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Influence of biofertilizers and phosphorus on growth and yield of greengram

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Abstract
A field experiment was conducted during *Zaid* season 2023 at Crop Research Farm, Department of Agronomy, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Sciences and Technology. To determine "Influence of Biofertilizers and Phosphorus on growth and yield of Greengram". The result revealed that treatment 9 (Rhizobium + PSB + Phosphorus 50 kg/ha) recorded significant and higher plant height (47.13 cm), maximum number of nodules/plant (8.55), higher plant dry weight (7.75 g), maximum number of pods/plant (29.51), maximum number of seeds/pod (7.47), higher test weight (40.59 g), higher seed yield (1204.92 kg/ha), and higher stover yield (2209.93 kg/ha), maximum gross return (97,498.83 INR/ha), maximum net return (64,684.83 INR/ha), maximum B:C ratio (1.97) was recorded in treatment 9 (Rhizobium + PSB + Phosphorus 50 kg/ha) as compared to other treatments was found to be productive as well as economically feasible.

Keywords: Greengram, biofertilizers, phosphorus, growth, yield and economic

1. Introduction

Greengram, also known as "Moong Dal" in India, is the third most significant pulse crop in the legume family, covering around 8% of the country's total pulse-growing area. Widely cultivated across Asia, particularly in India, it is prized for its high digestibility and palatability, making it a crucial protein source for India's vegetarian population. India leads globally in greengram production, accounting for 65% of its cultivation area and 54% of its total output. This versatile crop is packed with nutrients, offering 334 calories per 100 grams, with a crude protein content of 24.0%, fat content of 1.3%, carbohydrate content of 56.6%, minerals content of 3.5%, lysine content (0.43%), ionine content (0.10%), and tryptophan content (0.04%). Due to its short growth cycle, it is commonly intercropped with other major crops, making it a vital component of India's agriculture.

In the global scenario, India ranks first in pulse production, with an impressive area of 959.68 lakh ha with a production of 973.92 lakh tonnes and an average productivity of 1015 kg/ha (FAO, 2022). India currently ranks greengram as the fourth most important pulse crop, accounting for nearly 17% of the total pulse area in the country. In India, greengram is grown in 48.52 lakhs ha area with a production of 26.48 lakh tonnes and productivity of 546 kg/ha. Uttar Pradesh is one of the major greengram producing state in India. In Uttar Pradesh, greengram is grown in area of 0.89 lakh ha with production of 0.54 lakh tonnes and the average productivity is 608 kg/ha (GOI, 2022) [9].

Greengram holds paramount importance in India not only for grain production but also for forage and green manure purposes. However, poor pulse yields on various soils are often linked to deficiencies in biofertilizers and phosphorus. Biofertilizers are critical for protein and nucleic acid synthesis, impacting crop productivity significantly. Inadequate fertilizer management, especially on marginal lands, diminishes soil fertility, affecting mungbean and other pulse crop growth. The scarcity of phosphorus in Indian soils exacerbates this issue, impacting vegetative growth, branching, and leaf development in crops. Balancing fertilization strategies is essential to optimize pulse yields and sustain agricultural productivity. Despite their pivotal role, rising fertilizer costs, particularly for nitrogenous and phosphatic types, present financial challenges for farmers. Sustainable agricultural practices are crucial for improving pulse yields and ensuring economic viability. Effective use of biofertilizers like Rhizobium and PSB enhances nitrogen and phosphorus availability through biological nitrogen fixation and increased phosphorus uptake. Phosphorus, a vital mineral element, is essential for pulse crop growth and development, constituting a major part of proteins and nucleic acids.

Biofertilizers play a critical role in integrated nutrient management systems for sustainable agriculture in India, offering a cost-effective and eco-friendly alternative to chemical fertilizers. Inoculating pulse seeds with phosphorus solubilizers enhances phosphorus availability in the rhizosphere, crucial for improving pulse yields across diverse soil types. Efficient strains of Rhizobium introduced into nitrogen-deficient soil can significantly boost nitrogen fixation, thereby enhancing productivity. Additionally, phosphorus-solubilizing bacteria improve phosphorus use efficiency by solubilizing insoluble phosphate in the root zone, supporting green gram yield. Given the scarcity and rising costs of chemical fertilizers, judicious use of both chemical fertilizers and biofertilizers is essential for maximizing greengram production. Phosphorus is particularly vital for root and dry matter production, nodulation, nitrogen fixation, and protein synthesis (Bhatt *et al.* 2013) [3].

Phosphorus is a vital nutrient essential for plant growth, serving as a key component of enzymes involved in vital processes like carbohydrate metabolism, energy transformation, and photosynthesis. Adequate phosphorus levels are crucial for optimal nodulation and efficient nitrogen fixation, leading to higher yields. During early growth stages, plants require significant phosphorus for cell division. Deficiency symptoms include slow, weak, and stunted growth, along with dark to blue-green discoloration on older leaves due to phosphorus mobility within plants. Severe phosphorus deficiency can cause leaf and stem purpling, delayed maturity, and poor seed and fruit development, ultimately reducing overall plant growth and yield (Singh. *et al*. 2020) [17]. Approximately 30% of applied phosphorus is accessible to crops, with the remainder being converted into insoluble forms. Adding extra phosphorus beyond the recommended dose enhances nitrogen fixation, ultimately boosting greengram productivity. Phosphorus is vital for various metabolic processes in plants, such as photosynthesis, energy transfer, signal transduction, macromolecular biosynthesis, and respiration (Singh *et al*. 2021) [19].

Keeping in view the above facts, the experiment was conducted to find out "Influence of Biofertilizers and Phosphorus on growth and yield of Greengram".

2. Materials and Methods

The experiment was conducted during *Zaid* season 2023 at Crop Research Farm, Department of Agronomy, SHUATS, Prayagraj (U.P). The soil of the experimental field was sandy loam in texture, a pH of 7.8 that was virtually neutral, low level of organic carbon (0.62%), available N (225 Kg/ha), P (38.2 kg/ha), K (240.7 kg/ha) and Zn (2.32 mg/kg). The treatment consists of three levels of Biofertilizer along with the combination of three levels of Phosphorus and a control. The experiment was laid out in RBD with 10 treatments each replicated thrice. The treatment combinations are T_1 Rhizobium + Phosphorus 30 kg/ha, T_2 Rhizobium + Phosphorus 40 kg/ha, T_3 Rhizobium + Phosphorus 50 kg/ha, T_4 PSB + Phosphorus 30 kg/ha, T_5 PSB + Phosphorus 40 kg/ha, T_6 PSB + Phosphorus 50 kg/ha, T_7 [Rhizobium + PSB]+ Phosphorus 30 kg/ha, T_8 [Rhizobium + PSB]+ Phosphorus 40 kg/ha, T_9 [Rhizobium + PSB] + Phosphorus 50 kg/ha, T_{10} (Control) N:P:K 25:50:25 kg/ha. Data recorded on different aspects of crop, *viz.*, growth, yield attributes and yield were subjected to statistically analysed by analysis of variance method as described by Gomez and Gomez (1976) [8].

3. Result and Discussion

3.1 Growth Attributes

3.1.1 Plant height (cm)

The data revealed that significant and higher plant height (47.13 cm) was recorded in treatment 9 [Rhizobium + PSB + Phosphorus 50 kg/ha]. However, treatment 6 [PSB + Phosphorus 50 kg/ha], was found to be statistically at par with treatment 9 [Rhizobium + PSB + Phosphorus 50 kg/ha]. Significant and higher plant height was observed with the application of Rhizobium along with PSB might be due to seed inoculation with Rhizobium and PSB improved plant nutrient uptake and translocation by the greengram plant. Its inoculation may also have benefited the plants by supplying atmospheric nitrogen and making the insoluble phosphorous available form. Similar results were also reported by Singh *et al.* (2019) [18]. Further, significant and higher plant height was observed with the application of phosphorus (50kg/ha) might be due to the adequate availability of plant nutrient through appropriate nutrient supply and sunlight to each plant. An adequate phosphorus supply indirectly helps in providing nitrogen supply and its availability helps the plants to attain more vigour in term of plant height. Similar results were also reported by Khan *et al*. (2017) [10].

3.1.2 Number of nodules/plant

The data revealed that significant and maximum number of nodules/plant (8.55) was recorded in treatment 9 [Rhizobium + PSB + Phosphorus 50 kg/ha]. However, treatment 6 [PSB + Phosphorus 50 kg/ha], was found to be statistically at par with treatment 9 [Rhizobium + PSB + Phosphorus 50 kg/ha]. Significant and maximum number of nodules/plant was observed with the application of Rhizobium along with PSB may be due to the of biofertilizers like rhizobium and along with PSB helped in higher nitrogen fixation and phosphorous solubilization respectively which helped in higher root growth and nodules development. Similar results were also reported by Verma *et al.* (2022) [20]. Further, significant and maximum number of nodule/plant was observed with the application of Phosphorus (50kg/ha) might be due to better proliferation of roots and increased nodulation due to higher phosphorus availability which leads to higher plant growth. Similar results were also reported by Patel *et al*. (2020) [12].

3.1.3 Plant dry weight (g)

The data revealed that significant and higher plant dry weight (7.75 g) was recorded in treatment 9 [Rhizobium + PSB + Phosphorus 50 kg/ha]. However, treatment 6 [PSB + Phosphorus 50kg/ha], was found to be statistically at par with treatment 9 [Rhizobium + PSB + Phosphorus 50 kg/ha]. Significant and higher plant dry weight was observed with the application of Rhizobium and along with PSB biofertilizers inoculation might be due to increase in yield characteristics resulting in improved plant growth parameters, ultimately yielding a larger dry matter production. Similar results were also reported by Abhishali *et al.* (2023) [1]. Further significant and Higher Plant dry weight was observed with the application of Phosphorus (50kg/ha), might be due to adequate supply and availability of Phosphorus increased plant dry weight and better photosynthetic activity due to greater exposure to light and increases the availability of nutrients in plants. Similar result was reported by Swamy *et al*. (2020) [4].

3.1.4 Crop Growth Rate (g/m^2/day)

The data revealed that During 45-60 DAS, treatment 9 [Rhizobium + PSB + Phosphorus 50 kg/ha] recorded highest crop growth rate (6.22 g/m^2/day), though there was no significant difference among the treatments.

3.1.5 Relative Growth Rate (g/g/day)

The data revealed that During 45-60 DAS, treatment 1 [Rhizobium + Phosphorus 30 kg/ha]. recorded highest Relative Growth Rate (0.038 g/g/day), though there was no significant difference among the treatments.

3.2 Yield and Yield Parameters

3.2.1 Number of pods/plant

The data revealed that significant and maximum number of pods/plant (29.51) was recorded in treatment 9 [Rhizobium + PSB + Phosphorus 50 kg/ha]. However, treatment 5 [PSB + Phosphorus 40 kg/ha], treatment 6 [PSB + Phosphorus 50 kg/ha], was found to be statistically at par with treatment 9 [Rhizobium + PSB + Phosphorus 50 kg/ha]. Significant and maximum number of pods/plant was observed with the application of Rhizobium along with PSB which improves the availability of Nitrogen and Phosphorous, more pods are generated as a result of higher rates of primordial production. Similar results were also reported by Verma *et al.* (2022) [20]. Further the significant and maximum number of pods/plant with the application of Phosphorus (50kg/ha) might be due to rapid transfer of energy facilitates increased photosynthates this resulted in increased total biomass production and their translocation in various plant parts. Similar result were reported by Punse *et al*. (2018) [11].

3.2.2 Number of seeds/pods

The data revealed that significant and maximum number of seeds/pods (7.47) was recorded in treatment 9 [Rhizobium + PSB + Phosphorus 50 kg/ha]. However, treatment 6 [PSB + Phosphorus 50 kg/ha], was found to be statistically at par with treatment 9 [Rhizobium + PSB + Phosphorus 50 kg/ha]. Significant and maximum number of seeds/pods was observed with the application of Rhizobium along with PSB might be due to in addition to accelerating growth, overall increased nodulation, an extensive root system, and higher metabolite production and translocation, particularly to productive structures (pods and seeds). Similar results were also reported by Ghanshyam *et al.* (2010) [6]. Further the significant and maximum number of seeds/pods with the application of Phosphorus (50kg/ha) might be due to sufficient availability of nutrients and their absorption by the plants, with better photosynthetic activity. Similar result was reported by Kumar and Debbarma (2023) [16].

3.2.3 Test weight (g)

The data revealed that significant and higher test weight (40.59 g) was recorded in treatment 9 [Rhizobium + PSB + Phosphorus 50 kg/ha]. However treatment 6 [PSB + Phosphorus 50 kg/ha], treatment 5 [PSB + Phosphorus 40 kg/ha], was found to be statistically at par with treatment 9 [Rhizobium + PSB + Phosphorus 50 kg/ha]. Significant and higher test weight was observed with the application of Rhizobium along with PSB might be due to applying a medium degree of fertility may have increased test weight because it improved the removal and translocation of nutrients, notably phosphorus, which led to hold seed production by growing the size and weight of grains. Similar results were also reported by Abhishali *et al.* (2023) [1]. Further the significant and higher test weight was observed with the application of Phosphorus (50kg/ha) might be due to root growth resulted plant absorbed more nutrient from soil for effective dry matter production and translocation of photosynthates from leaves to reproductive parts for better development of seeds. Similar result was reported by Reddy *et al.* (2023) [5].

3.2.4 Seed yield (kg/ha)

The data revealed that significant and higher seed yield (1204.92 kg/ha) was recorded in treatment 9 [Rhizobium + PSB + Phosphorus 50 kg/ha]. However, treatment 6 [PSB + Phosphorus 50 kg/ha], treatment 3 [Rhizobium + Phosphorus 50 kg P/ha], was found to be statistically at par with treatment 9 [Rhizobium + PSB + Phosphorus 50 kg/ha]. Significant and higher seed yield was observed with the application of Rhizobium might be due to synergistic effects by improving growth prompting hormones, controlling pathogenesis and growth reducing agents via producing fungicide antibiotics and compounds (antagonistic effect), nitrogen fixing and also producing growth prompting hormones such as auxin, cytokinin and gibberellin and solving mineral compound, ultimately increases seed yield. Similar result was reported by Khatana *et al.* (2021) [13] in blackgram. Further, significant and higher seed yield was observed with the application of PSB might be due to increase in phosphorus avalibility by solubilization of phosphate rich compounds it secreates various organic acids that can form chelates, resulting in effective solubilization of phosphate, helped higher nitrogen fixation, dry matter accumulation, rapid plant growth, higher absorption and utilization of phosphorus and other plant nutrients and ultimately leading to positive effects on yield attributes, particularly seed yield. Similar results were also reported by Bhabai *et al.* (2019) [2]. Another reason, the significant and higher seed yield was observed with application of Phosphorus (50 kg/ha) might be due to cumulative favourable effect of the higher number of effective pods/plant and seed/pod occurred due to better plant metabolism which in turn produced higher seed yield. Similar result was reported by Abbas *et al.* (2011) [7].

3.2.5 Stover yield (kg/ha)

The data revealed that significant and higher stover yield (2209.93 kg/ha) was recorded in treatment 9 [Rhizobium + PSB + Phosphorus 50 kg/ha]. However, treatment 8 [Rhizobium + PSB + Phosphorus 40 kg/ha], was found to be statistically at par with treatment 9 [Rhizobium + PSB + Phosphorus 50 kg/ha]. Significant and higher stover yield was observed with the application of Rhizobium along with PSB might be due to the best root development and higher dry matter build up allowed for maximal nutrient and moisture absorption, which produced the highest possible stover yield. Similar results were also reported by Rajesh *et al.* (2013) [14]. Further, significant and higher stover yield was obtained with the application of phosphorus (50kg/ha) might be due to increase in photosynthetic activities of plant and root system enabled the plant to extract more water and nutrient from soil. Similar results were also reported by Rekha *et al*. (2018) [15].

3.2.6 Harvest index (%)

The data revealed that highest harvest index (37.92%) was recorded in treatment 3 [Rhizobium + Phosphorus 50 kg P/ha]. There was no significant difference among the treatments.

3.3 Economics

The result showed that Maximum gross return (97,498.83 INR/ha), Maximum net return (64684.83 INR/ha) and Maximum benefit cost ratio (1.97) was recorded in treatment 9 [Rhizobium + PSB + Phosphorus 50 kg/ha] as compared to other treatments. Maximum benefit cost ratio was recorded with the application of Rhizobium along with PSB might be due to increase in grain and straw yield with increasing levels of phosphorus, wich in turn produces maximum benefit cost ratio and net return. Further, Maximum gross return, net return and benefit cost ratio was recorded with application of Phosphorus (50kg/ha) might be due to better growth and yield attributing character resulting in more seed and stover yield. Similar results were also reported by Singh *et al*. (2020) [17].

Table 1: Effect of Biofertilizers and Phosphorus on growth parameters of Greengram:

S. No.	Treatments	60 DAS			45-60 DAS	
		Plant height (cm)	Number of nodules/plant	Plant dry weight(gm)	CGR ($g/m^2/day$)	RGR (g/g/day)
1.	Rhizobium + Phosphorus 30 kg/ha	43.33	4.36	6.09	5.79	0.038
2.	Rhizobium + Phosphorus 40 kg/ha	43.71	4.86	6.17	5.27	0.033
3.	Rhizobium + Phosphorus 50 kg P/ha	43.89	5.48	5.45	4.92	0.032
4.	PSB + Phosphorus 30 kg/ha	44.04	6.04	5.98	5.43	0.033
5.	PSB + Phosphorus 40 kg/ha	45.43	7.49	6.42	5.80	0.035
6.	PSB + Phosphorus 50 kg/ha	46.12	7.90	7.08	5.87	0.031
7.	Rhizobium + PSB + Phosphorus 30 kg/ha	44.92	7.76	6.40	4.70	0.027
8.	Rhizobium + PSB + Phosphorus 40 kg/ha	45.76	7.73	6.30	4.51	0.026
9.	Rhizobium + PSB + Phosphorus 50 kg/ha	47.13	8.55	7.75	6.22	0.030
10.	Control	43.19	5.02	5.51	4.99	0.035
	F-test	S	S	S	NS	NS
	SEm ±	0.42	0.26	0.42	0.96	0.0058
	CD (P=0.05)	1.26	0.77	1.24	--	--

Table 2: Effect of Biofertilizers and phosphorus on yield parameters of Greengram:

S. No.	Treatments	Number of pods/plant	Seeds/pod	Test weight (g)	Seed yield (kg/ha)	Stover yield (kg/ha)	Harvest index (%)
1.	Rhizobium + Phosphorus 30 kg/ha	23.63	5.94	36.38	965.83	1751.76	35.55
2.	Rhizobium + Phosphorus 40 kg/ha	24.24	6.07	36.93	1045.06	1934.36	35.05
3.	Rhizobium + Phosphorus 50 kg P/ha	24.96	6.24	37.54	1156.66	1892.22	37.92
4.	PSB + Phosphorus 30 kg/ha	25.29	6.68	37.10	1114.17	2031.18	35.41
5.	PSB + Phosphorus 40 kg/ha	28.78	6.74	38.90	1037.83	1989.60	34.30
6.	PSB + Phosphorus 50 kg/ha	28.67	7.14	39.34	1161.96	1986.07	36.91
7.	Rhizobium + PSB + Phosphorus 30 kg/ha	27.19	6.87	37.92	1115.58	1911.97	36.99
8.	Rhizobium + PSB + Phosphorus 40 kg/ha	26.94	7.02	37.76	1114.17	2110.03	34.57
9.	Rhizobium + PSB + Phosphorus 50 kg/ha	29.51	7.47	40.59	1204.92	2209.93	35.26
10.	Control	25.13	5.53	36.97	936.71	1824.03	33.93
	F-test	S	S	S	S	S	NS
	SEm ±	0.35	0.12	0.79	28.29	57.70	1.01
	CD at 5%	1.03	0.36	2.34	84.06	171.42	--

Table 3: Effect of Biofertilizers and Phosphorus on economics of Greengram:

S. No.	Treatments	Total cost of cultivation (₹/ha)	Gross Return (₹/ha)	Net Returns (₹/ha)	B:C Ratio
1.	Rhizobium + Phosphorus 30 kg/ha	31,754.00	78,142.55	46,388.55	1.46
2.	Rhizobium + Phosphorus 40 kg/ha	32,254.00	84,571.71	52,317.71	1.62
3.	Rhizobium + Phosphorus 50 kg P/ha	32,754.00	93,478.91	60,724.91	1.85
4.	PSB + Phosphorus 30 kg/ha	31,784.00	90,149.19	58,365.19	1.84
5.	PSB + Phosphorus 40 kg/ha	32,284.00	84,021.20	51,737.20	1.60
6.	PSB + Phosphorus 50 kg/ha	32,784.00	93,949.84	61,165.84	1.87
7.	Rhizobium + PSB + Phosphorus 30 kg/ha	31,814.00	90,202.39	58,388.38	1.84
8.	Rhizobium + PSB + Phosphorus 40 kg/ha	32,314.00	90,188.88	57,874.88	1.79
9.	Rhizobium + PSB + Phosphorus 50 kg/ha	32,814.00	97,498.83	64,684.83	1.97
10.	Control	32,224.00	75,848.55	43,624.55	1.35

Conclusion

It is concluded that in Greengram (treatment 9) with the combination of Rhizobium, PSB along with phosphorus (50 kg/ha) was observed highest grain yield and benefit cost ratio.

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