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Effect of Phosphorus Levels and Biofertilizers on the Growth and Yield of Summer Black Gram (*Phaseolus mungo* L.)

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ABSTRACT

Background: India is the world's leading producer and consumer of pulses, contributing a quarter to global production. Pulses are crucial in the Indian diet, providing 14% of total protein intake, especially for vegetarians. However, production falls short of demand due to inadequate nutrient management, particularly phosphorus, and biofertilizers. Black gram (*Phaseolus mungo* L.), a key *kharif* pulse crop, has significant potential but suffers from low productivity. Proper fertilization, especially phosphorus, and biofertilizers, is essential to bridge this productivity gap.

Methods: A field experiment was conducted during the summer season of 2022 at the experimental farm of the School of Agricultural Sciences (SAS), Nagaland University, Medziphema Campus, to evaluate the effect of phosphorus levels and biofertilizers on the growth and yield of summer black gram. The experiment was conducted by adopting a Factorial Randomized block design with four phosphorus levels , *viz.* P_0- Control, P_1- 15 kg ha^{-1}, P_2- 30 kg ha^{-1}, and P_3- 45 kg ha^{-1} and four treatments of biofertilizers , *viz.* B_0- Control, B_1- *Rhizobium* (20 g kg $^{-1}$ seed), B_2- Phosphate solubilizing bacteria (20 g kg^{-1} seed) and B_3- *Rhizobium* (20 g kg^{-1} seed) + Phosphate solubilizing bacteria (20 g kg^{-1} seed), and the treatments were replicated thrice. Black gram variety "Pusa-1" was sown at a spacing of 30 cm × 10 cm, and it was uniformly fertilized by 20 kg N ha^{-1} through urea. However, phosphorus and biofertilizers were applied as per the treatment requirements.

Result: The experimental results revealed that among the levels of phosphorus, application of 45 kg ha^{-1} phosphorus recorded significantly the highest plant height, number of primary branches, leaf area index, plant dry weight, and seed yield (724.17 kg ha^{-1}). Among the biofertilizer treatments, *Rhizobium* (20 g kg^{-1} seed) + phosphate solubilizing bacteria (20 g kg^{-1} seed) resulted at highest growth attributes and yield of black gram. Thus, for summer black gram cultivation, application of 45 kg ha^{-1} phosphorus and treatment of *Rhizobium* (20 g kg^{-1} seed) + Phosphate solubilizing bacteria (20 g kg^{-1} seed) treatment was identified as the most promising method for boosting black gram yield.

Key words: Biofertilizers, Black gram, Growth, Phosphorus, Yield.

INTRODUCTION

India leads globally in production (2,76,68,511.27 t for the year 2022; FAOSTAT, 2024) and consumption of pulse crops, contributing approximately 27.44% to the total pulse production worldwide. Despite having one-third of the global acreage dedicated to pulse cultivation, pulses hold a critical position in the Indian food chain, especially for vegetarians, constituting roughly 14% of the total protein intake in the average Indian diet. However, pulse production within the country falls significantly short of meeting the minimum per capita consumption level. The productivity of pulses is primarily contingent on effective nutrient management practices, notably phosphorus (P) and biofertilizers. Challenges such as low organic matter content in light-textured soils, coupled with insufficient and imbalanced nutrient application, curtail the maximum yield potential and serve as the primary obstacles to crop productivity (Ghosh *et al*., 2003) this subsequently led to a decline in soil health and productivity.

Black gram (*Phaseolus mungo* L.), constituting approximately 10% of India's total pulse production holds significant importance as a kharif pulse crop (Marimuthu *et al*., 2024). This protein-rich staple food, with a protein content of around 25% surpasses cereals by nearly threefold. Apart from its nutritional value, black gram also plays a crucial role in soil conservation by controlling erosion and effectively competing with weeds owing to its deep root system and

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dense foliage cover. Black gram contributes to soil fertility enhancement by converting atmospheric nitrogen into a form usable by plants. Despite its potential, there is a notable difference between its potential productivity and what is actually achieved. To address this, proper fertilization is essential, although black gram can naturally meet its nitrogen needs through atmospheric nitrogen fixation. Phosphorus is a crucial nutrient that requires attention, as indicated by Nandal *et al*. (1987). Being a leguminous crop, black gram relies on an adequate supply of phosphorus and biofertilizers, among other nutrients, which directly support its growth and development.

Phosphorus (P) is an essential element found in all living cells, serving critical functions in various biological processes and plays vital roles in photosynthesis, sugar metabolism, energy storage and transfer, cell division, enlargement, genetic information transfer, root growth, nodulation and nitrogen fixation in plants (Khan *et al*., 2023). Furthermore, phosphorus promotes seed formation, strengthens straw, accelerates crop maturity and improves the grain-to-straw ratio. According to Motsara (2002), approximately 80% of Indian soils require phosphorus application at recommended rates. Moreover, applying phosphorus fertilizers is necessary to prevent phosphorus depletion from the soils and to sustain high crop yields.

Biofertilizers are composed of live microorganisms like bacteria, algae and fungi, convert essential elements into usable forms, aiding soil fertility and plant growth. They can be applied to seeds, roots or soil providing cost-effective, eco-friendly and renewable plant nutrients in India's sustainable agriculture. While pulses have similar nutritional needs to cereals, only 20 kg ha^{-1} nitrogen is recommended due to biological nitrogen fixation with Rhizobium bacteria playing a key role. Microorganisms also help solubilize inorganic phosphates in soil making them available to plants (Barroso *et al*., 2006). Inoculating black gram seeds with biofertilizers boosts NPK uptake, enhancing protein and nutrient content in seeds and eventually increase black gram production (Murtaza *et al*., 2014). Similarly, inoculation of black gram seeds with phosphate solubilizing bacteria (PSB) play a vital role in supplementing of phosphorus required by the crop. The combination of sufficient phosphorus fertilizers and appropriate biofertilizer strains is crucial for maximizing yield and economic returns from black gram cultivation, thus, a study was carried out to see the effect of phosphorus levels and biofertilizers on growth and yield of summer black gram.

MATERIALS AND METHODS

The experiment was carried out during *summer* season in the year 2022 at the experimental farm of School of Agricultural Sciences (SAS), Nagaland University. The experimental site is situated at 25.45°N latitude, 95.53°E longitude at the elevation of 310 m above the mean sea level. The climate is subtropical with high humidity, moderate temperatures and medium to high rainfall. The sandy loam soil in the experimental field is rich in organic carbon and has medium levels of nitrogen, phosphorus and potassium with electrical conductivity within a safe range in Table 1.

The experiment was conducted in Factorial Randomized block design with four levels of phosphorus *viz.* P_0- (Control), P_1- 15 kg ha^{-1}, P_2- 30 kg ha^{-1} and P_3- 45 kg ha^{-1} and four treatments of biofertilizers *viz.* B_0- (Control), B_1- *Rhizobium* (20 g kg^{-1} seed), B_2- Phosphate solubilizing bacteria (20 g kg^{-1} seed) and B_3- *Rhizobium* (20 g kg^{-1} seed) + Phosphate solubilizing bacteria (20 g kg^{-1} seed), which were replicated thrice. The recommended blanket dose of phosphorus for black gram in Nagaland climatic conditions is 40 kg ha^{-1} as reported by (Islam *et al*., 2013). Black gram variety "Pusa 1" was sown at a spacing of 30 cm × 10 cm and it was uniformly fertilized by 20 kg N ha^{-1} through urea. However, phosphorus (Supplied through straight fertilizer, i.e., single super phosphate) and biofertilizers was applied as per the requirement of the treatments. The crop was managed as per regional recommendations of the crop. Growth attributes were assessed at various stages with five randomly selected plants per plot excluding border rows. Yield data were collected at harvest by harvesting the net plot for grain and stover yield, then weighed and expressed in kg ha^{-1}. Analysis followed Gomez and Gomez (1984) method, with significance tested at $p<0.05$. Standard error of the mean (SEm±) and critical difference (CD) values were provided for comparing mean differences.

RESULTS AND DISCUSSION

Growth attributes

Plant height (cm)

Application of 45 kg P ha^{-1} led to maximum plant height (29.00 cm and 40.54 cm) at 40 and 60 days after sowing (DAS), likely due to stimulation of root growth attributed to phosphorus's role in root development and nodulation. Similar results were reported by (Khaswa *et al*., 2014). Additionally, biofertilizers significantly influenced plant height with maximum height (28.90 cm and 40.43 cm) observed with Rhizobium + PSB application at 40 and 60 DAS followed by PSB and Rhizobium application. These findings align with those of (Hussain *et al*., 2011), where seed treatment with Rhizobium and PSB resulted in maximum plant height.

Number of primary branches plant^{-1}

Different levels of phosphorus significantly increased the number of primary branches per plant at 40 and 60 DAS of

Table 1: Properties of soil.

Soil type	pH	Electrical conductivity (EC; dS m^{-1})	Organic carbon (O.C.; g kg^{-1})	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
Sandy loam	4.80	0.41	1.63	262.54	17.21	190.54

summer black gram crop compared to control. The maximum number of primary branches per plant (1.38 and 2.11) were observed with the application of 45 kg P ha^{-1} at 40 and 60 DAS, followed by 30 kg P ha^{-1}. This increase may be attributed to phosphorus's role in enhancing physiological processes like cell division and chlorophyll formation, similar findings were reported by Khaswa *et al*., (2014) and (Yadav *et al*., 2017). Additionally, the application of Rhizobium + PSB resulted in the maximum number of primary branches per plant (1.36 and 2.09) at 40 and 60 DAS, likely due to improved nutrient availability and nitrogen fixation, similarly, (Saket and Rahi, 2019) also reported similar results in black gram.

Leaf area index (LAI)

LAI was significantly increased due to different levels of phosphorus at 40 and 60 DAS of summer black gram crop in Table 2. The maximum leaf area index (0.66 and 1.18) was recorded with the application of 45 kg P ha^{-1} at 40 and 60 DAS, followed by the application of 30 kg P ha^{-1}, and the application of 15 kg P ha^{-1}). The result is in agreement with the findings of Parashar and Tripathi (2020) where they observed that yield of black gram increased with a higher range of P fertilizes up to 60 kg P ha^{-1}. From the obtained results, a higher leaf area index (0.64 and 1.16) was observed with both inoculations when applied after 40 and 60 DAS. This was the result of a change in leaf and substantial appearance that is directly linked to the growth factor and photosynthetic potentiality of the plant. The similar kind of observation has been documented by Rajendar *et al.* (2022) of the growth and yield of green gram (*Vigna radiata* L.) using different doses of PSB. They concluded that the application of PSB contributes toward the production of growth promoting hormones like IAA, GA and the N_2-enriching of the soil.

Plant dry weight (g $plant^{-1}$)

Plant dry weight was significantly increased due to different levels of phosphorus at 40 and 60 DAS of summer black gram crop as compared to control. The maximum plant dry weight (1.18 and 1.74) was recorded under with the application of 45 kg P ha^{-1} at 40 and 60 DAS. This is because the increment of a number of primary and secondary branches per plant and the number of leaf per area contributed more to the increase in the dry weight of the plant in 45 kg of P ha^{-1}. Similar results were reported by (Abraham *et al*., 2021). The maximum plant dry weight (1.15 and 1.68) was recorded with the application of *Rhizobium* + PSB) at 40 and 60 DAS. This is because of the increase in starch and carbohydrates contents in leaves due to sufficient nutrients available towards plant growth after application of biofertilizers which would have resulted in the increase plant dry weight. Similar findings were corroborated by Kumawat *et al*., 2013) in black gram.

Yield attributes

Seed yield (kg ha^{-1})

The seed yield of summer black gram crop was significantly influenced by varying phosphorus levels, with the highest yield (726.75 kg ha^{-1}) observed at 45 kg P ha^{-1}. This increase may be attributed to enhanced photosynthetic activity and root development, leading to improved nutrient and water uptake. Similar findings were reported by (Kokani *et al*. (2014) and Niraj and Parkash (2014) in black gram and Dudwal *et al*. (2021) in urdbean. Additionally, seed yield was significantly effected by biofertilizer application, with the maximum yield (708.08 kg ha^{-1}) observed with Rhizobium + PSB. This increase could be due to enhanced plant hormone supply or root colonization by microorganisms, as suggested by (Avivi and Feldman,

Table 2: Effect of levels of phosphorus and biofertilizers on growth attributes of blackgram.

Treatments	Plant height (cm)		Number of primary branches $plant^{-1}$		Leaf area index (LAI)		Plant dry weight (g $plant^{-1}$)	
	40 DAS*	60 DAS*	40 DAS*	60 DAS*	40 DAS*	60 DAS*	40 DAS*	60 DAS*
Phosphorus levels								
P_0 (Control)	21.45	33.93	1.12	1.71	0.41	0.73	0.85	1.27
P_1 (15 kg ha^{-1})	23.47	36.35	1.24	1.89	0.53	0.89	1.00	1.44
P_2 (30 kg ha^{-1})	26.74	38.45	1.31	2.02	0.59	0.97	1.10	1.60
P_3 (45 kg ha^{-1})	29.00	40.54	1.38	2.11	0.66	1.18	1.18	1.74
SEm±	0.59	0.70	0.02	0.04	0.01	0.02	0.02	0.03
CD (P=0.05)	1.69	2.03	0.05	0.12	0.04	0.07	0.06	0.09
Biofertilizers								
B_0 (Control)	21.66	34.17	1.16	1.75	0.47	0.79	0.91	1.35
B_1 (*Rhizobium*)	23.38	36.31	1.23	1.88	0.52	0.87	0.98	1.45
B_2 (PSB$)	26.72	38.37	1.30	2.02	0.57	0.96	1.08	1.56
B_3 (*Rhizobium* + PSB)	28.90	40.43	1.36	2.09	0.64	1.16	1.15	1.68
SEm±	0.59	0.70	0.02	0.04	0.01	0.02	0.02	0.03
CD (P=0.05)	1.69	2.03	0.05	0.12	0.04	0.07	0.06	0.09

*: Days after sowing; $: Phosphate solubilizing bacteria.

Table 3: Effect on seed yield, stover yield, and harvest index of black gram.

Treatments	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Harvest index (%)
Phosphorus levels			
P_0 (control)	558.33	1273.33	31.10
P_1 (15 kg ha^{-1})	610.00	1595.26	28.07
P_2 (30 kg ha^{-1})	684.83	1790.49	27.90
P_3 (45 kg ha^{-1})	726.75	1885.93	28.01
SEm±	11.97	56.48	0.95
CD (P=0.05)	34.56	163.10	NS
Biofertilizers			
B_0 (Control)	576.17	1286.73	31.57
B_1 (*Rhizobium*)	619.75	1600.43	28.25
B_2 (PSB)	675.92	1781.67	27.70
B_3 (*Rhizobium*+ PSB)	708.08	1876.17	27.56
SEm±	11.97	56.48	0.95
CD (P=0.05)	34.56	163.10	NS

1982). Similar results were reported by Singh and Prasad (2011) and Rajendar *et al*. (2022).

Stover yield (kg ha^{-1})

The stover yield of the summer black gram crop was significantly affected by varying phosphorus levels, with the highest yield (1885.93 kg ha^{-1}) observed at 45 kg P ha^{-1}. This increase is attributed to improved dry matter production, and similar results were reported by Patel *et al*. (2019) and Thakur and Negi (1985) in black gram. Additionally, stover yield was significantly influenced by biofertilizer application, with the maximum yield (1876.17 kg ha^{-1}) observed with Rhizobium + PSB and the minimum (1286.73 kg ha^{-1}) under control conditions. Bulk inoculation of beneficial microbes is crucial for enhancing yield through improved sink development, higher photosynthesis, and increased assimilate production, as noted by Kumar *et al*. (2015) and Saket and Rahi (2019).

Harvest index (%)

The data on harvest index of black gram as affected by varying levels of phosphorus and biofertilizers are presented in Table 3 revealed that there was no significant effect on harvest index due to different levels of phosphorus. However, application of biofertilizers also have no significant effect on harvest index of black gram.

CONCLUSION

The conclusion can be drawn that as the phosphorus levels increased phosphorus input of 45 kg ha^{-1} resulted in remarkable increase in plant height, number of primary branches, leaf area index, plant dry weight, and seed yield, *i.e*., 724.17 kg ha^{-1}. Among the biofertilizers treatments, Rhizobium (20 g kg^{-1} seed) + Phosphate solubilizing bacteria (20 g kg^{-1} seed) were the ones that delivered the highest growth attributes and yield of black gram. Therefore, with regard to summer black gram cultivation, 45 kg ha^{-1} phosphorus rate and the inoculation of Rhizobium with phosphate solubilizing bacteria (10 g kg^{-1} seed) were found to be the most promising treatment in order to increase the black gram yield.

Conflict of interest

The authors state no conflict of interest.

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