, with 10 branches per plant at 60 DAS, indicating that the biofertilizer combination enhanced branch development. This improvement likely resulted from better nutrient availability and plant growth promotion, as also observed by Reddy *et al*. (2019) [7], who concluded that biofertilizers stimulate lateral branch growth by improving soil health and nutrient cycling. Similarly, T8 recorded the highest dry weight at 60 DAS (4.0 g), suggesting better overall plant health and biomass production. In contrast, the control treatment had the lowest dry weight at 2.0 g, reinforcing the benefit of biofertilizer application in promoting plant development, as demonstrated by Ali *et al*. (2018) [8], who found that biofertilizers significantly increase plant biomass. Regarding yield parameters, the combined biofertilizer treatment T8 resulted in the

highest number of pods per plant (15), followed by T5 (14 pods), while the control produced only 10 pods per plant. This indicates that biofertilizers play a crucial role in enhancing pod formation, supporting the findings of Gupta and Singh (2019) [9], who observed that biofertilizers significantly improve pod production. T8 also exhibited the longest pods (5.5 cm), while the control had shorter pods (4.5 cm), suggesting that the biofertilizer combination improved pod development and size. These findings are in line with the research of Patel *et al*. (2021) [10], who reported that biofertilizers enhance pod length by promoting better root and shoot development.

In terms of seed yield, T8 resulted in the highest seed yield (1200 kg/ha), followed by T5 (1100 kg/ha), while the control produced the lowest seed yield (800 kg/ha). This demonstrates the clear benefit of biofertilizers in improving seed production, as noted by Soni *et al*. (2020) [11], who found that biofertilizers increase seed yield by improving the plant's nutrient uptake and stress tolerance. Additionally, T8 recorded the highest stover yield (1900 kg/ha), indicating that the biofertilizers not only boosted seed yield but also contributed to increased vegetative growth. This finding is consistent with the work of Khan *et al*. (2022) [12], who highlighted that biofertilizers improve both seed and stover yield by enhancing overall plant growth and biomass production.

Conclusion

The application of Azotobacter, Bacillus, and Pseudomonas biofertilizers, particularly in combination, significantly improved the agronomic performance of green gram. These results indicate that biofertilizers can be a sustainable and effective alternative to chemical fertilizers, promoting both better plant growth and higher yields. The study recommends the use of T8 (Azotobacter + Bacillus + Pseudomonas) as an optimal biofertilizer combination for enhancing green gram growth and yield, supporting the findings of Prakash and Mishra (2020) [13], who emphasized the potential of microbial inoculants in sustainable agriculture.

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