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Effects of Phosphate solubilizing bacteria and Phosphorus on growth and yield of Greengram (*Vigna radiata* L.)

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Abstract
A field experiment was conducted during *Zaid Season* 2024 to study the "Effects of Phosphate solubilizing bacteria and Phosphorus on growth and yield of Greengram (*Vigna radiata* L.)" at Crop Research Farm, Department of Agronomy, SHUATS, Prayagraj (U.P) India. The experiment was laid out in a randomized block design with ten treatments replicated thrice. The treatments consist of Phosphate solubilizing bacteria and Phosphorus along with recommended doses of fertilizers. The experimental field soil was sandy loam in texture, moderately basic in reaction (p H 7.6), available medium organic Carbon (1.149%) medium in available nitrogen (245.5 kg/ha), and very high accessible phosphorus (38.6 kg/ha) and available potassium (253.4 kg/ha). The treatment details are as follows T_1: Control (20:40:20) NPK kg/ha, T_2: P2O5 25% + PSB 10 g/kg, T_3: P2O5 25% + PSB 20 g/kg, T_4: P2O5 25% + PSB 30 g/kg, T_5: P2O5 50% + PSB 10 g/kg, T_6: P2O5 50% + PSB 20 g/kg, T_7: P2O5 50% + PSB 30 g/kg, T_8: P2O5 100% + PSB 10 g/kg, T_9: P2O5 100%+ PSB 20 g/kg, and T_{10}: P2O5 100%+ PSB 30 g/kg. The result showed that significantly higher growth parameters *viz*., plant height (57.75 cm), number of nodules/plant (7.63), number of branches/plant (10.77), plant dry weight (7.10 g), pods/plant (11.92), Seed/pod (11.00) and seed yield (1433.86 kg/ha), Test weight (37.19) were recorded with the application of Treatment 6 (P2O5 50% + PSB 20 g/kg). However highest stover yield was recorded in Treatment 8 (P2O5 100% + PSB 10 g/kg). Higher gross return (INR 117395.04/ha), net return (INR 80495.04/ha) and B:C ratio (2.18) were also recorded in Treatment 6 (P2O5 50% + PSB 20 g/kg).

Keywords: Greengram Phosphate solubilizing bacteria, Phosphorus, Growth, Yield and Economics

Introduction
Greengram's excellent nutritional value and ease of digestion give it an advantage over other pulse crops. According to estimates, each 100 g of the seed has 60.4% carbs, 1.30% fat, and 24.20% protein. Important minerals including calcium (Ca) 118 mg and phosphorous (P) 340 mg per 100 g of seed are also present in the seed (Imran). Nonetheless, green grams hold a prominent place in our everyday diet and are a crucial part of our agricultural production system. The lack of good seeds, high seed prices, fertilizers, pesticides, and manpower shortages during periods of heavy agricultural activity are the main causes of this crop's low production in India. As well as wide gap in adoption of recommended production technology for Greengram (Pardava). India is the major producer of green gram in the world and grown in almost all the states. In India during 2022-2023, Greengram is grown in about 31.5 lakh/ ha with the total production of 2.64 million tones with a productivity of 783 kg/ha and contributing 11% to the total pulse production. and Uttar Pradesh (0.30 lakh/ ha) are the major producers of green gram in India (GOI, 2023).
PSB (phosphate solubilizing bacteria) is a type of biofertilizer used to develop high-quality pulse produce. Phosphate solubilizing bacteria are the name of the majority of biofertilizers that are shown to be advantageous in crop yield. A decline in yield and deterioration of soil fertility due to the ongoing use of chemical fertilizers suggests that relying solely on chemical-based fertilizers is inappropriate for attaining sustainable agricultural production. When chemical fertilizers are used to meet crop nutrient requirements, both the environment and human health suffer. Adding an effective strain of Rhizobium to nitrogen-deficient soil could help increase production by increasing nitrogen fixation. Large amounts of phosphorus

are required in the early phases of cell division, and the first general indication is weak, slowed growth. Some plants have dark to blue-green hue on their older leaves as a result of phosphorus's relative mobility, which allows it to be moved to areas of new growth. Leaf and stem purpling may occur in cases of severe shortage (Singh *et al*., 2020) [16].

Methods

During the *Zaid* season of 2024, a field experiment was conducted in alluvial soil at the Crop Research Farm of the Department of Agronomy, SHUATS, Prayagraj, U.Phe sandy loam soil used in the experimental plot had a pH of 7.6, a nearly neutral soil response, an electrical conductivity of 0.538 (ds/m), limited amounts of accessible phosphorous (38.6 kg/ha), and medium amounts of available potassium (253.4 kg/ha) and nitrogen (245.5 kg/ha). Greengram seeds PDM-139 (Samrat) were planted on March 20, 2024, 30 x 10 cm. Ten treatment combinations and three replications were used in the Randomized Block Design trial. Using a manual hoe, 4-5 cm deep furrows were formed along the seed rows in order to apply fertilizers as band placement. In accordance with the suggested dosage of 20-40-20 kg NPK/ha, urea, single super phosphate (SSP), and murate of potash (MOP) were used as the fertilizer sources. A 10% sugar solution was used to inoculate seeds with biofertilizer (bacteria that dissolve phosphate) in accordance with the treatment. After evenly coating the seeds with a mixture of sugar solution and biofertilizer, they were allowed to dry for half an hour in the shade before being sown right away. After ten days of sowing, the gaps were closed by transplanting following germination. Seedlings were thinned out wherever required to maintain spacing of 30 cm x 10 cm. At 15 and 30 days following sowing, Khurpi was used to assist in manual weeding in order to reduce crop weed competition. June 26, 2024, was the date of crop harvest. At regular intervals from germination to harvest, plant growth parameters such as plant height (cm), dry weight (g/plant), number of nodules/plant, and number of branches were measured. At harvest, yield metrics such as pods/plant, seeds/pod, test weight (g), seed yield (kg/ha), stover yield (kg/ha), and harvest index (%) were measured. Analysis of variance (ANOVA) was used to statistically examine the observed data in accordance with randomized block design (Gomez and Gomez, 1984).

Results and Discussions Growth parameter

The data of growth parameter are presented in Table 1. The application of (P_2O_5 50% and PSB 20 g/kg seeds) Treatment 6 showed resulted in the substantially maximum plant height (41.41 cm). Nonetheless, treatments 2, 5, 9, and 10 were statistically comparable to the best. The treatment with the greatest number of branches at 60 DAS was treatment 6 (P2O5 50% and PSB 20 g/kg), which had statistically comparable results for 2, 3, 8, and 9. When phosphorus and PSB were applied, the number of nodules increased significantly (7.63) in treatment 6. Treatments 2, 4, 7, and 10, however, are statistically comparable to the best. This could result from PSB inoculation of the seeds, which boosts germination potential.

The seedlings grow early as a result. Thus, the plant height reaches its maximum in this treatment. The findings of Singh *et al*. (2020) [16] and Malhotra were similar. The maximum dry weight (7.10 g) was recorded with PSB 20 g/kg seed and P2O5 50% seed inoculation, which was statistically comparable to treatments 5, 7, 8, 9, and 10, respectively. Plant height was higher with this treatment, which was thought to be the likely cause of this outcome. In order to enhance nutrient uptake and shoot development, PSB and phosphorus promote the growth and development of roots (Rekha *et al*., 2018).

Yield attributes

Table. 2 displays the information related to yield-attributing characters. The application of Treatment 6 (P2O5 50% and PSB 20 g/kg) produced the highest number of pods/plant (11.92), which was statistically comparable to treatments 7, 8, and 9. With treatment of 6 (P2O5 50% and PSB 20 g/kg), a significantly increased number of seeds/pod (11.0) and test weight (37.19 g) were observed. The probable reason for these results attributed to seeds injected with biofertilizer are well-nourished and able to transport necessary nutrients and metabolites to the growing seedling. Phosphorus is a major plant nutrient that influences cell division, germination of seeds, flowering, fruiting, synthesis of fat and starch. Besides, the nutrient take part in various biochemical activities is involved in the regulation of metabolic pathways inclusive of enzyme reactions (Singh *et al.*, 2019) [25].

Grain yield

According to Table 2's statistical data, treatment 6 (P2O5 50% and PSB 20 g/kg) had the considerably largest grain yield (1433.86 kg/ha), which was statistically comparable to treatments 7 (P2O5 50% and PSB 30 g/kg) and 8 (P2O5 100% and PSB 10 g/kg). The early sustenance provided to the seeds by phosphate-solubilizing bacteria in the form of growth-promoting compounds may be the cause of these outcomes, which could include improved seed germination and a bigger root system for nutrient uptake. One important nutrient for plants is phosphorus, which affects cell division, seed germination, flowering, fruiting, and the synthesis of fat and carbohydrates. Additionally, the nutrient participates in a number of metabolic processes that are involved in the control biochemical activities is involved in the regulation of metabolic pathways inclusive of enzyme reactions.

Stover yield

According to the data in Table 2, the application in treatment 8 (P2O5100% and PSB 10 g/kg) resulted in a significantly higher stover yield (2446.30 kg/ha), which was statistically comparable to treatments 7 (P2O5 50% and PSB 30 g/kg). Treatment 6 (P2O5 100% and PSB 20 g/kg) was also found to be statistically comparable to the highest in treatment 8. Significantly higher stover output was obtained by applying phosphorus and phosphate-solubilizing bacteria; this could be because of enhanced growth in terms of plant height, seedling emergence, and dry matter buildup, all of which increase photosynthetic efficiency. Superior vegetative development results from increased photosynthetic accumulation in vegetative components, which raises stover production.

Harvest index

Data presented in table 2. showed that the highest harvest index (42.62%) was recorded with the application of (P2O5 50% and PSB 20 g/kg) Treatment 6 which was statistically at par to all treatment.

Economics

The data on the economics of different treatments presented in Table 3 showed that the Higher gross return (117395.04 INR/ha), Net return (80495.04 INR/ha) and benefit-cost ratio (2.18) was recorded with application of (P2O5 50% and PSB 20 g/kg) and the minimum gross return (72607.52 INR/ha) and net return (34707.52 INR/ha) and lowest benefit-cost ratio (0.92) was recorded in treatment 10 (P2O5 100%+ PSB 30 g/kg). These results might be attributable to an increase in grain and stover yields in the same treatment as a result of greater availability of nutrients by the biofertilizer and phosphorus.

Table 1: Effect of Phosphate solubilizing bacteria and Phosphorus on growth attributes of Greengram

S. No.	Treatments	Plant height (cm)	No. of Branches	Dry weight (g)	No of Nodules
		60 DAS	60 DAS	60 DAS	60 DAS
1	Control: - 20:40:20 NPK kg/ha	41.10	7.20	2.82	5.50
2	P2O5 25% + PSB 10 g/kg	55.00	9.60	5.80	6.83
3	P2O5 25% + PSB 20 g/kg	47.07	9.27	6.08	6.00
4	P2O5 25% + PSB 30 g/kg	48.17	9.87	5.98	6.33
5	P2O5 50% + PSB 10 g/kg	51.17	9.27	6.95	7.00
6	P2O5 50% + PSB 20 g/kg	57.75	10.77	7.10	7.63
7	P2O5 50% + PSB 30 g/kg	54.48	9.53	6.43	7.33
8	P2O5 100% + PSB 10 g/kg	50.80	9.80	6.30	5.83
9	P2O5 100%+ PSB 20 g/kg	51.17	9.20	6.43	5.09
10.	P2O5 100%+ PSB 30 g/kg	50.73	9.00	6.17	7.23
SEm(±)		2.61	0.57	0.32	0.52
CD (P= 0.05)		7.78	1.71	0.96	1.55

Table 2: Effect of Phosphate solubilizing bacteria and Phosphorus on yield attributes of Greengram

S. No.	Treatments	No. of Pods/plant	No. of Seeds/pod	Test weight (g)	Grain yield (kg/ha)	Stover yield (kg/ha)	Harvest index (%)
1	Control: - 20:40:20 NPK kg/ha	8.50	10.17	31.02	888.20	1352.59	39.71
2	P2O5 25% + PSB 10 g/kg	9.00	10.67	31.83	1049.78	1942.59	35.19
3	P2O5 25% + PSB 20 g/kg	9.83	10.00	32.56	1054.96	1761.11	37.62
4	P2O5 25% + PSB 30 g/kg	8.50	10.50	32.80	966.04	1811.11	34.88
5	P2O5 50% + PSB 10 g/kg	9.83	10.80	31.79	1165.82	1972.96	37.07
6	P2O5 50% + PSB 20 g/kg	11.92	11.00	37.19	1433.86	1934.81	42.62
7	P2O5 50% + PSB 30 g/kg	11.48	9.90	35.64	1400.24	2351.48	38.52
8	P2O5 100% + PSB 10 g/kg	11.00	10.37	36.21	1402.18	2446.30	36.63
9	P2O5 100%+ PSB 20 g/kg	10.50	9.66	34.02	1219.02	1988.52	38.01
10.	P2O5 100%+ PSB 30 g/kg	8.83	9.67	30.54	860.44	2025.19	30.08
SEm(±)		0.57	0.37	1.51	62.18	194.39	2.49
CD (P= 0.05)		1.20	1.13	-	184.78	-	-

Table 3: Effect of Phosphate solubilizing bacteria and Phosphorus on economics of Greengram

S. No.	Treatments	Cost of cultivation (₹/ha)	Gross returns (₹/ha)	Net returns (₹/ha)	Benefit-cost ratio (B:C)
1	Control: - 20:40:20 NPK kg/ha	35,500.00	73105.18	37605.18	1.06
2	P2O5 25% + PSB 10 g/kg	36,200.00	87264.21	51064.21	1.41
3	P2O5 25% + PSB 20 g/kg	36,600.00	87217.14	50617.14	1.38
4	P2O5 25% + PSB 30 g/kg	37,000.00	80361.92	43361.92	1.17
5	P2O5 50% + PSB 10 g/kg	36,500.00	96449.27	59949.27	1.64
6	P2O5 50% + PSB 20 g/kg	36,900.00	117395.04	80495.04	2.18
7	P2O5 50% + PSB 30 g/kg	37,300.00	115797.54	78497.54	2.10
8	P2O5 100% + PSB 10 g/kg	37,100.00	116186.88	79086.88	2.13
9	P2O5 100%+ PSB 20 g/kg	37,500.00	100664.37	63164.37	1.68
10	P2O5 100%+ PSB 30 g/kg	37,900.00	72607.52	34707.52	0.92

Conclusion

On the basis of one season experimentation, From the results, it can be concluded that application of (P2O5 50% + PSB 20 g/kg) Treatment 6 in Greengram has recorded highest grain yield, gross return, net return and benefit cost ratio.

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Competing Interests

Authors have declared that no competing interests exits.

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