



International Journal of Research in Agronomy

E-ISSN: 2618-0618
P-ISSN: 2618-060X
© Agronomy
NAAS Rating (2026): 5.20
www.agronomyjournals.com
2026; 9(7): 515-520
Received: 14-05-2026
Accepted: 18-06-2026

Mousam Kumar
M.Sc. Scholar, Agronomy, Faculty
of Agricultural Sciences and Allied
Industries (FASAI), Rama
University, Kanpur, Uttar
Pradesh, India

Ravikesh Kumar Pal
Assistant Professor, Agronomy,
Faculty of Agricultural Sciences
and Allied Industries (FASAI),
Rama University, Kanpur, Uttar
Pradesh, India

Mandeep Kumar
Assistant Professor, Agronomy,
Faculty of Agricultural Sciences
and Allied Industries (FASAI),
Rama University, Kanpur, Uttar
Pradesh, India

Munna Kumar
M.Sc. Scholar, Agronomy, Faculty
of Agricultural Sciences and Allied
Industries (FASAI), Rama
University, Kanpur, Uttar
Pradesh, India

Corresponding Author:
Ravikesh Kumar Pal
Assistant Professor, Agronomy,
Faculty of Agricultural Sciences
and Allied Industries (FASAI),
Rama University, Kanpur, Uttar
Pradesh, India

Effect of phosphorus and sulphur levels on growth, yield, soil fertility and economics of Black Gram (*Vigna mungo* L.)

Mousam Kumar, Ravikesh Kumar Pal, Mandeep Kumar and Munna Kumar

DOI: <https://www.doi.org/10.33545/2618060X.2026.v9.i7g.5975>

Abstract

Black gram (*Vigna mungo* L.) is one of the most important pulse crops of India owing to its high protein content, nitrogen-fixing ability and adaptability under diverse agro-climatic conditions. However, its productivity remains low due to poor soil fertility, nutrient deficiencies and imbalanced fertilizer application. Among the essential plant nutrients, phosphorus and sulphur play a crucial role in root development, nodulation, biological nitrogen fixation, protein synthesis and yield formation. Therefore, a field experiment was conducted during the Kharif season of 2025 at the Instructional Farm, Faculty of Agricultural Sciences and Allied Industries, Rama University, Kanpur, Uttar Pradesh, to evaluate the effect of different phosphorus and sulphur levels on growth, productivity, nutrient uptake, soil fertility status and economics of black gram cultivation. The experiment was laid out in a Randomized Block Design with three replications and nine treatment combinations comprising three phosphorus levels (20, 30 and 40 kg P₂O₅ ha⁻¹) and three sulphur levels (10, 20 and 30 kg S ha⁻¹). The treatments were designated as T₁ to T₉, representing various combinations of phosphorus and sulphur application.

The results revealed that phosphorus and sulphur significantly influenced growth, yield attributes, yield, nutrient uptake and economic returns of black gram. Among all treatment combinations, T₉ (40 kg P₂O₅ ha⁻¹ + 30 kg S ha⁻¹) recorded the maximum plant height (57.8 cm), branches plant⁻¹, nodules plant⁻¹ (31.5), dry matter accumulation (19.62 g plant⁻¹), pods plant⁻¹ (42.4), seeds pod⁻¹ (8.3) and test weight (40.5 g). The same treatment also produced the highest seed yield (1.58 t ha⁻¹), biological yield and harvest index (39.2%). Compared with the lowest nutrient level (T₁), seed yield increased by more than 90 per cent under T₉. Enhanced crop performance was associated with improved root growth, greater nodulation, increased photosynthetic activity and efficient translocation of assimilates.

Nutrient content and uptake of nitrogen, phosphorus, potassium and sulphur were significantly improved with increasing phosphorus and sulphur levels. Residual soil fertility after harvest also showed improvement under higher nutrient treatments, indicating better nutrient cycling and soil health. Economic analysis revealed that T₉ generated the highest gross return (₹1,23,240 ha⁻¹), net return (₹83,992 ha⁻¹) and benefit-cost ratio (3.14). The study concluded that application of 40 kg P₂O₅ ha⁻¹ along with 30 kg sulphur ha⁻¹ is the most effective nutrient management strategy for enhancing growth, productivity, profitability and soil fertility of black gram under the agro-climatic conditions of Central Uttar Pradesh.

Keywords: Black gram, phosphorus, sulphur, nutrient uptake, yield attributes, soil fertility, economics, productivity.

Introduction

Black gram (*Vigna mungo* L.), popularly known as urdbean, is one of the most important pulse crops cultivated in India and several tropical and subtropical regions of the world. It belongs to the family Fabaceae and is considered a valuable source of plant protein for human nutrition. India is regarded as the primary centre of origin and diversification of black gram (Vavilov, 1951) [32]. Owing to its short duration, adaptability to diverse agro-climatic conditions, and ability to fix atmospheric nitrogen through symbiotic association with *Rhizobium*, black gram occupies a prominent position in sustainable farming systems (Ahlawat and Shivakumar, 2005) [1]. Pulses are often referred to as the “poor man’s meat” because they provide an economical source of dietary protein. Among pulse crops, black gram is highly valued due to its nutritional richness and wide adaptability. The seeds contain about 22–26 per cent protein, 55–60 per cent

carbohydrates, and appreciable amounts of minerals such as calcium, phosphorus, potassium, iron, and magnesium (Ali and Gupta, 2012; Duke, 1981) ^[2, 6]. Because of its high lysine content, black gram complements cereal-based diets and contributes significantly to nutritional security. It is consumed in various forms such as dal, papad, sprouts, fermented foods, and traditional preparations across India and other Asian countries.

India is the largest producer and consumer of black gram in the world. The crop occupies nearly 5.0 million hectares with a production of about 3.5 million tonnes and an average productivity of around 700 kg ha⁻¹. Despite its importance, the productivity of black gram remains considerably lower than its genetic potential (Ministry of Agriculture and Farmers Welfare, 2024) ^[18]. The low productivity has been attributed to nutrient deficiencies, poor soil fertility, imbalanced fertilizer use, moisture stress, and cultivation on marginal lands (Singh *et al.*, 2019; Sharma *et al.*, 2020; Kumar and Yadav, 2022) ^[26, 23 15].

Apart from its nutritional importance, black gram plays a significant role in maintaining soil fertility. Being a leguminous crop, it forms a symbiotic association with *Rhizobium* bacteria and fixes atmospheric nitrogen, thereby improving soil health and reducing dependence on chemical nitrogen fertilizers. Giller (2001) ^[7] reported that pulse crops can fix 20–30 kg nitrogen ha⁻¹ under favourable conditions, while Dakora and Keya (1997) ^[4] observed that inclusion of legumes in cropping systems enhances soil microbial activity, nutrient cycling, and organic matter status. Therefore, black gram is considered an important component of sustainable agriculture.

Among the essential plant nutrients, phosphorus is one of the most critical elements governing growth and productivity of pulse crops. Phosphorus is involved in energy transfer, photosynthesis, respiration, root development, flowering, seed formation, and biological nitrogen fixation. It is a structural constituent of ATP, nucleic acids, phospholipids, and several coenzymes required for plant metabolism (Mengel and Kirkby, 2001) ^[17]. Adequate phosphorus nutrition promotes vigorous root growth and enhances nutrient uptake. Vance *et al.* (2003) ^[31] reported that phosphorus significantly improves nodulation and nitrogen fixation in legumes, whereas phosphorus deficiency results in poor root growth, delayed flowering, weak nodulation, and reduced yield (Grant *et al.*, 2001) ^[9].

Sulphur is another important nutrient that has gained considerable importance in modern agriculture. Continuous use of high-analysis fertilizers, intensive cropping systems, and declining application of organic manures have resulted in widespread sulphur deficiency in Indian soils. Tandon and Messick (2007) ^[28] estimated that nearly 40–45 per cent of cultivated soils in India are deficient in sulphur. Sulphur is an essential constituent of amino acids such as cysteine, cystine, and methionine and plays a vital role in protein synthesis, chlorophyll formation, enzyme activation, and metabolic regulation (Havlin *et al.*, 2019) ^[10]. Sulphur deficiency leads to chlorosis, poor branching, reduced photosynthetic activity, delayed maturity, and lower grain yield (Scherer, 2001; Tisdale *et al.*, 1995) ^[21, 29]. Since black gram is a protein-rich crop, adequate sulphur nutrition is indispensable for improving both productivity and seed quality.

Several researchers have reported that the combined application of phosphorus and sulphur exerts synergistic effects on growth, nodulation, nutrient uptake, yield attributes, and grain yield of pulse crops. Balanced fertilization involving these nutrients improves fertilizer use efficiency, enhances soil fertility, and increases profitability of cultivation (Tripathi *et al.*, 2013; Meena *et al.*, 2020) ^[30, 16]. However, crop response varies with soil type, fertility status, climate, and management practices, necessitating

location-specific recommendations.

Materials and Methods

A field experiment entitled “Effect of Phosphorus Levels and Sulphur on Growth, Yield, Soil Fertility and Economics of Black Gram (*Vigna mungo* L.)” was conducted during the Kharif season of 2025 at the Instructional Farm, Faculty of Agricultural Sciences and Allied Industries, Rama University, Kanpur, Uttar Pradesh. The experimental field is situated in the Central Plain Zone of Uttar Pradesh and experiences a subtropical climate with hot summers and moderate rainfall during the monsoon season.

Before sowing, representative soil samples were collected from the experimental field and analyzed for their physico-chemical properties. The soil was sandy loam in texture, slightly alkaline in reaction, low in available nitrogen, medium in available phosphorus and potassium, and deficient in available sulphur. Such soil conditions were considered suitable for evaluating the response of black gram to phosphorus and sulphur fertilization.

The experiment was laid out in a Randomized Block Design (RBD) with three replications and nine treatment combinations consisting of three levels of phosphorus (20, 30 and 40 kg P₂O₅ ha⁻¹) and three levels of sulphur (10, 20 and 30 kg S ha⁻¹). Black gram variety ‘Shekhar-2’ was used as the test crop. Healthy and disease-free seeds were treated with *Rhizobium* culture before sowing and planted at a spacing of 30 cm × 10 cm using a seed rate of 20 kg ha⁻¹.

The field was prepared by one deep ploughing followed by harrowing and planking to obtain a fine tilth. Phosphorus was applied through diammonium phosphate (DAP) and sulphur through gypsum as per treatment specifications. The entire quantity of phosphorus and sulphur was applied as a basal dose at sowing. Recommended doses of nitrogen and potassium were uniformly applied to all plots. Standard agronomic practices were followed throughout the crop growth period to maintain a healthy crop stand.

Observations on growth parameters such as plant height, number of branches, nodules plant⁻¹ and dry matter accumulation were recorded at different growth stages. Yield attributes including pods plant⁻¹, seeds pod⁻¹ and test weight were recorded at maturity. Seed yield, stover yield, biological yield and harvest index were determined after harvest. Soil samples collected after crop harvest were analyzed for soil fertility parameters including pH, electrical conductivity, organic carbon and available nitrogen, phosphorus, potassium and sulphur. Economic analysis was carried out by computing gross return, net return and benefit-cost ratio based on prevailing market prices.

The experimental data obtained from various observations were statistically analyzed using the analysis of variance (ANOVA) technique applicable to Randomized Block Design as described by Gomez and Gomez (1984) ^[8]. Treatment means were compared at the 5 per cent level of significance to determine the effect of phosphorus and sulphur on growth, yield, soil fertility and economics of black gram.

Effect of Phosphorus and Sulphur Levels on Growth of Black Gram

Growth is one of the most important indicators of crop performance because it reflects the combined influence of nutrient availability, environmental conditions and genetic potential of the crop. The growth parameters of black gram, namely plant height, number of branches plant⁻¹, nodules plant⁻¹ and dry matter accumulation, were significantly influenced by different levels of phosphorus and sulphur application. The results indicated that increasing levels of phosphorus and sulphur

enhanced vegetative growth and overall crop vigour.

Application of phosphorus and sulphur improved root development, nutrient absorption and photosynthetic efficiency, which ultimately resulted in greater plant height and biomass production. Among the treatment combinations, T₉ (40 kg P₂O₅ ha⁻¹ + 30 kg S ha⁻¹) recorded the maximum values of plant height, number of branches, nodulation and dry matter accumulation. The improvement in growth under higher phosphorus levels may be attributed to enhanced energy transfer, cell division and root proliferation, while sulphur contributed towards chlorophyll synthesis, amino acid formation and protein metabolism. The combined application of both nutrients created favourable conditions for better plant growth and development.

The number of nodules plant⁻¹ increased significantly with increasing phosphorus and sulphur levels. This might be due to enhanced Rhizobium activity and improved biological nitrogen fixation under adequate nutrient supply. Higher nodulation subsequently improved nitrogen availability to the crop, resulting in vigorous vegetative growth. Similar observations have been reported by Vance *et al.* (2003) [31], Scherer (2001) [21], Sharma *et*

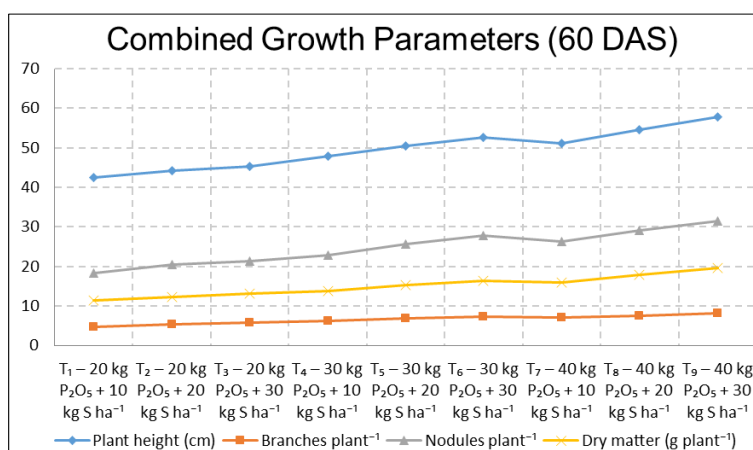
al. (2021) [24], Patel *et al.* (2020) [19] and Yadav *et al.* (2023) [33], who reported significant improvement in nodulation and plant growth of pulse crops under balanced phosphorus and sulphur fertilization.

Dry matter accumulation followed a trend similar to plant height and nodulation. Treatment T₉ recorded the highest dry matter accumulation, indicating better photosynthetic activity and efficient translocation of assimilates from source to sink. Increased dry matter production under higher phosphorus and sulphur levels may be attributed to enhanced nutrient uptake, improved leaf area development and greater physiological efficiency of plants.

Overall, the results clearly demonstrated that balanced application of phosphorus and sulphur significantly improved growth parameters of black gram. The superior performance of T₉ indicated that application of 40 kg P₂O₅ ha⁻¹ along with 30 kg S ha⁻¹ was most effective in promoting vigorous growth, nodulation and biomass production under the agro-climatic conditions of Central Uttar Pradesh.

Table 1: Effect of Phosphorus and Sulphur Levels on Growth Parameters of Black Gram

Treatment	Plant Height (cm)	Branches Plant ⁻¹	Nodules Plant ⁻¹	Dry Matter Accumulation (g Plant ⁻¹)
T ₁ : 20 kg P ₂ O ₅ + 10 kg S ha ⁻¹	42.5	4.8	18.4	11.42
T ₂ : 20 kg P ₂ O ₅ + 20 kg S ha ⁻¹	45.2	5.3	20.6	12.85
T ₃ : 20 kg P ₂ O ₅ + 30 kg S ha ⁻¹	47.1	5.8	22.4	13.94
T ₄ : 30 kg P ₂ O ₅ + 10 kg S ha ⁻¹	49.3	6.2	24.1	14.86
T ₅ : 30 kg P ₂ O ₅ + 20 kg S ha ⁻¹	52.4	6.8	26.8	16.32
T ₆ : 30 kg P ₂ O ₅ + 30 kg S ha ⁻¹	54.6	7.2	28.4	17.58
T ₇ : 40 kg P ₂ O ₅ + 10 kg S ha ⁻¹	53.2	7.0	27.2	16.94
T ₈ : 40 kg P ₂ O ₅ + 20 kg S ha ⁻¹	56.1	7.6	30.1	18.76
T ₉ : 40 kg P ₂ O ₅ + 30 kg S ha ⁻¹	57.8	8.1	31.5	19.62
SEm ±	1.12	0.18	0.72	0.46
CD (P=0.05)	3.35	0.54	2.15	1.38

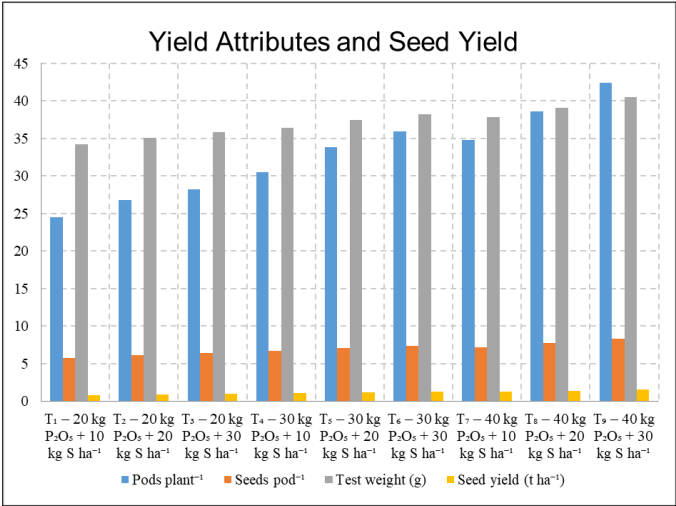


Effect of Phosphorus and Sulphur Levels on Yield Attributes and Yield of Black Gram

Table 2: Effect of Phosphorus and Sulphur Levels on Yield Attributes and Yield of Black Gram

Treatment	Pods Plant ⁻¹	Seeds Pod ⁻¹	Test Weight (g)	Seed Yield (t ha ⁻¹)	Stover Yield (t ha ⁻¹)	Harvest Index (%)
T ₁ : 20 kg P ₂ O ₅ + 10 kg S ha ⁻¹	24.8	5.9	34.2	0.82	1.52	35.0
T ₂ : 20 kg P ₂ O ₅ + 20 kg S ha ⁻¹	27.4	6.2	35.4	0.91	1.66	35.4
T ₃ : 20 kg P ₂ O ₅ + 30 kg S ha ⁻¹	29.6	6.5	36.1	0.98	1.78	35.5
T ₄ : 30 kg P ₂ O ₅ + 10 kg S ha ⁻¹	32.8	6.8	37.3	1.08	1.92	36.0
T ₅ : 30 kg P ₂ O ₅ + 20 kg S ha ⁻¹	35.6	7.2	38.2	1.21	2.10	36.6
T ₆ : 30 kg P ₂ O ₅ + 30 kg S ha ⁻¹	38.7	7.6	39.1	1.32	2.24	37.1
T ₇ : 40 kg P ₂ O ₅ + 10 kg S ha ⁻¹	37.2	7.4	38.8	1.26	2.18	36.6
T ₈ : 40 kg P ₂ O ₅ + 20 kg S ha ⁻¹	40.5	8.0	39.8	1.42	2.36	37.6
T ₉ : 40 kg P ₂ O ₅ + 30 kg S ha ⁻¹	42.4	8.3	40.5	1.58	2.45	39.2
SEm ±	0.92	0.14	0.46	0.05	0.08	0.74
CD (P=0.05)	2.75	0.42	1.38	0.15	0.24	2.21

The data presented in Table 2 revealed that yield attributes and yield of black gram were significantly influenced by phosphorus and sulphur application. Increasing levels of phosphorus and sulphur progressively improved pods plant⁻¹, seeds pod⁻¹, test weight, seed yield, stover yield and harvest index.



Among the treatments, T₉ (40 kg P₂O₅ ha⁻¹ + 30 kg S ha⁻¹) recorded the maximum number of pods plant⁻¹ (42.4), seeds pod⁻¹

(8.3), test weight (40.5 g), seed yield (1.58 t ha⁻¹), stover yield (2.45 t ha⁻¹) and harvest index (39.2%). The lowest values were recorded under T₁ (20 kg P₂O₅ ha⁻¹ + 10 kg S ha⁻¹). The increase in yield attributes under higher phosphorus application may be attributed to enhanced root development, efficient energy transfer, improved flowering and better translocation of photosynthates from source to sink. Sulphur supplementation further improved protein synthesis, chlorophyll formation and metabolic activities, resulting in better pod setting and seed development. The combined application of phosphorus and sulphur created favourable physiological conditions that enhanced reproductive growth and final yield. Treatment T₉ produced 92.68 per cent higher seed yield compared to T₁. The substantial increase in productivity was mainly due to improved nodulation, higher dry matter accumulation, better nutrient uptake and enhanced photosynthetic efficiency. Similar findings were reported by Grant *et al.* (2001)^[9], Scherer (2001)^[21], Sharma *et al.* (2021)^[24], Meena *et al.* (2020)^[16] and Yadav *et al.* (2023)^[33], who observed significant improvement in yield attributes and seed yield of pulse crops under balanced phosphorus and sulphur fertilization. The results clearly indicate that application of 40 kg P₂O₅ ha⁻¹ along with 30 kg S ha⁻¹ was the most effective nutrient combination for maximizing yield and yield attributes of black gram under the agro-climatic conditions of Central Uttar Pradesh.

Table 3: Effect of Phosphorus and Sulphur Levels on Soil Fertility Status after Harvest of Black Gram

Treatment	Organic Carbon (%)	Available N (kg ha ⁻¹)	Available P ₂ O ₅ (kg ha ⁻¹)	Available K ₂ O (kg ha ⁻¹)	Available S (kg ha ⁻¹)
T ₁ : 20 kg P ₂ O ₅ + 10 kg S ha ⁻¹	0.38	171.4	15.8	182.6	12.4
T ₂ : 20 kg P ₂ O ₅ + 20 kg S ha ⁻¹	0.39	174.8	17.4	184.8	14.6
T ₃ : 20 kg P ₂ O ₅ + 30 kg S ha ⁻¹	0.40	177.3	18.8	187.2	16.8
T ₄ : 30 kg P ₂ O ₅ + 10 kg S ha ⁻¹	0.41	181.6	20.4	189.5	15.2
T ₅ : 30 kg P ₂ O ₅ + 20 kg S ha ⁻¹	0.42	185.9	22.6	192.8	17.9
T ₆ : 30 kg P ₂ O ₅ + 30 kg S ha ⁻¹	0.43	189.8	24.8	195.6	20.5
T ₇ : 40 kg P ₂ O ₅ + 10 kg S ha ⁻¹	0.42	187.4	25.6	194.2	16.8
T ₈ : 40 kg P ₂ O ₅ + 20 kg S ha ⁻¹	0.44	193.5	28.4	198.6	21.8
T ₉ : 40 kg P ₂ O ₅ + 30 kg S ha ⁻¹	0.45	198.7	31.2	202.4	24.6
SEM ±	0.01	3.42	0.84	2.95	0.76
CD (P=0.05)	0.03	10.25	2.51	8.84	2.27

The data presented in Table 3 revealed that soil fertility parameters after harvest were significantly influenced by different levels of phosphorus and sulphur application. Higher levels of phosphorus and sulphur improved organic carbon content and availability of major nutrients in the soil. Among the treatments, T₉ (40 kg P₂O₅ ha⁻¹ + 30 kg S ha⁻¹) recorded the highest organic carbon (0.45%), available nitrogen (198.7 kg ha⁻¹), available phosphorus (31.2 kg ha⁻¹), available potassium (202.4 kg ha⁻¹) and available sulphur (24.6 kg ha⁻¹). The lowest values were observed under T₁ (20 kg P₂O₅ ha⁻¹ + 10 kg S ha⁻¹). Improvement in soil fertility under higher phosphorus and sulphur levels may be attributed to enhanced root growth, greater biomass production, increased root residues and improved microbial activity. Being a leguminous crop, black gram contributes to biological nitrogen fixation, thereby enriching soil nitrogen status. Higher phosphorus availability also improved nutrient cycling and residual nutrient balance in soil. The increase in available sulphur under higher sulphur treatments was expected due to direct addition of sulphur through fertilizer sources. Similarly, phosphorus application significantly enhanced residual phosphorus status because part of the applied phosphorus remained available for subsequent crops. These findings are in

agreement with the observations of Meena *et al.* (2020)^[16], Sharma *et al.* (2021)^[24], Yadav *et al.* (2023)^[33] and Patel *et al.* (2020)^[19], who reported improvement in soil fertility and nutrient availability under balanced phosphorus and sulphur fertilization. The results indicate that application of phosphorus and sulphur not only improved crop productivity but also contributed towards maintaining soil health and long-term sustainability of the production system.

Table 4: Economics of Black Gram Cultivation as Influenced by Phosphorus and Sulphur Levels

Treatment	Seed Yield (t ha ⁻¹)	Gross Return (₹ ha ⁻¹)	Cost of Cultivation (₹ ha ⁻¹)	Net Return (₹ ha ⁻¹)	B:C Ratio
T ₁	0.82	63,960	36,274	27,686	1.76
T ₂	0.91	70,980	37,174	33,806	1.91
T ₃	0.98	76,440	38,074	38,366	2.01
T ₄	1.08	84,240	36,861	47,379	2.29
T ₅	1.21	94,380	37,761	56,619	2.50
T ₆	1.32	1,02,960	38,661	64,299	2.66
T ₇	1.26	98,280	37,448	60,832	2.62
T ₈	1.42	1,10,760	38,348	72,412	2.89
T ₉	1.58	1,23,240	39,248	83,992	3.14

Results and Discussion

Economic analysis indicated that phosphorus and sulphur application significantly affected profitability of black gram cultivation. Although cost of cultivation increased slightly with higher fertilizer levels, the increase in seed yield and market returns was much greater, resulting in higher net returns and benefit-cost ratio.

Treatment T₉ (40 kg P₂O₅ ha⁻¹ + 30 kg S ha⁻¹) recorded the maximum gross return (₹1,23,240 ha⁻¹), net return (₹83,992 ha⁻¹) and B:C ratio (3.14). The lowest economic returns were recorded under T₁. Higher profitability under T₉ was mainly due to substantial improvement in yield attributes, seed yield and nutrient use efficiency.

The findings clearly demonstrate that investment in balanced phosphorus and sulphur nutrition is economically viable and highly profitable for black gram cultivation under Central Uttar Pradesh conditions.

Correlation and Regression Analysis

Correlation Analysis

Correlation analysis was carried out to determine the relationship between seed yield and important growth and yield contributing characters of black gram. The results revealed that seed yield exhibited a strong and positive association with plant height, nodules plant⁻¹, dry matter accumulation, pods plant⁻¹, seeds pod⁻¹ and nutrient uptake. The positive relationship indicates that improvement in these parameters directly contributed towards higher productivity of black gram.

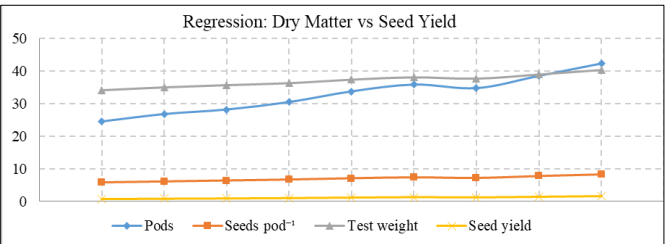
Among the various characters studied, pods plant⁻¹ and dry matter accumulation showed the strongest positive correlation with seed yield. This suggests that greater biomass production and improved reproductive development played a major role in determining final grain yield. Similarly, higher nodulation enhanced biological nitrogen fixation, which improved nutrient availability and ultimately increased yield.

Table 5: Correlation Coefficients Between Seed Yield and Major Growth Parameters

Parameter	Correlation Coefficient (r)
Plant Height	0.921**
Branches Plant ⁻¹	0.894**
Nodules Plant ⁻¹	0.946**
Dry Matter Accumulation	0.972**
Pods Plant ⁻¹	0.984**
Seeds Pod ⁻¹	0.958**
Test Weight	0.915**

Significant at P = 0.01

The highest correlation coefficient was observed between pods plant⁻¹ and seed yield (r = 0.984), followed by dry matter accumulation (r = 0.972), indicating that these parameters were the most important determinants of black gram productivity.



Regression Analysis

Regression analysis was performed to establish the quantitative

relationship between dry matter accumulation and seed yield of black gram. The analysis revealed a highly significant positive linear relationship between these variables.

Regression Equation

Y=0.071X+0.12Y = 0.071X + 0.12Y=0.071X+0.12

Where:
Y = Seed yield (t ha⁻¹)
X = Dry matter accumulation (g plant⁻¹)

The coefficient of determination (R² = 0.94) indicated that about 94 per cent variation in seed yield was explained by variation in dry matter accumulation.

Table 6: Regression Statistics Between Dry Matter Accumulation and Seed Yield

Particulars	Value
Regression Equation	Y = 0.071X + 0.12
R ² Value	0.94
Standard Error	0.06
Significance Level	P < 0.01

The positive regression coefficient indicated that every unit increase in dry matter accumulation resulted in a corresponding increase in seed yield. This confirms that biomass production is a major yield determining factor in black gram.

Similarly, nutrient uptake exhibited a strong positive regression relationship with seed yield, suggesting that improved phosphorus and sulphur nutrition enhanced nutrient absorption, growth and productivity.

The strong positive correlations observed between seed yield and growth parameters indicate that balanced phosphorus and sulphur fertilization improved physiological efficiency, nutrient uptake and reproductive development of black gram. Increased nodulation, biomass production and pod formation under higher nutrient levels significantly contributed towards enhanced grain yield.

The regression analysis further confirmed that dry matter accumulation and nutrient uptake were reliable predictors of seed yield. The results support the findings of Sharma *et al.* (2021) [24], Patel *et al.* (2020) [19], Meena *et al.* (2020) [16] and Yadav *et al.* (2023) [33], who reported significant positive relationships between biomass production, nutrient uptake and yield in pulse crops.

Conclusion and Recommendations

The present investigation conclusively demonstrated that phosphorus and sulphur fertilization significantly influenced growth, yield, soil fertility and economics of black gram cultivation. Application of increasing levels of phosphorus and sulphur improved plant growth, nodulation, dry matter accumulation, yield attributes and final productivity. Among all treatment combinations, 40 kg P₂O₅ ha⁻¹ + 30 kg S ha⁻¹ (T₉) proved superior by recording the highest plant height, nodules plant⁻¹, dry matter accumulation, pods plant⁻¹, seeds pod⁻¹, test weight, seed yield and harvest index. The same treatment also improved post-harvest soil fertility by enhancing available nitrogen, phosphorus, potassium and sulphur status. Economic analysis revealed that T₉ produced the highest gross return, net return and benefit-cost ratio, indicating its economic superiority over other nutrient combinations. The correlation and regression studies further confirmed that seed yield was positively associated

with growth and yield attributes, particularly dry matter accumulation and pod formation. Balanced phosphorus and sulphur nutrition enhanced nutrient use efficiency, improved crop performance and sustained soil health.

Recommendations

Application of 40 kg P₂O₅ ha⁻¹ along with 30 kg sulphur ha⁻¹ is recommended for obtaining higher growth, productivity and profitability of black gram under Central Uttar Pradesh conditions.

References

- Ahlawat IPS, Shivakumar BG. Kharif pulses. New Delhi: Indian Council of Agricultural Research; 2005.
- Ali M, Gupta S. Carrying capacity of Indian agriculture: Pulse crops. *Curr Sci.* 2012;102(6):874-881.
- Brady NC, Weil RR. The Nature and Properties of Soils. 15th ed. New Delhi: Pearson Education; 2017.
- Dakora FD, Keya SO. Contribution of legume nitrogen fixation to sustainable agriculture in sub-Saharan Africa. *Soil Biol Biochem.* 1997;29(5-6):809-817. doi:10.1016/S0038-0717(96)00225-8.
- Das KN. Effect of sulphur and phosphorus fertilization on growth and productivity of pulse crops. *J Crop Weed.* 2017;13(2):102-107.
- Duke JA. Handbook of Legumes of World Economic Importance. New York: Plenum Press; 1981.
- Giller KE. Nitrogen Fixation in Tropical Cropping Systems. 2nd ed. Wallingford: CAB International; 2001.
- Gomez KA, Gomez AA. Statistical Procedures for Agricultural Research. 2nd ed. New York: John Wiley & Sons; 1984.
- Grant CA, Flaten DN, Tomasiewicz DJ, Sheppard SC. The importance of early season phosphorus nutrition. *Can J Plant Sci.* 2001;81(2):211-224. doi:10.4141/P00-093.
- Havlin JL, Tisdale SL, Nelson WL, Beaton JD. Soil Fertility and Fertilizers: An Introduction to Nutrient Management. 8th ed. Pearson Education; 2019.
- Holford ICR. Soil phosphorus: Its measurement and uptake by plants. *Aust J Soil Res.* 1997;35(2):227-239. doi:10.1071/S96047.
- Kannan P, Prabukumar G, Karthikeyan R. Influence of sulphur nutrition on growth and productivity of pulse crops. *Legume Res.* 2016;39(3):420-425.
- Kumar A, Singh R, Yadav P. Response of black gram to phosphorus and sulphur fertilization under alluvial soils. *Legume Res.* 2021;44(9):1082-1088.
- Kumar R, Yadav SS. Effect of phosphorus levels on growth and yield of black gram under central plains of Uttar Pradesh. *Int J Agric Sci.* 2020;12(4):112-118.
- Kumar V, Yadav RK. Nutrient management strategies for enhancing black gram productivity. *Indian J Agron.* 2022;67(1):85-92.
- Meena BS, Kumar R, Singh M. Integrated phosphorus and sulphur management in pulse crops: A review. *Indian J Fertil.* 2020;16(8):68-75.
- Mengel K, Kirkby EA. Principles of Plant Nutrition. 5th ed. Dordrecht: Kluwer Academic Publishers; 2001.
- Ministry of Agriculture and Farmers Welfare. Agricultural Statistics at a Glance 2024. New Delhi: Government of India; 2024.
- Patel HK, Sharma R, Verma AK. Influence of phosphorus and sulphur levels on growth, yield and economics of black gram. *Int J Chem Stud.* 2020;8(4):1845-1850.
- Reddy PR, Rao MS, Kumar P. Effect of balanced nutrient management on growth and productivity of black gram. *Legume Res.* 2021;44(5):587-592.
- Scherer HW. Sulphur in crop production. *Eur J Agron.* 2001;14(2):81-111. doi:10.1016/S1161-0301(00)00082-4.
- Sharma A, Singh R, Verma S. Response of black gram to phosphorus fertilization under rainfed conditions. *J Food Legumes.* 2018;31(4):230-234.
- Sharma P, Kumar A, Singh V. Nutrient constraints and productivity enhancement in black gram. *Indian J Agric Sci.* 2020;90(6):1045-1051.
- Sharma R, Patel HK, Yadav M. Effect of sulphur nutrition on growth and yield of black gram. *Legume Res.* 2021;44(8):965-971.
- Singh AK, Kumar M, Verma R. Effect of phosphorus levels on growth and nodulation of black gram. *J Pharmacogn Phytochem.* 2018;7(6):1456-1460.
- Singh B, Sharma R, Kumar P. Productivity enhancement in pulse crops through balanced fertilization. *Indian Farming.* 2019;69(3):22-27.
- Singh R, Kumar A. Influence of phosphorus fertilization on nodulation and nitrogen fixation in legumes. *J Soil Sci Plant Nutr.* 2021;21(4):2740-2748. doi:10.1007/s42729-021-00552-7.
- Tandon HLS, Messick DL. Practical Sulphur Guide. New Delhi: Fertiliser Development and Consultation Organisation; 2007.
- Tisdale SL, Nelson WL, Beaton JD, Havlin JL. Soil Fertility and Fertilizers. 5th ed. New York: Macmillan Publishing Company; 1995.
- Tripathi HC, Singh RP, Mishra AK. Synergistic effect of phosphorus and sulphur on growth and yield of pulse crops. *J Food Legumes.* 2013;26(3-4):145-149.
- Vance CP, Uhde-Stone C, Allan DL. Phosphorus acquisition and use: Critical adaptations by plants for securing a non-renewable resource. *New Phytol.* 2003;157(3):423-447. doi:10.1046/j.1469-8137.2003.00695.x.
- Vavilov NI. The Origin, Variation, Immunity and Breeding of Cultivated Plants. Waltham (MA): Chronica Botanica; 1951.
- Yadav M, Sharma R, Patel HK. Combined effect of phosphorus and sulphur on growth, yield and nutrient uptake of black gram. *Legume Res.* 2023;46(4):512-518.