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Impact of Phosphorous and Sulphur on growth and yield of Greengram (*Vigna radiata* L.)

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Abstract
During the Zaid season of 2025, a field study titled "Effect of Phosphorus and Sulphur on growth and yield of Greengram (*Vigna radiata* L.)" was carried out at the Crop Research Farm, Department of Agronomy, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj (U.P.). The experimental field soil had a sandy loam texture, a moderately basic response (pH 7.2), medium levels of available organic carbon (0.310%), low levels of available nitrogen (269.75 kg/ha), and extremely high levels of available potassium (246.4 kg/ha) and phosphorus (18.0 kg/ha). The experiment was laid out in a Randomized Block Design (RBD) with ten treatments and replicated thrice *viz.*, T_1: Phosphorus 30 kg/ha along with Sulphur 20 kg/ha, T_2: Phosphorus 40 kg/ha along with Sulphur 30 kg/ha, T_3: Phosphorus at 50 kg/ha along with Sulphur 40 kg/ha, T_4: Phosphorus 30 kg/ha along with Sulphur 20 kg/ha, T_5: Phosphorus 40 kg/ha along with Sulphur 30 kg/ha, T_6: Phosphorus 50 kg/ha along with Sulphur 40 kg/ha, T_7: Phosphorus 30kg/ha along with Sulphur 20 kg/ha, T_8: Phosphorus 40 kg/ha along with Sulphur 30 kg/ha, T_9: Phosphorus 50 kg/ha along with Sulphur 40 kg/ha and T_{10}: RDF: 20:40:60 NPK kg/ha as control. The result sowed highest plant height (48.80 cm), plant dry weight (30.38 g), and number of nodules (22.47) were all considerably greater with (T_9) phosphorus 50 kg/ha and sulfur 40 kg/ha. It was determined that applying phosphorus and sulfur together resulted in a noticeably larger number of growth parameters and Greengram production.

Keywords: Sulphur, Phosphorus, Growth and Yield, Greengram (Virat)

Introduction

Greengram (*Vigna radiata* L.) is one of the most significant traditional Zaid and Kharif pulse crops grown in India. Green gram's excellent nutritional value and ease of digestion give it an advantage over other pulse crops. According to estimates, each 100 grams of the seed has 24.20% protein, 1.30% fat, and 60.4% carbs. Important minerals including calcium (Ca) 118 mg and phosphorus (P) 340 mg per 100 g of seed are also present in the seed (Das *et al*., 2016) [7]. Nonetheless, green gram plays a vital role in both our everyday food and our agricultural production system. According to Singh *et al.* (2017) [19], the low productivity of this crop in India can be attributed to a number of factors, including the lack of healthy seeds, the high cost of seeds, fertilizers, and pesticides, a lack of labor during peak agricultural operations, and a large gap in the adoption of recommended production technology for greengram. In India, mungbean (greengram) is grown on an average of 5.1 million hectares, with a yield of 583 kg/ha and a production of about 2.98 million tons. With a productivity of 492 kg/ha, Rajasthan tops the states in both area and output, accounting for almost 48% of the total area and 40% of the overall production. Greengram (moong) was grown on around 1.12 lakh hectares in Uttar Pradesh and Madhya Pradesh Chaudhary.

Phosphorus are required in the early phases of cell division; the first general indication is weak, slow, and stunted growth. Some plants have symptoms of dark to blue-green coloration on their older leaves because phosphorus is relatively mobile in plants and can be moved to areas of new growth. Purpling of the leaves and stems may occur in cases of severe shortage. By restricting plant growth, phosphorus deficit results in delayed maturity and poor seed and fruit development, which lowers production (Singh *et al*., 2015) [28]. It promotes the bacterial cell's symbiotic nitrogen fixation to root hair for nodulation. Phosphorus availability in Indian soils ranges from poor to medium. Only around 30% of the phosphorus that is applied can be used by crops, with the other portion becoming insoluble. Continuous replacement of soluble P from inorganic and organic sources is required to meet the crop's phosphorus requirements since the concentration of accessible P in the soil solution is typically insufficient to maintain plant growth. The growth and development of crops, particularly pulses, depend on the element Sulphur. For pulse crops to synthesize proteins and vitamins, Sulphur is necessary. Additionally, Sulphur has been shown to increase nodulation activity in legumes, which increases N2 fixation. Throughout the greengram growing season, Sulphur has an impact on the plant's height, branches, nodulation, number of pods, and grains per pod (Kumar). Additionally, Sulphur affects the formation of dry matter and the plant's intake of phosphorus and Sulphur. Singh and colleagues (2017). Since Sulphur is a primary source of three amino acids—chitin, cysteine, and methionine—it is crucial for plants to produce protein. Additionally, Sulphur is linked to improved pulse market quality and nutritional value.

Materials and Methods

A field study in alluvial soil was carried out at the Department of Agronomy's Crop Research Farm, SHUATS, Prayagraj, U.P., during the Zaid season of 2025. The experimental field soil had a sandy loam texture, a moderately basic response (pH 7.2), medium levels of available organic carbon (0.310%), low levels of available nitrogen (269.75 kg/ha), and extremely high levels of available potassium (246.4 kg/ha) and phosphorus (18.0 kg/ha). Ten treatments were used in the Randomized Block Design (RBD) experiment, which was repeated three times T_1: Phosphorus 30 kg/ha along with Sulphur 20 kg/ha, T_2: Phosphorus 40 kg/ha along with Sulphur 30 kg/ha, T_3: Phosphorus at 50 kg/ha along with Sulphur 40 kg/ha, T_4: Phosphorus 30 kg/ha along with Sulphur 20 kg/ha, T_5: Phosphorus 40 kg/ha along with Sulphur 30 kg/ha, T_6: Phosphorus 50 kg/ha along with Sulphur 40 kg/ha, T_7: Phosphorus 30kg/ha along with Sulphur 20 kg/ha, T_8: Phosphorus 40 kg/ha along with Sulphur 30 kg/ha, T_9: Phosphorus 50 kg/ha along with Sulphur 40 kg/ha and T_{10}: RDF: 20:40:60 NPK kg/ha as control.

Soil physico-chemical properties

Representative soil samples were taken from each plot using an auger at a depth of 0 to 15 cm. Before being analyzed for several criteria, the soil samples were carefully handled and kept in plastic bags. According to Jackson (1975) [13], a pH metre was used to measure the features of the soil, including pH (7.2). An EC meter in solution was used to measure electrical conductivity (0.350 ds/m). Piper's (1950) approach was used to determine the amount of organic carbon (0.310%) in soil samples. and the alkaline KMNO4 approach, first suggested by Subbaih and Asija in 1966, was used to determine the availability of nitrogen (269.5 kg/ha) and phosphorus (18.0 kg/ha). Potassium was measured in kilos per acre using the leaching process' leftover filtrate, which was then analyzed using a flame photometer (Jackson, 1975) [13]. According to Olsen *et al*. (1954) [19], potassium (246.4 kg/ha) was determined by colorimetric measurement using a spectrophotometer and soil sample that contained a mixture of 25 milliliters of a solution containing 0.03 M NH4F and 0.025 M HCl for five minutes.

Statistical analysis

According to Gamez and Gomez (1984), a statistica analysis of variance (ANOVA) was performed on the collected experimental data. The 'F' test was significant at the 5% level, and Critical Difference (CD) values were calculated.

Results and Discussion Growth parameter

Plant Height (cm)

There were notable variations amongst the treatments. However, applying 50 kg/ha of phosphorus and 40 kg/ha of Sulphur resulted in a considerably greater plant height (48.80 cm) in (T_9), which was shown to be statistically equivalent to all treatments. On the other hand, the greatest values are (T_4) Phosphorus 50 kg/ha + Sulphur 10 kg/ha, (T_5) Phosphorus 50 kg/ha + Sulphur 15 kg/ha, and (T_6) Phosphorus 50 kg/ha + Sulphur 40 kg/ha. Growing phosphorus levels aided in the creation of new cells and roots, which made all the nutrients and water from the deeper soil layers available for increased photosynthetic activity. This resulted in a rise in plant height. Additionally, Sulphur was involved in the synthesis of proteins and the production of chlorophyll, which encouraged vegetative development and raised plant height. Singh and associates (2017) [19].

Number of Nodules/plant

The application of phosphorus 50 kg/ha and Sulphur 40 kg/ha resulted in the considerably greatest number of nodules/plant (21.72) in (T_9), which was shown to be statistically comparable to all treatments. Applying phosphorus aided in the effective use of nutrients, which improved crop canopy and further enhanced radiant energy absorption and use, leading to an increase in both the effective and total number of nodules. Additionally, phosphorus stimulated rhizobia activity and root nodule growth, which aided in fixing more atmospheric nitrogen in the root nodule. Patel *et al*. (2020) [24] confirmed similar findings. Additionally, Sulphur aided in fixing atmospheric nitrogen, which enhanced nodulation and boosted mungbean plant development. Singh and associates (2015) [28].

Plant dry weight (g/plant)

The maximum plant dry weight (30.38 g) was found in (T_9) with the application of 50 kg/ha of phosphorus and 40 kg/ha of Sulphur, according to data at 60 DAS. The greater plant height seen in this treatment was identified as the likely cause of this outcome. According to Patel *et al*. (2017) [20], phosphorus promotes root growth and development, which enhances nutrient intake and shoot development and causes seedlings to grow early. The plant height is therefore at its maximum under this treatment. (Das *et al*. 2016 and Singh *et al*. 2017) [7, 19]. The greater plant height seen in this treatment was identified as the likely cause of this outcome. Phosphorus promotes root growth and development, which enhances crop shoot development and nutrient intake. Phosphorus promotes the growth of new cells, increases plant vigor, and speeds up the development of leaves, all of which aid in increasing solar energy harvesting and improving nitrogen consumption. Growth characteristics consequently improved as phosphorus dosages increased. According to Arun Raj *et al*. (2018) [2], the cumulative effect of increasing plant height and branch count may have contributed to the higher dry weight by causing the plant to produce more dry matter.

Yield attributes

Number of pods per plant

The application of phosphorus 50 kg/ha and Sulphur 40 kg/ha resulted in the significantly largest number of pods per plant (22.93) in (T_9), which was shown to be statistically comparable to all treatments. But (T_3) 30 kg/ha of phosphorus and 20 kg/ha of Sulphur, (T_5) 50 kg/ha of phosphorus and 15 kg/ha of Sulphur, and (T_6) 50 kg/ha of phosphorus and 40 kg/ha of Sulphur. The maximum number of pods per plant after applying phosphorus may be the result of improved photosynthetic activity, enough light availability, a balanced supply of nutrients during the developing stage, and an increase in branches, which produce more pods per plant.

Additionally, the use of Sulphur may have increased the number of pods per plant because it is crucial for tissue differentiation, carbohydrate metabolism, and sugar translocation. Bharvi and Singh *et al*. (2015) [28]. One important plant nutrient that affects cell division, seed germination, flowering, fruiting, and the synthesis of fat and carbohydrates is Sulphur. Additionally, the nutrient participates in a number of biochemical processes and regulates metabolic pathways, including enzyme reactions (Das *et al*., 2016) [7].

Number of Seeds per pod

The treatment of 50 kg/ha of phosphorus and 40 kg/ha of sulfur resulted in the largest number of seeds per pod (8.20) in T_9. Nonetheless, (T_3) Phosphorus 30 kg/ha and Sulfur 20 kg/ha and (T_6) Phosphorus 50 kg/ha and Sulfur 40 kg/ha were statistically comparable to the highest (T_9) seed. The likely cause of these outcomes is that biofertilizer-inoculated seeds are well-nourished and capable of delivering sufficient nutrients and metabolites to the developing seedling. One important nutrient for plants, phosphorus affects cell division, seed germination, flowering, fruiting, and the synthesis of carbohydrates and fat. Additionally, the nutrient participates in a number of biochemical processes and regulates metabolic pathways, including enzyme reactions.

Test weight (g)

Importantly The application of 50 kg/ha of phosphorus and 40 kg/ha of sulfur resulted in a higher test weight (38.22 g) in (T_9). The maximum number of pods per plant after applying phosphorus may be the result of improved photosynthetic activity, enough light availability, a balanced supply of nutrients during the developing stage, and an increase in branches, which produce more pods per plant. Additionally, the use of sulfur may have increased the number of pods per plant because it is crucial for tissue differentiation, carbohydrate metabolism, and sugar translocation. Bharvi and Singh *et al*. (2015) [28].

Grain yield

The statistical information in Table 1 demonstrated that applying 50 kg/ha of phosphorus and 40 kg/ha of sulfur produced the maximum seed production (1794.66 kg/ha) in (T_9), which was statistically comparable to treatments 8 (1365 kg/ha). These outcomes could be attributed to improved seed germination and a larger root system for nutrient uptake. The application of sulfur may also increase seed yield by improving cell walls, tissue differences, sugar transport, maintaining conducting tissue with regulatory effects on another element, and metabolism of nucleic acids, carbohydrates, auxins, and phenols. Kumar *et al*. obtained similar results (2022). One important nutrient for plants, phosphorus affects cell division, seed germination, flowering, fruiting, and the synthesis of carbohydrates and fat. According to Choudhary *et al*. (2015) [5], nutrients also participate in a variety of biochemical processes and regulate metabolic pathways, including enzyme reactions**.**

Stover yield

The Data in Table 1 demonstrated that the application of phosphorus (50 kg/ha) and sulfur (40 kg/ha) produced the greatest stover production (2946.80 kg/ha) at harvest, which was found to be statistically comparable to the highest. Improved development in terms of seedling emergence, plant height, and dry matter accumulation, which increases photosynthetic efficiency, may be the cause of the noticeably higher stover yield following the application of phosphorus and sulfur. Superior vegetative development results from increased photosynthetic accumulation in vegetative components, which raises the stover production. Additionally, the higher and significant seed yield obtained with the application of phosphorus (20 kg/ha) may be due to a well-developed root system and greater translocation of photosynthates from source to sink, while the increased stover yield with the application of sulfur may be due to vegetative development creating too many sites. The application of sulfur had the combined impact of increasing plant height, number of leaves per plant, and number of branches per plant—that is, enhanced growth parameters—which led to an increase in straw yield. This result closely aligns with findings by Arun Raj *et al*. (2018) [2], Parashar *et al*. (2020) [23], Yadav *et al*. (2017) [29], and Gajera *et al*. (2014) [11].

Harvest index

The application of 50 kg/ha of phosphorus and 40 kg/ha of sulfur resulted in a significantly higher harvest index (31.08%) in (T_9). Nonetheless, the minimum harvest index for all treatments was Control (28.14%), and there was no discernible difference between the treatments. When phosphorus levels were applied, there were more branches, which led to more pods. Weight of a thousand grains, which resulted in increased seed production through the optimization of photosynthesis, respiration, energy storage, transfer, cell division, and cell elongation These findings were in line with those findings by Choudhary *et al*. (2015) [5].

Table 1: Effect of Phosphorus and Sulphur on growth attributes of Greengram

S. No.	Treatments	Plant height (cm)	Dry weight (g)	No of Nodules
		60 DAS	60 DAS	60 DAS
1	Phosphorus 30 kg/ha + Sulphur 20 kg/ha	44.07	23.71	17.47
2	Phosphorus 40 kg/ha + Sulphur 30 kg/ha	44.87	24.01	17.73
3	Phosphorus 50 kg/ha + Sulphur 40 kg/ha	47.20	28.80	20.87
4	Phosphorus 30 kg/ha + Sulphur 20 kg/ha	44.53	27.04	18.07
5	Phosphorus 40 kg/ha + Sulphur 30 kg/ha	46.53	26.93	19.60
6	Phosphorus 50 kg/ha + Sulphur 40 kg/ha	48.20	28.79	21.67
7	Phosphorus 30 kg/ha + Sulphur 20 kg/ha	45.67	25.58	18.40
8	Phosphorus 40 kg/ha + Sulphur 30 kg/ha	45.87	27.63	20.33
9	Phosphorus 50 kg/ha + Sulphur 40 kg/ha	48.80	30.38	22.47
10.	Control (RDF): 20:60:40 NPK kg/ha	45.33	26.00	19.73
SEm (+)		2.51	1.29	1.09
CD (P= 0.05)		7.47	3.82	3.24

Table 2: Effect of Phosphorus and Sulphur on yield and yield attributes of Greengram

Post-harvest							
S. No.	Treatments	No. of pods/plants	No. of seed/pod	Test weight (g)	Seed yield (Kg/ha)	Stover yield (kg/ha)	Harvest index (%)
1.	Phosphorus 30 kg/ha + Sulphur 20 kg/ha	16.87	5.93	34.81	874.06	1991.86	30.48
2.	Phosphorus 40 kg/ha + Sulphur 30 kg/ha	17.73	6.20	35.37	972.24	2016.84	32.47
3.	Phosphorus 50 kg/ha + Sulphur 40 kg/ha	21.07	7.20	37.88	1427.84	2793.21	33.86
4.	Phosphorus 30 kg/ha + Sulphur 20 kg/ha	18.07	6.40	35.77	1031.73	2352.13	30.55
5.	Phosphorus 40 kg/ha + Sulphur 30 kg/ha	19.80	6.87	37.28	1268.86	2611.82	32.64
6.	Phosphorus 50 kg/ha + Sulphur 40 kg/ha	21.93	7.87	37.92	1634.30	2792.57	36.98
7.	Phosphorus 30 kg/ha + Sulphur 20 kg/ha	18.40	6.67	36.35	1117.65	2481.45	31.08
8.	Phosphorus 40 kg/ha + Sulphur 30 kg/ha	20.33	7.00	37.86	1354.57	2679.98	33.38
9.	Phosphorus 50 kg/ha + Sulphur 40 kg/ha	22.93	8.20	38.22	1794.66	2946.80	37.84
10.	Control (RDF): 20:60:40 NPK kg/ha	19.73	6.80	37.08	1247.96	2522.39	33.22
	F - Test	S	S	S	S	S	NS
	SEm±	1.01	0.39	0.64	97.56	121.38	2.34
	CD (p=0.05)	3.01	1.15	1.89	289.87	360.65	-

Conclusion
The application of phosphorus 50 kg/ha and sulfur 40 kg/ha (T_9) in Greengram has produced the maximum grain yield, gross return, net return, and benefit cost ratio, according to the results of a one-season trial.

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Competing Interests
Authors have declared that no competing interests exits.

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