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Influence of Phosphorus and Bio-fertilizers on Growth and Yield of Black Gram (*Phaseolus mungo* L.)

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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

The field study took place in *kharif* 2022 at the Crop Research Farm, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology, and Sciences, Prayagraj (U.P.). to determine the "Effect of Phosphorus and Bio -fertilizer on growth and yield of black gram (*Phaseolus mungo* L)." The results revealed that treatment -9 [Phosphorus -50 kg/ha + Rhizobium +PSB] significantly increased plant height (45.69 cm), number of nodules/ plant (38.15), plant dry weight (6.64 g), Crop growth rate (2.99 g/m^2/day), number of pods/plant (40.8), maximum number of seeds/pod(6.23), test weight (34.75 gm), seed yield (1371 kg/ha), stover yield (2980 kg/ha), gross return (INR 89,290.00/ha), and net return (INR 60,797.00/ha). also, the maximum B:C ratio (2.13) was taken captive in treatment-9[phosphorous 50 kg/ha + Rhizobium + PSB] in comparison to different treatments.

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Keywords: Black gram; phosphorus; bio-fertilizers; growth parameters; yield attributes and economics.

1. INTRODUCTION

In our nation's agricultural sector, pulses have a key place. They have three times as much high-quality protein per serving than cereals. Pulses are advantageous to include in a person's diet due to medical reasons since they include vitamin B, minerals, and a particular type of fiber. Through symbiotic nitrogen fixation from the atmosphere, pulse crops improve the soil. In addition to being a great source of protein, they are essential for sustainable agriculture because they maintain soil fertility through biological nitrogen fixation in the soil.

The third-most significant pulse crop, black gram grows in 90–100 days and nourishes the soil with nitrogen. It is planted under rainfed, rice fallow, irrigated, and during the kharif, rabi, and summer seasons. Black gramme is mostly produced and consumed in India. It is utilised to prepare a variety of foods with rice flour Sivasubramanian et al. [1].

Pulses are the "Marvel of Nature" because of their endurance to drought and their capacity to prevent soil erosion because of their deep root systems and lush vegetation. It has 154 mg Ca, 385 mg P, 9.1 mg Fe, and a negligible amount of vitamin-B complex along with 24% protein, 60% carbohydrate, 1.3% fat, 3.2% minerals, and 0.9% fibre. It includes significant amounts of vitamins A, B1, and B3, but only trace amounts of thiamine, riboflavin, niacin, and vitamin C. Albumin and globulin make up 78% to 80% of its nitrogen content.

Its principal place of origin is India, and it is mostly grown in Asian nations including Pakistan, Myanmar, and other regions of Southern Asia. The largest user and producer of black gramme in the world are both in India. From 46.7 lakh hectares of land, it produces roughly 23.4 lakh tonnes of black gramme annually, with an average yield of 501 kg per hectare in 2020–21. About 15.7% of India's total pulse acreage and 9.09% of all pulse output are produced in the blackgram region. The largest states for Kharif production are Uttar Pradesh (6.99 lakh acres). Telangana has 0.112 million hectares, Odisha 1.66 million ha, and Chhattisgarh 1.3 million ha [2].

Despite these qualities, this crop's production is below average due to a number of limitations. In addition to natural limitations, the country's poor production of black gramme is mostly caused by an imbalance in the supply and utilization of nutrients. For black gramme to produce more, proper fertilization is crucial. It can symbiotically repair atmospheric nitrogen to suit its nitrogen needs. Phosphorus is the nutrient that requires care. There is a widespread phosphorus deficit in soil, and crops cultivated under deficient conditions respond significantly to phosphorus fertilizer Rathore et al. [3].

The most important single factor that causes a poor yield of pulses on all soils is typically a biofertilizer deficit. It is a crucial component of nucleic acids and proteins. It is necessary to employ certain less expensive sources of fertilisers, such as Rhizobium and phosphatic solubilizing bacteria, etc., because the cost of nitrogenous and phosphatic fertilisers is rising daily. By boosting the biological fixation of atmospheric nitrogen and improving the availability of phosphorus to the crop, bio-fertilizers like Rhizobium and phosphate solubilizing bacteria play a significant part in raising the availability of nitrogen and phosphorus. Abhishali & Debbarama [4].

One of the most crucial minerals that has a considerable impact on plant development and metabolism is phosphorus. The fast rate of energy transfer that occurs in the nodule of legumes and the high need for P are congruent. Phosphorous plays a crucial role in energy storage and transmission for metabolic activities, which has an influence on growth and biological production." Singh et al. [5].

Biofertilizers like (PSB) create plant development ingredients in the soil by saturating insoluble soil phosphates like tri-calcium phosphate. Rhizobium is among the different bio-fertilizers of utmost significance. With the help of legumes, rhizobium fixes atmospheric nitrogen symbiosis [6,7]. More phosphorus was readily accessible in the soil after PSB inoculation, which encouraged improved root development and produced a positive nodulation effect with higher PSB bacterial activity. The green gramme must not suffer from insufficient mineral nutrients, notably nitrogen and phosphorus, in order to maximize the production.

Increased nitrogen fixation might increase output if a productive strain of Rhizobium is introduced to a nitrogen-deficient soil. As inoculants in the root zone of crop plants, phosphorus-solubilizing bacteria partially solubilize the insoluble phosphate and increase phosphorus usage productivity. In addition to helping crops reach their full potential, mineral nutrition is crucial for preserving the soil's viability as an agricultural resource. Keeping these considerations in mind, the current study, "Influence of Phosphorus and Bio-fertilizers on growth and yield of Blackgram (*Vigna mungo* L.)", During the 2022 Kharif season, Naini Agriculture Institute will be a part of Sam Higginbottom University of Agriculture Technology and Sciences in Prayagraj, Uttar Pradesh.

2. MATERIALS AND METHODS

The study was carried out in Uttar Pradesh's Prayagraj during the Kharif of 2022 at the Crop Research Farm, Department of Agronomy, Naini Agriculture Institute, and Sam Higginbottom University of Agriculture Technology and Sciences. It is situated 98 metres above mean sea level (SL) at 25.24' 42" N latitude, 81.50' 56" E longitude. Ten treatments, each duplicated three times, were used in the experiment's Randomized Block Design. Each treatment's plot was 3m x 3m in size. Three amounts of phosphorus (30,40,50 kg/ha) and biofertilizers are Rhizobium -20g/kg seeds, PSB - 20g/kg seeds, Rhizobium(10g) +PSB (10g)/kg seeds. The Black gram crop was sown on 20 June 2022 by maintaining a spacing of 30 cm × 10 cm. Harvesting was done by taking $1m^2$ area from each plot. And from it, five plants were randomly selected for recording growth and yield parameters. The treatment details were as follows, T1 –[Phosphorus (30kg/ha) + Rhizobium), T2 –[(Phosphorus (40kg/ha) + Rhizobium], T3 – [Phosphorus (50kg/ha) + Rhizobium] T4 –[Phosphorus (30 kg/ha) + PSB], T5 –[(Phosphorus (40kg/ha) + PSB], T6 – [(Phosphorus (40kg/ha) +PSB], T7 – [Phosphorus (30 kg/ha)+ Rhizobium +PSB], T8 -(Phosphorus (40 kg/ha) +Rhizobium + PSB], T9 –[Phosphorus -50 kg/ha + Rhizobium +PSB], and Control Plot. The following observations were made: plant height, dry weight, nodule count per plant, crop growth rate, number of pods per plant, number of seeds per pod, test weight, seed yield, and stover yield. The data were analysed statistically using the analysis of variance approach Gomez and Gomez [8].

3. RESULTS AND DISCUSSION

3.1 Growth Parameters

Plant height: The result revealed that a significantly higher plant height (45.69 cm) was recorded with the treatment-9 [Phosphorus -50 kg/ha + Rhizobium +PSB] compare to the other treatments. However, treatments -6[Phosphorous 50 kg/ha + PSB] and treatment -8[Phosphorus -40 kg/ha + Rhizobium+ PSB] were found to be statistically at par with treatment-9 [Phosphorus -50 kg/ha + Rhizobium+ PSB] (Table 1). Significant and higher plant height was observed with the application of biofertilizer PSB and Rhizobium might be due to better uptake and translocation of plant nutrients. Similar results were reported by Yadav et al. [9]. Plant height will also rise with the addition of 50 kg/ha of phosphorus. It may be caused by the establishment of new cells, which encourage plant vigour and speed up leaf development, which aids in the collecting of more solar energy and the better utilisation of nitrogen, which aids in greater growth qualities. A comparable outcome was noted by Mir et al. [10].

The number of nodules/plant: The result revealed that significantly higher number of nodules/plant (9.61) was recorded with the treatment-9 [Phosphorus -50 kg/ha + Rhizobium+PSB] over the other treatments. However, treatments-6 [Phosphorous 50 kg/ha + PSB] and treatment-8 [Phosphorus -40 kg/ha + Rhizobium + PSB] were found to be statistically at par with treatment-9 [Phosphorus-50 kg/ha + Rhizobium+PSB] (Table 1). Significant and higher number of nodules/plant was recorded When Rhizobium is used, the maximum number of nodules/plant is more likely to occur, which may be related to the more intense competition for microorganisms near roots, the site of microbial infection, and a well-developed root system. Hussain et al. [11] observed similar findings. Additionally, the application of phosphorus (50 kg/ha) increased the number of nodules per plant, which may have affected the protein production that results in an increase in nodules. Similar outcomes were in accordance with Kachave et al. [12].

Plant dry weight(g/plant):` The result revealed that the treatment-9 [Phosphorus -50 kg/ha + Rhizobium(10g) +PSB (10g)] recorded significantly higher dry weight/plant (6.64 g/plant) However, treatment -8 [Phosphorus -40 kg/ha + Rhizobium +PSB]were found to be statistically at par with treatment-9 [Phosphorus -50 kg/ha + Rhizobium +PSB] (Table 1) It could be because phosphorus, which is a key component of nucleoproteins and lipoids, is abundant in the meristematic zone, which may have aided in cell division and multiplication as well as nitrogen fixation, carbohydrate transformation, and cell division, all of which contribute to increased plant development. Parshar et al. [13] observed similar findings. Furthermore, the fact that the plant's dry weight rose after PSB treatment may be attributable to the strains' enhanced availability of P, which allowed the plant to absorb more P and improve its development characteristics. A comparable outcome was noted by Kachave et al. [14].

Crop Growth Rate (g/m^2day): The result revealed that a significantly higher Crop growth rate (2.99 g/m^2/day) was observed in treatment-9 [Phosphorous (50 kg/ha) +Rhizobium + PSB]. However, treatment -8 [Phosphorous (40 kg/ha) +Rhizobium + PSB] (2.79 g/m^2/day) were found statistically par with treatment -9 [Phosphorous (50 kg/ha) +Rhizobium + PSB] (Table 2). The significant and higher crop growth rate noticed with the application of PSB may be attributable to better dry matter accumulation throughout the vegetative and reproductive phases of the plant. This improves physiological and metabolic activity and growth by assimilation of nutrients that are accessible at a greater extent of growth parameters and facilitating more photosynthesis, ultimately resulting in higher crop growth rate. A similar outcome was noted by [15].

3.2 Yield Attributes

Number of pods/plant: The result revealed that a significant and higher Number of Pods/Plant (40.08) was observed in treatment -9 [Phosphorus -50 kg/ha + Rhizobium +PSB]. However, the treatment -8 [Phosphorus -40 kg/ha + Rhizobium +PSB] was found to be statistically at par with treatment-9 [Phosphorous (50 kg/ha +Rhizobium + PSB] (Table 2). The significant and higher number of pods/plant were observed with the application of rhizobium, this might be due to enhanced nitrogen fixation, thereby increasing the availability of plant efficient growth and development, particularly number of pods/plant. A similar result was concluded by Kumar et al. [16]. Further, the maximum number of pods/plant with application of Phosphorous (50kg/ha). Enhanced root growth, improved root proliferation, and enhanced nutrient availability and absorption might all be contributing factors. Similar results lined with by Hussain et al. [17].

Number of seeds/pod: The Significantly and higher number of seeds/pod (6.23) were recorded in treatment-9 [Phosphorus (50kg/ha) +Rhizobium +PSB]. However, the treatment -8 [Phosphorus (40kg/ha) +Rhizobium +PSB] was found to be statistically at par with treatment-9 [Phosphorous (50kg/ha) +Rhizobium+ PSB] (Table 2). The significant and higher number of seeds/pod were observed with application of rhizobium Due to increased nodulation, an extensive root system, and increased metabolite production and translocation to various sinks, particularly the fruiting structures (pods and seeds), the number of pods for each plant may have increased in furtherance to the plant's overall growth. Ghansyam et al. [18] noticed similar findings in green gramme. Furthermore, the application of phosphorus (50 kg/ha) resulted in the highest number of seeds/pods, which may be attributable to the increased availability of other plant nutrients that led to an increase in carbohydrate development and their re-mobilization to the plant's reproductive parts, which are the closest sinks. Given that phosphorus is known to promote blossoming and fruiting, which may have encouraged the plants to develop more pods and allowed for higher plant growth increased development of seed/pod numbers. The same results were reported by Shah et al. [19].

Test Weight (gm): The Significantly higher Test Weight (34.75 g) was observed in treatment-9 [Phosphorus (50 kg/ha) + Rhizobium +PSB] over the other treatments. However, treatment -8 [Phosphorus (40 kg/ha) + Rhizobium +PSB] was found to be statistically at par with treatment-9 [Phosphorus -50 kg/ha + Rhizobium +PSB] (Table 2). Because PSB and basal phosphorus application together have beneficial effects on the development of extensive root systems that can extract more water and nutrients from the soil and improve plant growth and yield attributes, significant and maximum test weight was seen with PSB application. Similar outcomes were seen by Pramanik and Singh et al. [20] in cowpea. Additionally, the rise in test weight seen with the application of phosphorus (50 kg/ha) may be the result of an increase in the symbiotic nitrogen fixation power, which in turn leads to an increase in the number of plants, the length of pods, the number of grains per pod, the test weight, and eventually grain production. A comparable outcome was noted by Parashar et al. [13].

Table 1. Influence of Phosphorus and Bio-fertilizers on growth parameters of Black gram

S. No.	Treatment combinations	Plant height	Number of nodules	Plant Dry weight	Crop Growth Rate (g/m^2day)
1.	Phosphorus -30kg/ha + Rhizobium	42.40	7.02	5.69	2.20
2.	Phosphorus -40kg/ha + Rhizobium	43.36	7.64	5.97	2.33
3.	Phosphorus -50kg/ha + Rhizobium	44.47	8.67	6.29	2.66
4.	Phosphorus -30kg/ha + PSB	42.81	7.27	5.78	2.26
5.	Phosphorus -40kg/ha + PSB	43.66	8.13	6.09	2.45
6.	Phosphorus -50kg/ha + PSB	44.98	8.91	6.40	2.79
7.	Phosphorus -30 kg/ha + Rhizobium + PSB	44.12	8.47	6.16	2.56
8.	Phosphorus -40 kg/ha + Rhizobium + PSB	45.41	9.36	6.46	2.87
9.	Phosphorus -50 kg/ha + Rhizobium + PSB	45.69	9.61	6.64	2.99
10.	Control (20:40:20 NPK Kg/ha)	41.52	6.75	5.44	1.93
	F test	**S**	**S**	**S**	**S**
	S Em.(±)	0.30	0.24	0.11	0.14
	CD (P=0.05)	0.88	0.70	0.32	0.41

Table 2. Influence of Phosphorus and Bio-fertilizers on yield attributes of Black gram

S. No.	Treatments	Pods/plant	Seeds/pod	Test Weight (g)	Seed Yield (kg/ha)	Stover Yield (kg/ha)
1.	Phosphorus -30kg/ha + Rhizobium	27.2	4.75	32.64	942	1853.33
2.	Phosphorus -40kg/ha + Rhizobium	29.5	5.06	33.11	976	2173.33
3.	Phosphorus -50kg/ha + Rhizobium	32.3	5.64	33.52	1035	2080.00
4.	Phosphorus -30kg/ha + PSB	30.6	4.90	32.74	1101	2280.00
5.	Phosphorus -40kg/ha + PSB	34.0	5.23	33.26	1160	2333.33
6.	Phosphorus -50kg/ha + PSB	35.3	5.70	34.01	1209	2490.00
7.	Phosphorus -30 kg/ha + Rhizobium + PSB	37.4	5.40	33.49	1275	2573.33
8.	Phosphorus -40 kg/ha + Rhizobium + PSB	39.3	5.90	34.33	1333	2816.67
9.	Phosphorus -50 kg/ha + Rhizobium + PSB	40.8	6.23	34.75	1371	2980.00
10.	Control (20:40:20 NPK Kg/ha)	28.3	4.59	32.37	965	1833.33
	F test	**S**	**S**	**S**	**S**	**S**
	S. EM (±)	0.70	0.16	0.26	12.89	77.58
	CD (P = 0.05)	2.08	0.48	0.76	38.30	230.52

Table 3. Influence of Phosphorus and Bio-fertilizers on economic analysis of rice

S. No.	Treatments	Cost of cultivation	Gross returns	Net returns	B:C Ratio
1.	Phosphorus -30kg/ha + Rhizobium	27290	61840	34550	1.27
2.	Phosphorus -40kg/ha + Rhizobium	27842	64128	36286	1.30
3.	Phosphorus -50kg/ha + Rhizobium	28393	67929	39536	1.39
4.	Phosphorus -30kg/ha + PSB	27490	71883	44393	1.61
5.	Phosphorus -40kg/ha + PSB	28042	75759	47717	1.70
6.	Phosphorus -50kg/ha + PSB	28593	78965	50372	1.76
7.	Phosphorus -30 kg/ha + Rhizobium + PSB	27390	83025	55635	2.03
8.	Phosphorus -40 kg/ha + Rhizobium + PSB	27942	86618	58676	2.10
9.	Phosphorus -50 kg/ha + Rhizobium + PSB	28493	89290	60797	2.13
10.	Control (20:40:20 NPK Kg/ha)	27242	63174	35932	1.32

No data were included in the statistical analysis

Seed Yield (kg/ha): The significantly higher Seed yield (1371 kg/ha) was observed in treatment-9 [Phosphorus -50 kg/ha + Rhizobium +PSB]. However, the treatment -8 [Phosphorus (40 kg/ha) + Rhizobium +PSB] was found to be statistically at par with treatment-9 [Phosphorous (50kg/ha) +Rhizobium +PSB] (Table 2). With the treatment, a significant and greater seed production was seen. Phosphorous (50 kg/ha) may be responsible for the increased photosynthesis and assimilate translocation to various plant parts for the crop's enhanced growth and yield-attributing characteristics, as seen in the number of pods/plant and number of seeds/pods. Later on, the excess assimilates stored in the leaves were translocated towards sink development, which ultimately contributed to higher seed yield. Yumna et al. [21] observed similar findings. Additionally, the bio-fertilizer Rhizobium has been linked to the supply of more plant hormones (auxin, cytokinin, gibberellin, etc.) by the microorganisms injected or by the root as a result of reaction to microbial population, which may be the cause of the increase in seed production with Rhizobium treatment. similar outcomes had been conformity to Umamaheswari et al. [22] in green gram.

Stover Yield (t/ha): The significantly and higher Stover yield (2980 kg/ha) was recorded in treatment -9 [Phosphorus -50 kg/ha + Rhizobium + PSB]. However, the treatment -8 [Phosphorus -40 kg/ha + Rhizobium +PSB] was found to be statistically at par with treatment-9 [Phosphorous (40 kg/ha) +Rhizobium + PSB] (Table 2). Significant and higher stover yield was observed with application Phosphorous (50kg/ha). Possibly as a result of the improved nutritional environment of the rhizosphere and plant system leading to better plant metabolism and photosynthetic activity, plants have grown and developed more in terms of height, branches, and dry matter. Yadav et al. [23] reported a similar outcome. More specifically, the increased dry matter buildup and improved root growth brought about by the treatment of PSB and Rhizobium may have contributed to the higher stover output by allowing for maximal nutrient and moisture absorption. The same outcomes were reported by Rajesh et al. [24].

3.3 Economic Analysis

3.3.1 Economics

The result revealed that Maximum gross return (89,290.00 INR/ha), Maximum net return (60,797.00 INR/ha) and highest benefit-cost ratio (2.13) was recorded in treatment-9 [Phosphorus (50 kg/ha) + Rhizobium + PSB] as compared to other treatments (Table 3). Higher gross Return, net return and benefit cost ratio was recorded with the application of[Phosphorus (50 kg/ha) + Rhizobium + PSB] it might be due to the higher growth and yield attributes resulting in more seed and stover yield with the recommended dose of phosphorus. Similar results were reported by Bhat et al. (2013) in field pea.

4. CONCLUSION

Based on the aforementioned results, it can be stated that Rhizobium and PSB, combined with Phosphorus applied at a rate of 50 kg per hectare, have improved growth metrics and yield characteristics while also being economically viable. Additional tests are required to corroborate the findings because they are based only on one season.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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