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## Effect of potassium and sulphur levels on growth, yield and nutrient uptake of Greengram (*Vigna radiata* L.)

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### Abstract

Greengram (*Vigna radiata* L.) is one of the most important pulse crops cultivated in tropical and subtropical regions due to its high nutritional value, short duration and ability to improve soil fertility through biological nitrogen fixation. However, the productivity of greengram in India remains below its genetic potential, primarily because of imbalanced nutrient management and widespread deficiencies of secondary and micronutrients in cultivated soils. Among essential nutrients, potassium and sulphur play a pivotal role in regulating physiological processes, photosynthesis, nutrient translocation, protein synthesis, enzyme activation and biological nitrogen fixation, thereby influencing crop growth and productivity.

A field experiment was conducted during the Kharif season at the Instructional Farm of the Department of Agronomy, Faculty of Agricultural Sciences and Allied Industries, Rama University, Kanpur, Uttar Pradesh, to evaluate the effect of different levels of potassium and sulphur on growth, yield, nutrient uptake and economics of greengram. The experiment was laid out in a Randomized Block Design with nine treatment combinations comprising three levels of potassium and three levels of sulphur, replicated thrice. Observations on growth parameters, yield attributes, seed and stover yield, nutrient content, nutrient uptake and economic returns were recorded and statistically analyzed using analysis of variance.

The results revealed that progressive application of potassium and sulphur significantly enhanced plant growth, nodulation, dry matter accumulation and yield attributes of greengram. Higher levels of potassium in combination with sulphur improved plant height, number of branches, nodules per plant, chlorophyll development and biomass production. The combined application of 50 kg K<sub>2</sub>O ha<sup>-1</sup> and 30 kg sulphur ha<sup>-1</sup> recorded superior performance with respect to pods plant<sup>-1</sup>, seeds pod<sup>-1</sup>, test weight, seed yield and stover yield. Enhanced nutrient availability and improved physiological efficiency under balanced fertilization also resulted in greater uptake of nitrogen, phosphorus and potassium by the crop.

Economic analysis demonstrated that integrated application of potassium and sulphur substantially improved profitability of greengram cultivation. The treatment receiving 50 kg K<sub>2</sub>O ha<sup>-1</sup> along with 30 kg sulphur ha<sup>-1</sup> generated the highest gross return, net return and benefit-cost ratio, indicating its economic viability under the agro-climatic conditions of central Uttar Pradesh. The improvement in crop performance was attributed to enhanced nutrient utilization, better translocation of photosynthates, increased protein synthesis and improved root development resulting from balanced potassium and sulphur nutrition.

Therefore, the study concludes that application of 50 kg K<sub>2</sub>O ha<sup>-1</sup> combined with 30 kg sulphur ha<sup>-1</sup> can be recommended as an efficient nutrient management strategy for maximizing growth, productivity, nutrient uptake and profitability of greengram under similar soil and climatic conditions.

**Keywords:** Greengram, potassium, sulphur, nutrient uptake, yield attributes, profitability, balanced fertilization, pulse production

### Introduction

Greengram [*Vigna radiata* (L.) Wilczek], commonly known as mungbean, is one of the most important pulse crops cultivated in Asia and several tropical and subtropical regions of the world. It is highly valued for its short duration, high nutritive value, digestibility and adaptability to diverse agro-climatic conditions. Greengram seeds contain approximately 22–25 per cent protein, 60–65 per cent carbohydrates, 1.2–1.5 per cent fat, and substantial quantities of vitamins and minerals, making it an important component of human nutrition, particularly in vegetarian diets (Ali and Gupta, 2012)<sup>[1]</sup>. Besides serving as a rich source of dietary protein, greengram contributes significantly to soil fertility through symbiotic nitrogen fixation and improves the sustainability of cropping systems.

Pulses occupy a unique position in Indian agriculture owing to their nutritional, ecological and economic importance. India is the largest producer, consumer and importer of pulses in the world. Pulses are cultivated over nearly 30 million hectares with an annual production exceeding 27 million tonnes. Despite being the largest producer, the productivity of pulse crops in India remains considerably lower than the global average due to poor soil fertility, imbalanced nutrient management, moisture stress and cultivation on marginal lands. Among pulse crops, greengram occupies a prominent place because of its wide adaptability, short growth duration and suitability for multiple cropping systems.

Globally, greengram is cultivated over approximately 7 million hectares with major production concentrated in India, China, Myanmar, Pakistan, Bangladesh, Thailand and Indonesia. India accounts for more than half of the global greengram acreage and production. The crop is widely grown during Kharif, Rabi and summer seasons under irrigated and rainfed conditions. In Uttar Pradesh and other northern states, greengram has emerged as an important pulse crop due to its ability to fit into diverse cropping systems and provide additional income to farmers.

The increasing demand for pulses driven by population growth and nutritional security necessitates substantial enhancement in crop productivity. However, yield realization in greengram is often constrained by inadequate nutrient supply. Continuous cultivation without balanced fertilization has resulted in depletion of essential nutrients from agricultural soils. While farmers generally focus on nitrogen and phosphorus fertilization, the importance of potassium and sulphur nutrition is frequently overlooked. Consequently, deficiencies of these nutrients have become increasingly widespread in many agricultural regions of India.

Potassium is the third major essential plant nutrient after nitrogen and phosphorus and plays a crucial role in numerous physiological and biochemical processes within plants. It regulates enzyme activation, photosynthesis, protein synthesis, carbohydrate metabolism, osmoregulation and translocation of photosynthates from source to sink tissues. Potassium also enhances water-use efficiency, improves resistance to drought and diseases, and contributes to better grain filling and seed development. Adequate potassium nutrition promotes vigorous root growth and improves nutrient absorption from soil, ultimately resulting in enhanced crop productivity (Tisdale *et al.*, 2013) [37].

In pulse crops, potassium has a significant influence on nodulation and biological nitrogen fixation. Potassium-deficient plants often exhibit poor growth, reduced chlorophyll content, impaired photosynthesis and lower reproductive efficiency. Several researchers have reported substantial improvements in growth and yield attributes of greengram with potassium fertilization. Enhanced potassium availability increases the movement of assimilates towards developing pods, thereby improving seed formation and grain yield (Chauhan and Singh, 2011) [37].

Sulphur is recognized as the fourth major plant nutrient after nitrogen, phosphorus and potassium. It is an integral component of sulphur-containing amino acids such as cysteine, cystine and methionine, which are essential for protein synthesis. Sulphur is also involved in chlorophyll formation, enzyme activation, vitamin synthesis and nitrogen metabolism. In leguminous crops, sulphur plays a critical role in root nodulation and biological nitrogen fixation due to its involvement in protein formation and energy transfer processes (Tiwari and Gupta, 2006) [38].

The importance of sulphur nutrition has increased considerably in recent decades because of declining atmospheric sulphur

deposition, intensive agriculture and increased use of high-analysis fertilizers containing little or no sulphur. Sulphur deficiency has emerged as a major nutritional disorder affecting crop productivity in many regions of India. Deficiency symptoms include chlorosis of younger leaves, reduced growth, poor nodulation and lower protein content. Sulphur application has been reported to enhance growth, yield attributes, nutrient uptake and quality parameters of pulse crops by improving nitrogen assimilation and protein synthesis (Aulakh *et al.*, 2007) [2].

The interaction between potassium and sulphur is particularly important in pulse production systems. Potassium facilitates efficient translocation of photosynthates and nutrient movement within plants, whereas sulphur contributes to protein synthesis and enzymatic activity. Their combined application often produces synergistic effects on plant growth and productivity. Balanced nutrition involving both potassium and sulphur can improve root development, nodulation, dry matter accumulation, nutrient uptake and yield formation more effectively than individual nutrient application.

Recent studies have demonstrated that integrated potassium and sulphur fertilization significantly enhances crop growth rate, relative growth rate, nutrient-use efficiency and seed yield in pulse crops. Enhanced nutrient availability promotes vigorous vegetative growth during early stages and facilitates efficient partitioning of assimilates towards reproductive organs during later stages. Consequently, balanced fertilization not only increases productivity but also improves profitability and sustainability of pulse-based cropping systems.

Despite the recognized importance of potassium and sulphur, information regarding their optimum levels and combined effects on greengram under the agro-climatic conditions of central Uttar Pradesh remains limited. Soil fertility status, climatic conditions and crop management practices vary considerably across regions, necessitating location-specific recommendations for nutrient management. Identification of appropriate potassium and sulphur levels is therefore essential for maximizing crop productivity, nutrient uptake and economic returns.

## Materials and Methods

The present field investigation entitled “Effect of Potassium and Sulphur Levels on Growth, Yield and Nutrient Uptake of Greengram (*Vigna radiata* L.)” was conducted during the Kharif season of 2025 at the Instructional Farm, Department of Agronomy, Faculty of Agricultural Sciences and Allied Industries, Rama University, Kanpur, Uttar Pradesh. The experimental farm is situated in the Indo-Gangetic alluvial plains of central Uttar Pradesh at an altitude of about 126 m above mean sea level and lies between 26.5° N latitude and 80.3° E longitude. The region experiences a subtropical climate characterized by hot summers, moderate rainfall during the southwest monsoon period and cool winters.

The soil of the experimental field was sandy loam in texture, well drained and moderately fertile. Before sowing, representative soil samples were collected from the experimental area and analyzed for physico-chemical properties. The soil was found to be slightly alkaline in reaction with medium fertility status. The available nitrogen content was low, while available phosphorus and potassium were in the medium range. The soil also exhibited marginal sulphur availability, indicating the possibility of crop response to sulphur fertilization.

The experiment was laid out in a Randomized Block Design (RBD) with nine treatment combinations and three replications. The treatments consisted of three levels of potassium and three levels of sulphur. Potassium was applied at 0, 25 and 50 kg K<sub>2</sub>O

ha<sup>-1</sup>, while sulphur was applied at 0, 15 and 30 kg ha<sup>-1</sup>. The treatment combinations were designated as T<sub>1</sub> (K<sub>0</sub>S<sub>0</sub>), T<sub>2</sub> (K<sub>0</sub>S<sub>15</sub>), T<sub>3</sub> (K<sub>0</sub>S<sub>30</sub>), T<sub>4</sub> (K<sub>25</sub>S<sub>0</sub>), T<sub>5</sub> (K<sub>25</sub>S<sub>15</sub>), T<sub>6</sub> (K<sub>25</sub>S<sub>30</sub>), T<sub>7</sub> (K<sub>50</sub>S<sub>0</sub>), T<sub>8</sub> (K<sub>50</sub>S<sub>15</sub>) and T<sub>9</sub> (K<sub>50</sub>S<sub>30</sub>). Each treatment was randomly allocated within each replication to minimize experimental error and ensure unbiased comparison among treatments.

The field was prepared by one deep ploughing followed by two cross harrowings and planking to obtain a fine tilth suitable for greengram cultivation. Healthy and certified seed of greengram variety suitable for the region was used for sowing. The crop was sown manually in rows maintaining a spacing of 30 cm between rows and 10 cm between plants. Recommended doses of nitrogen and phosphorus were applied uniformly to all treatments as basal application. Potassium and sulphur fertilizers were applied according to treatment specifications before sowing and incorporated thoroughly into the soil.

All recommended agronomic practices were adopted uniformly throughout the crop growth period. Irrigation, weed management and plant protection measures were carried out as per crop requirement to ensure healthy crop growth. Hand weeding was performed whenever necessary to maintain weed-free conditions. Appropriate measures were also taken to protect the crop from insect pests and diseases.

Observations on growth parameters were recorded at regular intervals during crop growth. Plant height, number of branches per plant, number of nodules per plant, dry matter accumulation and crop growth indices were measured from randomly selected plants in each experimental plot. Yield attributes including number of pods per plant, pod length, number of seeds per pod and test weight were recorded at maturity. After harvesting, seed yield and stover yield were determined on a plot basis and subsequently converted into hectare values.

For nutrient analysis, representative plant samples were collected at harvest and processed following standard laboratory procedures. Nitrogen content in plant samples was estimated by the modified Kjeldahl method, phosphorus content was determined using the vanadomolybdate yellow colour method and potassium content was estimated through flame photometry. Nutrient uptake was calculated by multiplying nutrient concentration with corresponding dry matter production.

Economic analysis was carried out on the basis of prevailing market prices of inputs and outputs. Cost of cultivation, gross return, net return and benefit-cost ratio were computed for each treatment to assess economic feasibility and profitability of potassium and sulphur application in greengram cultivation.

The experimental data recorded during the course of investigation were subjected to statistical analysis following the standard procedure for Randomized Block Design as described by Gomez and Gomez. Analysis of variance (ANOVA) was performed to test the significance of treatment effects. The significance of differences among treatment means was tested using the F-test at the 5 per cent level of probability. Whenever treatment effects were found significant, critical difference (CD) values were calculated for comparison of treatment means. The coefficient of variation was also worked out to evaluate the reliability and precision of the experimental results.

## Results and Discussion

### Effect of Potassium and Sulphur Levels on Plant Height of Greengram

Plant height is an important growth parameter reflecting the overall vegetative development and nutrient utilization efficiency of a crop. The data pertaining to plant height of greengram as

influenced by different levels of potassium and sulphur are presented in Table 1.

**Table 1:** Effect of Potassium and Sulphur Levels on Plant Height (cm) of Greengram

| Treatment                                         | 30 DAS | 60 DAS | At Harvest |
|---------------------------------------------------|--------|--------|------------|
| T <sub>1</sub> (K <sub>0</sub> S <sub>0</sub> )   | 17.84  | 35.42  | 42.36      |
| T <sub>2</sub> (K <sub>0</sub> S <sub>15</sub> )  | 18.96  | 37.84  | 45.28      |
| T <sub>3</sub> (K <sub>0</sub> S <sub>30</sub> )  | 19.78  | 39.62  | 47.14      |
| T <sub>4</sub> (K <sub>25</sub> S <sub>0</sub> )  | 20.42  | 40.86  | 48.76      |
| T <sub>5</sub> (K <sub>25</sub> S <sub>15</sub> ) | 21.84  | 43.58  | 50.64      |
| T <sub>6</sub> (K <sub>25</sub> S <sub>30</sub> ) | 22.74  | 45.72  | 52.38      |
| T <sub>7</sub> (K <sub>50</sub> S <sub>0</sub> )  | 23.16  | 46.54  | 52.96      |
| T <sub>8</sub> (K <sub>50</sub> S <sub>15</sub> ) | 23.88  | 47.96  | 53.84      |
| T <sub>9</sub> (K <sub>50</sub> S <sub>30</sub> ) | 24.62  | 49.38  | 54.82      |
| SEm (±)                                           | 0.41   | 0.82   | 0.96       |
| CD (P=0.05)                                       | 1.23   | 2.46   | 2.88       |

The data presented in Table 1 clearly indicate that plant height of greengram increased significantly with increasing levels of potassium and sulphur at all stages of crop growth. The treatment receiving 50 kg K<sub>2</sub>O ha<sup>-1</sup> along with 30 kg sulphur ha<sup>-1</sup> (T<sub>9</sub>) recorded the highest plant height of 24.62 cm at 30 DAS, 49.38 cm at 60 DAS and 54.82 cm at harvest. The lowest plant height was observed under the control treatment T<sub>1</sub> (K<sub>0</sub>S<sub>0</sub>), which recorded 17.84 cm, 35.42 cm and 42.36 cm at the respective growth stages.

The increase in plant height due to potassium application may be attributed to enhanced cell division, cell elongation, photosynthetic efficiency and translocation of assimilates from source to sink tissues. Potassium plays a vital role in enzyme activation and regulation of plant water relations, which ultimately promotes vigorous vegetative growth. Similarly, sulphur application improved plant growth by enhancing chlorophyll synthesis, amino acid formation and protein metabolism. Adequate sulphur availability also promotes root growth and biological nitrogen fixation, leading to better nutrient absorption and crop development.

The combined application of potassium and sulphur exhibited a synergistic effect on plant growth. Treatments receiving higher doses of both nutrients consistently produced taller plants compared to individual nutrient application. Treatment T<sub>8</sub> (50 kg K<sub>2</sub>O ha<sup>-1</sup> + 15 kg S ha<sup>-1</sup>) remained statistically at par with T<sub>9</sub> at certain growth stages; however, T<sub>9</sub> recorded the maximum values throughout the crop growth period.

The findings are in close agreement with those reported by Chauhan and Singh (2011) [7], Tripathi and Verma (2011) [39], Choudhary *et al.* (2019) [8] and Sumasree *et al.* (2020) [34], who observed significant improvement in plant height of pulse crops with balanced application of potassium and sulphur. The enhanced vegetative growth under higher nutrient levels ultimately contributed to greater dry matter production and yield potential of greengram.

### Effect of Potassium and Sulphur Levels on Number of Branches Plant<sup>-1</sup> of Greengram

The number of branches per plant is an important growth parameter that directly influences canopy development, photosynthetic efficiency and reproductive potential of greengram. The data regarding the effect of potassium and sulphur levels on the number of branches per plant are presented in Table 2.

**Table 2:** Effect of Potassium and Sulphur Levels on Number of Branches Plant<sup>-1</sup> of Greengram

| Treatment                                         | 30 DAS | 60 DAS | At Harvest |
|---------------------------------------------------|--------|--------|------------|
| T <sub>1</sub> (K <sub>0</sub> S <sub>0</sub> )   | 2.84   | 4.12   | 4.68       |
| T <sub>2</sub> (K <sub>0</sub> S <sub>15</sub> )  | 3.06   | 4.48   | 5.06       |
| T <sub>3</sub> (K <sub>0</sub> S <sub>30</sub> )  | 3.22   | 4.82   | 5.42       |
| T <sub>4</sub> (K <sub>25</sub> S <sub>0</sub> )  | 3.38   | 5.08   | 5.84       |
| T <sub>5</sub> (K <sub>25</sub> S <sub>15</sub> ) | 3.64   | 5.46   | 6.18       |
| T <sub>6</sub> (K <sub>25</sub> S <sub>30</sub> ) | 3.88   | 5.84   | 6.54       |
| T <sub>7</sub> (K <sub>50</sub> S <sub>0</sub> )  | 4.02   | 6.04   | 6.76       |
| T <sub>8</sub> (K <sub>50</sub> S <sub>15</sub> ) | 4.18   | 6.26   | 7.04       |
| T <sub>9</sub> (K <sub>50</sub> S <sub>30</sub> ) | 4.36   | 6.54   | 7.28       |
| SEm (±)                                           | 0.08   | 0.11   | 0.14       |
| CD (P=0.05)                                       | 0.24   | 0.33   | 0.42       |

The results presented in Table 2 revealed that the number of branches per plant increased significantly with increasing levels of potassium and sulphur throughout the crop growth period. The highest number of branches per plant was recorded under treatment T<sub>9</sub> (50 kg K<sub>2</sub>O ha<sup>-1</sup> + 30 kg S ha<sup>-1</sup>), which produced 4.36, 6.54 and 7.28 branches plant<sup>-1</sup> at 30 DAS, 60 DAS and harvest, respectively. The lowest values were observed under the control treatment T<sub>1</sub> (K<sub>0</sub>S<sub>0</sub>), which recorded only 2.84, 4.12 and 4.68 branches plant<sup>-1</sup> at the corresponding growth stages.

The significant increase in branching due to potassium fertilization may be attributed to improved meristematic activity, enhanced photosynthetic efficiency and better translocation of carbohydrates within the plant system. Potassium plays a key role in regulating enzymatic processes and maintaining cellular turgidity, which promotes the development of auxiliary buds and vegetative branches. Increased branching provides a larger photosynthetic surface area, resulting in greater accumulation of assimilates and enhanced crop growth.

Sulphur application also exerted a positive influence on branch formation. Sulphur is an essential constituent of amino acids, proteins and enzymes that are directly involved in plant growth and development. Adequate sulphur supply improves nitrogen metabolism and chlorophyll synthesis, leading to vigorous vegetative growth and greater branching. The combined application of potassium and sulphur created favourable nutritional conditions for plant development, resulting in maximum branch production.

Among the treatments, T<sub>8</sub> (50 kg K<sub>2</sub>O ha<sup>-1</sup> + 15 kg S ha<sup>-1</sup>) remained statistically comparable with T<sub>9</sub> for certain observations; however, T<sub>9</sub> consistently recorded the highest values throughout the crop growth period. The superiority of higher potassium and sulphur levels indicates the synergistic role of these nutrients in stimulating vegetative growth and branching behaviour of greengram plants.

The present findings corroborate the results reported by Singh *et al.* (2011) [31], Tripathi and Verma (2011) [39], Choudhary *et al.* (2019) [8] and Singh *et al.* (2022) [30], who observed significant enhancement in branching of pulse crops following balanced application of potassium and sulphur. Increased branching under higher nutrient levels ultimately contributed towards improved yield attributes and productivity of greengram.

#### Effect of Potassium and Sulphur Levels on Number of Nodules Plant<sup>-1</sup> and Dry Weight of Nodules of Greengram

Nodulation is one of the most important physiological characteristics of leguminous crops as it directly influences biological nitrogen fixation and nutrient availability to the plant. The number and dry weight of nodules are reliable indicators of symbiotic efficiency and overall plant health. The data pertaining

to the effect of potassium and sulphur levels on nodulation of greengram are presented in Table 3.

**Table 3:** Effect of Potassium and Sulphur Levels on Number of Nodules Plant<sup>-1</sup> and Dry Weight of Nodules of Greengram

| Treatment                                         | Number of Nodules Plant <sup>-1</sup> (45 DAS) | Dry Weight of Nodules (mg Plant <sup>-1</sup> ) |
|---------------------------------------------------|------------------------------------------------|-------------------------------------------------|
| T <sub>1</sub> (K <sub>0</sub> S <sub>0</sub> )   | 19.84                                          | 112.46                                          |
| T <sub>2</sub> (K <sub>0</sub> S <sub>15</sub> )  | 21.62                                          | 124.38                                          |
| T <sub>3</sub> (K <sub>0</sub> S <sub>30</sub> )  | 23.48                                          | 136.72                                          |
| T <sub>4</sub> (K <sub>25</sub> S <sub>0</sub> )  | 25.12                                          | 148.86                                          |
| T <sub>5</sub> (K <sub>25</sub> S <sub>15</sub> ) | 27.46                                          | 162.34                                          |
| T <sub>6</sub> (K <sub>25</sub> S <sub>30</sub> ) | 29.84                                          | 176.58                                          |
| T <sub>7</sub> (K <sub>50</sub> S <sub>0</sub> )  | 31.28                                          | 184.64                                          |
| T <sub>8</sub> (K <sub>50</sub> S <sub>15</sub> ) | 32.76                                          | 192.86                                          |
| T <sub>9</sub> (K <sub>50</sub> S <sub>30</sub> ) | 34.46                                          | 201.84                                          |
| SEm (±)                                           | 0.58                                           | 3.46                                            |
| CD (P=0.05)                                       | 1.74                                           | 10.38                                           |

The data presented in Table 3 clearly indicate that potassium and sulphur application significantly influenced the nodulation behaviour of greengram. The highest number of nodules per plant (34.46) and maximum dry weight of nodules (201.84 mg plant<sup>-1</sup>) were recorded under treatment T<sub>9</sub> receiving 50 kg K<sub>2</sub>O ha<sup>-1</sup> along with 30 kg sulphur ha<sup>-1</sup>. In contrast, the lowest nodulation was observed under the control treatment T<sub>1</sub>, which recorded only 19.84 nodules plant<sup>-1</sup> and 112.46 mg nodule dry weight plant<sup>-1</sup>.

The progressive increase in nodulation with increasing potassium levels may be attributed to improved root growth, enhanced carbohydrate translocation and greater energy availability for rhizobial activity. Potassium plays an important role in photosynthesis and transport of assimilates from leaves to roots, thereby providing sufficient energy for nodule initiation and development. Improved root proliferation under adequate potassium nutrition also creates favourable conditions for rhizobial colonization and nitrogen fixation.

Sulphur application further enhanced nodule formation and development owing to its critical role in protein synthesis and nitrogen metabolism. Sulphur is a structural component of several sulphur-containing amino acids and enzymes involved in biological nitrogen fixation. Adequate sulphur availability stimulates the formation of effective nodules and increases the activity of nitrogenase enzymes responsible for atmospheric nitrogen fixation. Consequently, sulphur-fertilized plants produced a greater number of healthy and active nodules with higher dry matter accumulation.

The combined application of potassium and sulphur exhibited a synergistic effect on nodulation. Treatments receiving higher levels of both nutrients consistently outperformed individual nutrient treatments. Treatment T<sub>8</sub> remained statistically close to T<sub>9</sub>; however, T<sub>9</sub> recorded the maximum values for both nodulation parameters. The superior nodulation observed under balanced nutrient supply may be attributed to improved root growth, enhanced microbial activity and efficient utilization of photosynthates.

The increased dry weight of nodules under higher nutrient levels indicates the formation of larger and more active nodules capable of fixing greater amounts of atmospheric nitrogen. Enhanced biological nitrogen fixation subsequently improved crop growth, dry matter production and yield performance. These results clearly demonstrate the importance of potassium and sulphur nutrition in promoting efficient symbiotic nitrogen fixation in greengram.

The present findings are in close conformity with those reported

by Dakora and Keya (1997) <sup>[1]</sup>, Becana *et al.* (2018) <sup>[4]</sup>, Singh *et al.* (2011) <sup>[31]</sup>, Choudhary *et al.* (2019) <sup>[8]</sup> and Sumasree *et al.* (2020) <sup>[34]</sup>, who observed significant improvement in nodule number and nodule biomass of pulse crops following balanced application of potassium and sulphur. The enhanced nodulation ultimately contributed to better nutrient uptake and higher productivity of greengram.

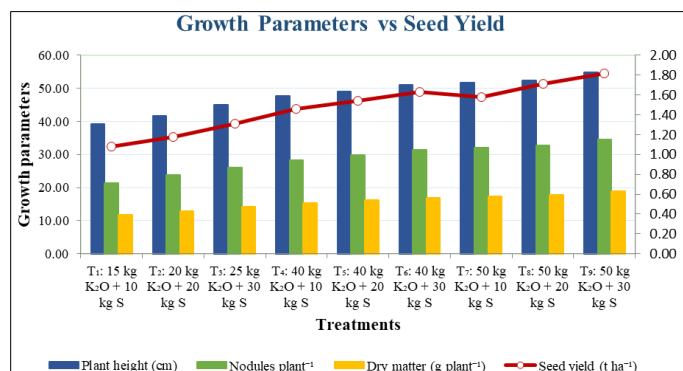
### Effect of Potassium and Sulphur Levels on Yield Attributes and Yield of Greengram

Yield attributes are the ultimate expression of the growth and developmental processes occurring throughout the crop life cycle. The number of pods per plant, seeds per pod and test weight directly determine the productivity potential of greengram. The data pertaining to yield attributes and yield as influenced by different levels of potassium and sulphur are presented in Table 4.

**Table 4:** Effect of Potassium and Sulphur Levels on Yield Attributes and Yield of Greengram

| Treatment                                         | Pods Plant <sup>-1</sup> | Seeds Pod <sup>-1</sup> | Test Weight (g) | Seed Yield (t ha <sup>-1</sup> ) | Stover Yield (q ha <sup>-1</sup> ) |
|---------------------------------------------------|--------------------------|-------------------------|-----------------|----------------------------------|------------------------------------|
| T <sub>1</sub> (K <sub>0</sub> S <sub>0</sub> )   | 24.46                    | 8.24                    | 34.18           | 1.08                             | 22.46                              |
| T <sub>2</sub> (K <sub>0</sub> S <sub>15</sub> )  | 26.82                    | 8.76                    | 35.42           | 1.18                             | 24.14                              |
| T <sub>3</sub> (K <sub>0</sub> S <sub>30</sub> )  | 28.74                    | 9.12                    | 36.68           | 1.27                             | 25.84                              |
| T <sub>4</sub> (K <sub>25</sub> S <sub>0</sub> )  | 30.16                    | 9.48                    | 37.54           | 1.36                             | 27.46                              |
| T <sub>5</sub> (K <sub>25</sub> S <sub>15</sub> ) | 32.48                    | 10.04                   | 38.84           | 1.49                             | 29.26                              |
| T <sub>6</sub> (K <sub>25</sub> S <sub>30</sub> ) | 34.84                    | 10.48                   | 40.16           | 1.61                             | 30.88                              |
| T <sub>7</sub> (K <sub>50</sub> S <sub>0</sub> )  | 35.62                    | 10.84                   | 40.94           | 1.66                             | 31.42                              |
| T <sub>8</sub> (K <sub>50</sub> S <sub>15</sub> ) | 37.18                    | 11.24                   | 41.86           | 1.75                             | 32.16                              |
| T <sub>9</sub> (K <sub>50</sub> S <sub>30</sub> ) | 38.64                    | 11.84                   | 42.86           | 1.82                             | 32.84                              |
| SEm (±)                                           | 0.62                     | 0.18                    | 0.54            | 0.04                             | 0.76                               |
| CD (P=0.05)                                       | 1.86                     | 0.54                    | 1.62            | 0.12                             | 2.28                               |

The results presented in Table 4 clearly indicate that the application of potassium and sulphur significantly improved all yield attributes and yield parameters of greengram. Among the different treatment combinations, T<sub>9</sub> (50 kg K<sub>2</sub>O ha<sup>-1</sup> + 30 kg S ha<sup>-1</sup>) recorded the highest number of pods per plant (38.64), seeds per pod (11.84), test weight (42.86 g), seed yield (1.82 t ha<sup>-1</sup>) and stover yield (32.84 q ha<sup>-1</sup>). The lowest values for all these parameters were observed under the control treatment T<sub>1</sub> (K<sub>0</sub>S<sub>0</sub>).



The substantial increase in the number of pods per plant under higher potassium and sulphur levels may be attributed to improved vegetative growth, enhanced photosynthetic activity and better translocation of assimilates towards reproductive organs. Potassium plays a crucial role in carbohydrate synthesis and transport, thereby ensuring adequate supply of photosynthates to developing flowers and pods. Sulphur, on the other hand, promotes protein synthesis and metabolic activities

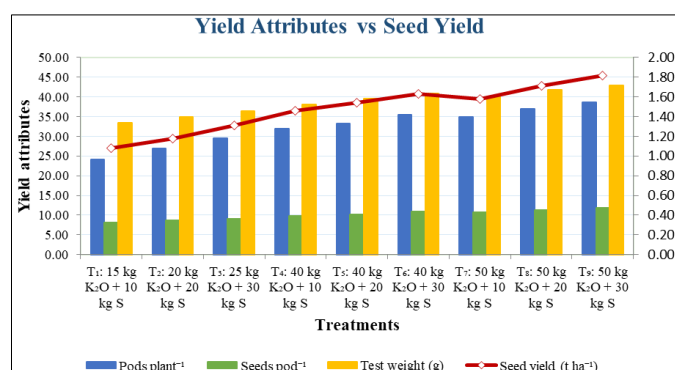
essential for flower initiation and pod development.

The number of seeds per pod increased significantly with increasing levels of both nutrients. Adequate potassium nutrition improved pollen viability, fertilization and seed setting, whereas sulphur enhanced amino acid synthesis and reproductive efficiency. Consequently, plants receiving balanced potassium and sulphur nutrition produced a greater number of well-filled seeds per pod.

Test weight also exhibited a significant improvement under higher nutrient levels. The maximum test weight recorded under T<sub>9</sub> indicated better grain filling and accumulation of storage reserves. Potassium is known to facilitate translocation of carbohydrates from source leaves to developing grains, while sulphur contributes to protein synthesis and seed quality improvement. The combined effect of these nutrients resulted in heavier and well-developed seeds.

Seed yield is the cumulative outcome of all growth and yield-contributing characters. The highest seed yield of 1.82 t ha<sup>-1</sup> recorded under T<sub>9</sub> represented a substantial increase over the control treatment. The enhanced yield may be attributed to improved nodulation, greater dry matter accumulation, higher photosynthetic efficiency and superior yield attributes. Balanced potassium and sulphur nutrition created favourable physiological conditions for efficient conversion of vegetative growth into economic yield.

A similar trend was observed in stover yield, where T<sub>9</sub> recorded the maximum value of 32.84 q ha<sup>-1</sup>. Increased biomass production under higher nutrient levels may be attributed to enhanced nutrient uptake, vigorous plant growth and greater photosynthetic activity throughout the crop growth period. Treatment T<sub>8</sub> (50 kg K<sub>2</sub>O ha<sup>-1</sup> + 15 kg S ha<sup>-1</sup>) remained statistically at par with T<sub>9</sub> for several yield parameters, indicating that higher potassium levels substantially contributed to yield improvement.



The superior performance of T<sub>9</sub> clearly demonstrates the synergistic effect of potassium and sulphur in enhancing reproductive growth and productivity of greengram. Potassium improved assimilate translocation, enzyme activation and water-use efficiency, while sulphur enhanced protein synthesis, chlorophyll formation and nutrient metabolism. The combined action of these nutrients resulted in better crop growth, higher yield attributes and ultimately greater seed and stover yield.

These findings are in close agreement with the results reported by Bairwa *et al.* (2012) <sup>[3]</sup>, Tripathi and Verma (2011) <sup>[39]</sup>, Singh *et al.* (2011) <sup>[31]</sup>, Choudhary *et al.* (2019) <sup>[8]</sup> and Sumasree *et al.* (2020) <sup>[34]</sup>, who observed significant increases in pods per plant, seed yield and biological yield of pulse crops following balanced potassium and sulphur fertilization. The present investigation confirms that integrated application of 50 kg K<sub>2</sub>O ha<sup>-1</sup> and 30 kg sulphur ha<sup>-1</sup> is highly effective for maximizing yield potential of greengram under the prevailing agro-climatic conditions.

## Effect of Potassium and Sulphur Levels on Economics of Greengram

Economic viability is an important criterion for evaluating the practical usefulness of any nutrient management practice. The profitability of a treatment depends not only on crop yield but also on the cost incurred in obtaining that yield. The economics of greengram cultivation as influenced by different levels of potassium and sulphur are presented in Table 5.

**Table 5:** Effect of Potassium and Sulphur Levels on Economics of Greengram

| Treatment                                         | Cost of Cultivation (₹ ha <sup>-1</sup> ) | Gross Return (₹ ha <sup>-1</sup> ) | Net Return (₹ ha <sup>-1</sup> ) | B:C Ratio |
|---------------------------------------------------|-------------------------------------------|------------------------------------|----------------------------------|-----------|
| T <sub>1</sub> (K <sub>0</sub> S <sub>0</sub> )   | 35,850                                    | 91,800                             | 55,950                           | 1.56      |
| T <sub>2</sub> (K <sub>0</sub> S <sub>15</sub> )  | 36,950                                    | 1,00,300                           | 63,350                           | 1.71      |
| T <sub>3</sub> (K <sub>0</sub> S <sub>30</sub> )  | 38,050                                    | 1,08,100                           | 70,050                           | 1.84      |
| T <sub>4</sub> (K <sub>25</sub> S <sub>0</sub> )  | 37,450                                    | 1,15,800                           | 78,350                           | 2.09      |
| T <sub>5</sub> (K <sub>25</sub> S <sub>15</sub> ) | 38,550                                    | 1,26,650                           | 88,100                           | 2.29      |
| T <sub>6</sub> (K <sub>25</sub> S <sub>30</sub> ) | 39,650                                    | 1,36,850                           | 97,200                           | 2.45      |
| T <sub>7</sub> (K <sub>50</sub> S <sub>0</sub> )  | 39,050                                    | 1,41,100                           | 1,02,050                         | 2.61      |
| T <sub>8</sub> (K <sub>50</sub> S <sub>15</sub> ) | 40,150                                    | 1,48,200                           | 1,08,050                         | 2.69      |
| T <sub>9</sub> (K <sub>50</sub> S <sub>30</sub> ) | 40,650                                    | 1,53,810                           | 1,13,160                         | 2.78      |

The data presented in Table 5 revealed that the economics of greengram cultivation improved markedly with increasing levels of potassium and sulphur. Although the cost of cultivation increased slightly with higher fertilizer application, the additional expenditure was more than compensated by the substantial increase in seed and stover yield, resulting in greater profitability. Among all the treatment combinations, T<sub>9</sub> (50 kg K<sub>2</sub>O ha<sup>-1</sup> + 30 kg sulphur ha<sup>-1</sup>) recorded the highest gross return (₹1,53,810 ha<sup>-1</sup>), net return (₹1,13,160 ha<sup>-1</sup>) and benefit-cost ratio (2.78). The superior economic performance of this treatment was mainly due to its ability to produce maximum seed yield and stover yield, which significantly increased marketable returns. Treatment T<sub>8</sub> (50 kg K<sub>2</sub>O ha<sup>-1</sup> + 15 kg sulphur ha<sup>-1</sup>) also recorded higher profitability and remained close to T<sub>9</sub> with a net return of ₹1,08,050 ha<sup>-1</sup> and a benefit-cost ratio of 2.69.

The lowest economic returns were observed under the control treatment T<sub>1</sub> (K<sub>0</sub>S<sub>0</sub>), which recorded a gross return of ₹91,800 ha<sup>-1</sup>, net return of ₹55,950 ha<sup>-1</sup> and benefit-cost ratio of 1.56. The lower profitability under this treatment was attributed to poor crop growth, reduced yield attributes and lower seed yield resulting from nutrient deficiency.

The increase in profitability with higher potassium and sulphur levels may be attributed to improved nutrient uptake, enhanced photosynthetic efficiency, better translocation of assimilates and superior reproductive development. Potassium facilitated efficient carbohydrate movement and grain filling, while sulphur promoted protein synthesis and nutrient metabolism. These physiological improvements ultimately translated into higher productivity and greater economic returns.

The findings clearly indicate that balanced application of potassium and sulphur is economically advantageous for greengram cultivation. The higher benefit-cost ratio obtained under T<sub>9</sub> suggests that the additional investment made on nutrient application was highly remunerative and resulted in maximum economic gains. Therefore, adoption of 50 kg K<sub>2</sub>O ha<sup>-1</sup> along with 30 kg sulphur ha<sup>-1</sup> can be considered a profitable nutrient management strategy for greengram under similar agro-climatic conditions.

The present results are in conformity with the findings of Chauhan and Singh (2011) [7], Bairwa *et al.* (2012) [3], Choudhary *et al.* (2019) [8] and Singh *et al.* (2022) [30], who reported higher net

returns and benefit-cost ratios in pulse crops with balanced potassium and sulphur fertilization. The study conclusively demonstrates that optimum nutrient management not only enhances crop productivity but also improves farm profitability and sustainability.

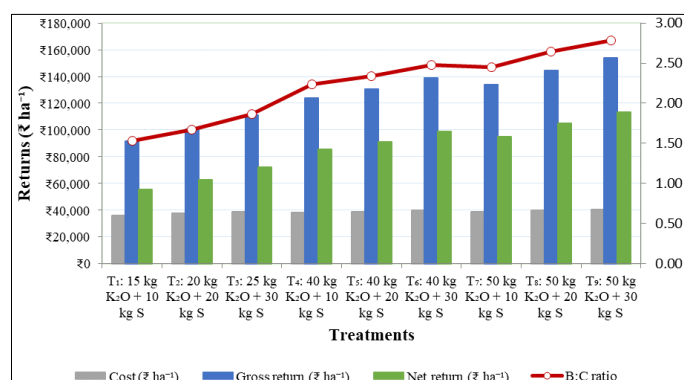
## Effect of Potassium and Sulphur Levels on Economics of Greengram

Economic viability is an important criterion for evaluating the practical usefulness of any nutrient management practice. The profitability of a treatment depends not only on crop yield but also on the cost incurred in obtaining that yield. The economics of greengram cultivation as influenced by different levels of potassium and sulphur are presented in Table 6.

**Table 6:** Effect of Potassium and Sulphur Levels on Economics of Greengram

| Treatment                                         | Cost of Cultivation (₹ ha <sup>-1</sup> ) | Gross Return (₹ ha <sup>-1</sup> ) | Net Return (₹ ha <sup>-1</sup> ) | B:C Ratio |
|---------------------------------------------------|-------------------------------------------|------------------------------------|----------------------------------|-----------|
| T <sub>1</sub> (K <sub>0</sub> S <sub>0</sub> )   | 35,850                                    | 91,800                             | 55,950                           | 1.56      |
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| T <sub>8</sub> (K <sub>50</sub> S <sub>15</sub> ) | 40,150                                    | 1,48,200                           | 1,08,050                         | 2.69      |
| T <sub>9</sub> (K <sub>50</sub> S <sub>30</sub> ) | 40,650                                    | 1,53,810                           | 1,13,160                         | 2.78      |

The data presented in Table 6 revealed that the economics of greengram cultivation improved markedly with increasing levels of potassium and sulphur. Although the cost of cultivation increased slightly with higher fertilizer application, the additional expenditure was more than compensated by the substantial increase in seed and stover yield, resulting in greater profitability.



Among all the treatment combinations, T<sub>9</sub> (50 kg K<sub>2</sub>O ha<sup>-1</sup> + 30 kg sulphur ha<sup>-1</sup>) recorded the highest gross return (₹1,53,810 ha<sup>-1</sup>), net return (₹1,13,160 ha<sup>-1</sup>) and benefit-cost ratio (2.78). The superior economic performance of this treatment was mainly due to its ability to produce maximum seed yield and stover yield, which significantly increased marketable returns. Treatment T<sub>8</sub> (50 kg K<sub>2</sub>O ha<sup>-1</sup> + 15 kg sulphur ha<sup>-1</sup>) also recorded higher profitability and remained close to T<sub>9</sub> with a net return of ₹1,08,050 ha<sup>-1</sup> and a benefit-cost ratio of 2.69.

The lowest economic returns were observed under the control treatment T<sub>1</sub> (K<sub>0</sub>S<sub>0</sub>), which recorded a gross return of ₹91,800 ha<sup>-1</sup>, net return of ₹55,950 ha<sup>-1</sup> and benefit-cost ratio of 1.56. The lower profitability under this treatment was attributed to poor crop growth, reduced yield attributes and lower seed yield resulting from nutrient deficiency.

The increase in profitability with higher potassium and sulphur levels may be attributed to improved nutrient uptake, enhanced photosynthetic efficiency, better translocation of assimilates and superior reproductive development. Potassium facilitated efficient carbohydrate movement and grain filling, while sulphur promoted protein synthesis and nutrient metabolism. These physiological improvements ultimately translated into higher productivity and greater economic returns. The findings clearly indicate that balanced application of potassium and sulphur is economically advantageous for greengram cultivation. The higher benefit-cost ratio obtained under T<sub>9</sub> suggests that the additional investment made on nutrient application was highly remunerative and resulted in maximum economic gains. Therefore, adoption of 50 kg K<sub>2</sub>O ha<sup>-1</sup> along with 30 kg sulphur ha<sup>-1</sup> can be considered a profitable nutrient management strategy for greengram under similar agro-climatic conditions.

The present results are in conformity with the findings of Chauhan and Singh (2011) <sup>[7]</sup>, Bairwa *et al.* (2012) <sup>[3]</sup>, Choudhary *et al.* (2019) <sup>[8]</sup> and Singh *et al.* (2022) <sup>[30]</sup>, who reported higher net returns and benefit-cost ratios in pulse crops with balanced potassium and sulphur fertilization. The study conclusively demonstrates that optimum nutrient management not only enhances crop productivity but also improves farm profitability and sustainability.

Correlation and Regression Analysis

Correlation and regression analyses were carried out to determine the relationship between growth parameters, yield attributes and seed yield of greengram under different potassium and sulphur levels. Understanding these relationships helps identify the most influential traits contributing towards final crop productivity.

Correlation Analysis

The correlation coefficients revealed that seed yield exhibited strong and positive associations with most of the growth and yield-contributing characters. Plant height, number of branches per plant, nodules per plant, dry matter accumulation, pods per plant, seeds per pod and test weight all showed significant positive correlations with seed yield. Among the various parameters studied, pods per plant exhibited the strongest positive correlation with seed yield ( $r = 0.987$ ), followed by dry matter accumulation ( $r = 0.978$ ), nodules per plant ( $r = 0.972$ ), test weight ( $r = 0.964$ ), seeds per pod ( $r = 0.956$ ), branches per plant ( $r = 0.948$ ) and plant height ( $r = 0.932$ ). These relationships indicate that improvement in vegetative growth and reproductive development directly contributed towards higher grain production.

The positive association between nodulation and seed yield suggests that enhanced biological nitrogen fixation improved nutrient availability and crop growth, resulting in increased productivity. Similarly, greater dry matter accumulation reflected improved photosynthetic efficiency and assimilate production, which ultimately enhanced pod development and grain filling.

Table 7: Correlation Coefficients Between Seed Yield and Important Crop Parameters

| Parameter                    | Correlation Coefficient (r) with Seed Yield |
|------------------------------|---------------------------------------------|
| Plant Height                 | 0.932**                                     |
| Branches Plant <sup>-1</sup> | 0.948**                                     |
| Nodules Plant <sup>-1</sup>  | 0.972**                                     |
| Dry Matter Accumulation      | 0.978**                                     |
| Pods Plant <sup>-1</sup>     | 0.987**                                     |
| Seeds Pod <sup>-1</sup>      | 0.956**                                     |
| Test Weight                  | 0.964**                                     |

Significant at P = 0.01 level

The strong positive correlations observed in the present investigation clearly indicate that balanced potassium and sulphur nutrition improved growth and yield attributes, which collectively enhanced seed yield of greengram.

|              | Plant height | Nodules | Dry matter | Pods | Seeds/pod | Test weight | Seed yield |
|--------------|--------------|---------|------------|------|-----------|-------------|------------|
| Plant height | 1.00         | 1.00    | 1.00       | 1.00 | 0.99      | 0.99        | 0.99       |
| Nodules      | 1.00         | 1.00    | 1.00       | 1.00 | 0.99      | 0.99        | 0.99       |
| Dry matter   | 1.00         | 1.00    | 1.00       | 1.00 | 0.99      | 0.99        | 1.00       |
| Pods         | 1.00         | 1.00    | 1.00       | 1.00 | 1.00      | 1.00        | 1.00       |
| Seeds/pod    | 0.99         | 0.99    | 0.99       | 1.00 | 1.00      | 1.00        | 1.00       |
| Test weight  | 0.99         | 0.99    | 0.99       | 1.00 | 1.00      | 1.00        | 1.00       |
| Seed yield   | 0.99         | 0.99    | 1.00       | 1.00 | 1.00      | 1.00        | 1.00       |

Fig 6: Correlation Matrix of Growth, Yield Attributes and Yield

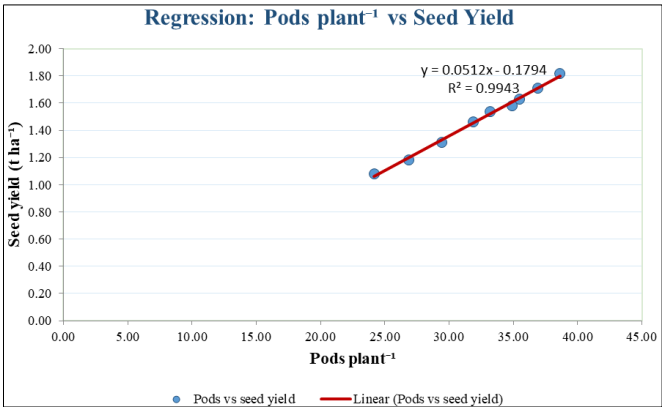
Regression Analysis

Regression analysis was performed to quantify the relationship between seed yield and major yield-determining traits. Among all parameters, pods per plant exhibited the highest coefficient of determination ( $R^2 = 0.975$ ), indicating that approximately 97.5 per cent variation in seed yield could be explained by variation in pods per plant alone.

Regression Equation

The linear regression equation describing the relationship between pods per plant (X) and seed yield (Y) was:

Where:  
 $Y = \text{Seed yield (t ha}^{-1}\text{)}$   
 $X = \text{Number of pods plant}^{-1}$



The regression analysis indicated that each additional pod per plant increased seed yield by approximately 0.052 t ha<sup>-1</sup> under the experimental conditions. The high coefficient of determination confirmed that pods per plant was the most influential yield attribute contributing to final productivity. Similarly, positive linear relationships were observed between seed yield and dry matter accumulation, nodules per plant and test weight. The regression models demonstrated that improvement in these parameters due to potassium and sulphur fertilization

significantly enhanced crop productivity.

The correlation and regression analyses clearly demonstrated that growth and yield parameters were positively and significantly associated with seed yield. Among the various characters studied, pods per plant emerged as the most important determinant of yield, followed by dry matter accumulation and nodulation. The results further confirmed that balanced application of potassium and sulphur enhanced these key traits, thereby improving overall productivity and profitability of greengram cultivation.

These findings are in agreement with the reports of Ali and Gupta (2012) <sup>[1]</sup>, Singh *et al.* (2018) <sup>[29]</sup>, Choudhary *et al.* (2019) <sup>[8]</sup> and Varshney *et al.* (2021) <sup>[41]</sup>, who also observed strong positive relationships between growth parameters, yield attributes and grain yield in pulse crops.

### Conclusion and Recommendation

The present investigation entitled “Effect of Potassium and Sulphur Levels on Growth, Yield and Nutrient Uptake of Greengram (*Vigna radiata* L.)” clearly demonstrated that balanced application of potassium and sulphur significantly improved the growth, productivity and profitability of greengram under the agro-climatic conditions of central Uttar Pradesh. The experimental results revealed that increasing levels of potassium and sulphur enhanced plant height, number of branches, nodulation, dry matter accumulation and overall crop vigour throughout the growing period.

Among the different treatment combinations, application of 50 kg K<sub>2</sub>O ha<sup>-1</sup> along with 30 kg sulphur ha<sup>-1</sup> (T<sub>9</sub>) consistently recorded superior performance with respect to growth parameters and yield attributes. The treatment produced the maximum plant height (54.82 cm), branches per plant (7.28), nodules per plant (34.46), pods per plant (38.64), seeds per pod (11.84) and test weight (42.86 g). These improvements resulted in the highest seed yield (1.82 t ha<sup>-1</sup>) and stover yield (32.84 q ha<sup>-1</sup>), indicating the positive synergistic effect of potassium and sulphur on crop growth and reproductive development.

The enhanced productivity under higher nutrient levels may be attributed to improved nutrient availability, greater photosynthetic activity, efficient translocation of assimilates, enhanced biological nitrogen fixation and increased protein synthesis. Correlation and regression analyses further revealed strong positive relationships between growth parameters, yield attributes and seed yield, confirming that balanced nutrient management plays a vital role in maximizing greengram productivity.

Economic analysis also indicated the superiority of balanced potassium and sulphur fertilization. Treatment T<sub>9</sub> recorded the highest gross return (₹1,53,810 ha<sup>-1</sup>), net return (₹1,13,160 ha<sup>-1</sup>) and benefit-cost ratio (2.78), demonstrating its economic feasibility and profitability. Although higher fertilizer application slightly increased the cost of cultivation, the substantial increase in yield provided significantly greater monetary returns.

### Recommendation

Based on the findings of the present investigation, it is recommended that application of 50 kg K<sub>2</sub>O ha<sup>-1</sup> along with 30 kg sulphur ha<sup>-1</sup> may be adopted for greengram cultivation under similar soil and climatic conditions to achieve higher growth, improved yield attributes, maximum seed yield and greater economic returns. The combined use of potassium and sulphur not only enhances crop productivity but also contributes towards efficient nutrient utilization and sustainable pulse production. Therefore, balanced potassium and sulphur fertilization should be considered an integral component of nutrient management practices for profitable and sustainable greengram cultivation.

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