D-6335
[1-6]

RESEARCH ARTICLE Agricultural Science Digest

Performance of Sulphur and Boron on Growth and Yield of Black Gram (*Vigna mungo* L.)

Shivanshu Ladohia[1], Navjot Rana[2], Saumya Sharma[2], Rajesh Kumar[2], Swati Mehta[2], Shrikant Choudhary[2]

10.18805/ag.D-6335

ABSTRACT

Background: A field experiment entitled "Performance of Sulphur and boron on growth and yield of Urd bean (*Vigna mungo* L.) was carried out during *Zaid* season 2023 on the farms of Lovely Professional University Phagwara, Punjab.

Methods: The experiment was carried out in Randomized Block design having ten treatments which are replicated three times. The treatments include T_1: Control, T_2: RDF + 0.1% Boron, T_3: RDF + 0.2% Boron, T_4: RDF + 0.3% Boron., T_5: RDF + 17.5 kg ha^{-1} Sulphur, T_6: RDF + 35 kg ha^{-1} Sulphur, T_7: RDF + 52.5 kg ha^{-1} Sulphur, T_8: RDF + 0.1% Boron + 17.5 kg ha^{-1} Sulphur, T_9: RDF + 0.2% Boron + 35 kg ha^{-1} Sulphur, T_{10}: RDF + 0.3% Boron + 52.5 kg ha^{-1} Sulphur.

Result: The results of study indicated that the agronomic characteristics of Black gram (*Vigna mungo L.*) crop were significantly maximum in plots treated with 0.2% Boron + 35 kg ha^{-1} Sulphur along with RDF and gave maximum growth and yield. The seed yield of 10.95 q ha^{-1}, stover yield of 24.03 q ha^{-1} and 31.30% harvest index with net return of Rs. 51668.67 ha^{-1} and B:C ratio of 1.62. Thus, it is suggested that the 0.2% Boron + 35 kg ha-^{1} Sulphur along with recommended dose of fertilizer (12: 25 kg NP ha^{-1}) would be useful in achieving maximum growth and yield of black gram under similar agro-climatic conditions and soil properties.

Key words: B:C ratio, Black gram, Boron, Grain yield, Gross return, Net return, RDF, Stover yield, Sulphur.

INTRODUCTION

In India, black gram (*Vigna mungo* L.) is also known as mash and urd bean. Black gram is a Leguminous crop and is self-pollinated. Presently, India produces the most of the black gram in the world, covering nearly 70% of worldwide production. The average yield in India is 598 kg/ha with around 2.7 million tones being produced from 4.4 million hectares of land (Nair *et al.,* 2024). Black gram accounts for nearly 10% of total pulse production in India (Anonymous, 2021). Black gram thrives at temperatures between 25°C and 35°C. However, they may withstand temperatures as high as 42°C. Black gram prefers a pH range of 6.5 to 7.5 and 600 to 1000 mm of rainfall each year (Hedayetullah and Zaman, 2018). Black gram is a hardy crop with a short growing period and able to grow in various climatic conditions (Reddy *et al.,* 2023). Being a leguminous crop, it is a miniature fertilizer producer and is unique in its capacity to fix atmospheric nitrogen in symbiosis with Rhizobium located in the root nodules (Akila *et al.,* 2024). It is also very vegetative that has potential for a green manure and silage crop and will cover the ground so well that suppress weeds growth and also prevents soil erosion (Reddy and Kumar, 2023).

High in protein, calcium, and vitamins (B9, B1, B2, B3, B5, B6, and trace quantities of A, K and E), potassium, calcium, iron, niacin, thiamine and riboflavin, as well as vital amino acids, black gram is primarily produced for their high nutritional value (Singh and Kaur, 2021). It is composed of 60% carbs, 1.35% fat and 24% protein (Manna *et al.,* 2024). Black grams are in the top 7 foods for potassium content, top 8% for iron concentration and also rich in minerals like magnesium, potassium, calcium, copper, zinc and manganese (Longvah *et al.,* 2017).

One of the vital components needed by plants for growth and development is sulfur. It belongs to the group of macronutrients and is a secondary nutrient. Vitamins like thiamine and biotin, as well as amino acids like methionine and cysteine, are synthesized with the aid of sulfur (Prasad *et al.,* 2018). Sulphur aids in the formation of glutathione, ferredoxin, acetic coenzyme A, and lipoic acid and also raises the oil content of oilseed crops (Saha *et al.,* 2018). Sulfur plays a crucial role in the symbiotic nitrogen fixation process in leguminous crops, which transforms nitrogen into protein (Becana *et al.,* 2018). As a result of its importance in the synthesis of proteins and its occurrence in cystein, cystine and methionine, black

[1]Department of Agronomy, Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Palampur-176 062, Himachal Pradesh, India.
[2]Department of Agronomy, School of Agriculture, Lovely Professional University, Phagwara-144 411, Punjab, India.

Corresponding Author: Navjot Rana, Department of Agronomy, School of Agriculture, Lovely Professional University, Phagwara-144 411, Punjab, India. Email: Navjotrana7@gmail.com

How to cite this article: Ladohia, S., Rana, N., Sharma, S., Kumar, R., Mehta, S. and Choudhary, S. (2025). Performance of Sulphur and Boron on Growth and Yield of Black Gram (*Vigna mungo* L.). *Agricultural Science Digest*. **1-6.** doi: 10.18805/ag.D-6335.

Submitted: 25-03-2025 **Accepted:** 07-08-2025 **Online:** 01-09-2025

gramme responds positively to sulphur fertilisation, especially from soils that are deficient in sulphur Phogat *et al.,* (2021).

For legume crops to develop and flourish, boron is a necessary micronutrient. Boron is a crucial component that controls the lignification of the cell wall and differentiation of vascular tissue Lewis, (2019). Since boron is necessary for the plant's reproductive phase, a boron shortage causes the reproductive organs of the plant to become infertile and deformed Day and Asim, (2020). Boron has a role in the metabolism of carbohydrates, namely in photosynthetic translocation Herrera-Rodríguez *et al.,* (2010). Boron increases nodulation, controls water absorption and is necessary for the production of ATP, DNA, RNA and pectin in leguminous crops Bolanos *et al.,* (2023).

MATERIALS AND METHODS

The experiment was conducted on the Agricultural Research Farm of Lovely Professional University (LPU), Jalandhar, Punjab during zaid season 2023. LPU is located at a height of 245 meters above the sea level Anonymous, (2025a). This region's climate is typically warm, with less rainfall throughout the summer and experiences an average annual rainfall of 816 mm (32.1 inches) and maintains an average yearly temperature of 23.2°C (73.8°F) Anonymous, (2025b). The monsoon season spans from late June to late September, with July and August receiving the highest rainfall, December and January are the coldest months in the Phagwara region, averaging 11°C, while June is the hottest month with an average temperature of 32°C Anonymous, (2024). The experiment laid down in Randomized block design with 10 treatments each replicated three times. The treatments consist of T_1: control, T_2: RDF + 0.1% Boron, T_3: RDF + 0.2% Boron, T_4: RDF + 0.3% Boron., T_5: RDF + 17.5 kg ha^{-1} Sulphur, T_6: RDF + 35 kg ha^{-1} Sulphur, T_7: RDF + 52.5 kg ha^{-1} Sulphur, T_8: RDF + 0.1% Boron + 17.5 kg ha^{-1} Sulphur, T_9: RDF + 0.2% Boron + 35 kg ha^{-1} Sulphur, T_{10}: RDF + 0.3% Boron + 52.5 kg ha^{-1} Sulphur. The treatments were applied at 30 DAS and 3 foliar sprays of boron were given at the interval of 10 days. Data pertaining to growth parameters including plant height (cm), number of leaves plant^{-1}, number of branches plant^{-1}, number of root nodules plant^{-1}, dry matter accumulation were recorded at regular intervals and yield attributes including number of pods plant^{-1}, seeds pod^{-1}, test weight (g), seed yield ha^{-1}, stover yield ha^{-1} and harvest index were calculated at harvest.

RESULTS AND DISCUSSION

Growth attributes

Plant height (cm)

Data pertaining the plant height is given in Table 1. Height of plant was recorded at 45 and 60 DAS. The maximum plant height at 45 and 60 DAS was observed in treatment 9 (RDF + 0.2% Boron + 35 kg ha^{-1} Sulphur) *i.e.* 30.5 cm at 45

Table 1: Effect of different treatments on growth attributes of Black gram (*Vigna mungo* L.).

Treatments	Plant height		No. of leaves		No. of branches		No. of root nodules		Dry matter accumulation	
	45 DAS	60 DAS	45 DAS	60 DAS	45 DAS	60 DAS	45 DAS	60 DAS	At flowering	At harvest
T_1: Control	19.6	27.1	19.6	27.1	6.1	8.4	13.1	17.2	9.50	12.37
T_2: RDF + 0.1% Boron	21.8	34.8	21.8	34.8	7.9	10.5	16.1	21.1	11.37	15.67
T_3: RDF + 0.2% Boron	23.8	38.9	23.8	38.9	8.3	11.3	17.1	25.4	11.83	16.00
T_4: RDF + 0.3% Boron	24.8	40.9	24.8	40.9	8.6	11.5	17.2	26.6	12.43	18.07
T_5: RDF + 17.5 kg ha^{-1} Sulphur	22.8	40.0	22.8	40.0	8.4	10.9	15.9	22.2	11.57	15.77
T_6: RDF + 35 kg ha^{-1} Sulphur	26.0	41.8	26.0	41.8	8.7	11.9	18.0	26.3	12.63	18.43
T_7: RDF + 52.5 kg ha^{-1} Sulphur	25.5	39.9	25.5	39.9	8.5	11.1	17.7	25.0	12.33	17.50
T_8: RDF + 0.1% Boron + 17.5 kg ha^{-1} Sulphur	24.6	39.5	24.6	39.5	8.2	10.8	17.0	25.6	12.23	17.23
T_9: RDF + 0.2% Boron + 35 kg ha^{-1} Sulphur	30.5	47.6	30.5	47.6	9.4	13.1	19.2	29.4	13.77	19.50
T_{10}: RDF + 0.3% Boron + 52.5 kg ha^{-1} Sulphur	29.5	45.5	29.5	45.5	8.9	12.8	18.7	28.9	12.93	18.57
F test	S	S	S	S	S	S	S	S	S	S
SEM±	0.2	0.3	0.2	0.3	0.2	0.3	0.3	0.6	0.20	0.23
CD (p<0.05)	0.5	0.6	0.5	0.6	0.5	0.6	0.7	1.3	0.42	0.47

DAS and 47.6 cm at 60 DAS which was at par with treatment 10 (RDF + 0.3% Boron + 52.5 kg ha^{-1} Sulphur) *i.e.* 29.5 cm at 45 DAS and 45.5 cm at 60 DAS. Similar results were found by Phogat *et al*., (2020) and Raj *et al.,* (2023) as sulphur is vital for stimulating cell division, supporting photosynthesis, and facilitating chlorophyll formation. hereby enhancing photosynthesis and also aids in converting nitrogen into protein similar results were also concluded by Arunraj *et al.,* (2018). Similarly, boron enhances tissue differentiation, cell division and cell development. It also boosts nitrogen absorption from the soil, further promoting overall growth and increasing plant height Singh *et al.,* (2014).

Number of leaves plant^{-1}

The significantly maximum number of leaves plant^{-1} at 45 and 60 DAS were recorded in T_9 *i.e.* 47.6 at 45 DAS and 30.5 at 60 DAS which is followed by T_{10} *i.e.* 29.5 at 45 DAS and 45.5 at 60 DAS (Table 1). Parashar *et al.,* (2020) revealed that, sulphur is integral to the synthesis of amino acids, which serve as building blocks for protein synthesis in plants and also promotes cell division and photo-synthesis by facilitating chlorophyll formation, ultimately leading to increased leaf production. Meanwhile, boron at 0.2% concentration plays a crucial role in enhancing cell division and promoting the absorption of nitrogen from the soil by enhanced root nodulation which increases growth and photosynthesis, resulting in an increased number of leaves plant^{-1} as demonstrated by Luxmi *et al.,* (2020) and Devi *et al.,* (2012).

Number of branches plant^{-1}

The data revealed that the maximum number of branches plant^{-1} at 45 DAS and 60 DAS were recorded in T_9 *i.e.* 9.4 at 45 DAS and 13.1 at 60 DAS which was observed at par with the T_{10} *i.e.* 8.9 at 45 DAS and 12.8 at 60 DAS as shown in Table 1. According to Parashar *et al.,* (2020) sulphur enhances root growth, allowing roots to penetrate deeper into the soil and thereby absorb more nutrients and supports overall plant health and vigor, leading to increased branching. Concurrently, boron plays a crucial role in nodule formation in legumes, which enhances nitrogen fixation and nitrogen availability to plant which promotes vegetative growth, stimulates photosynthesis and further contributing to the development of more branches as demonstrated by Raj *et al.,* (2023) and Movalia *et al.,* (2020).

Number of root nodules plant^{-1}

The maximum number of root nodules were recorded in T_9 at 45 DAS and 60 DAS *i.e.* 19.2 and 29.4 respectively (Table 1). These were observed at par with T_{10} which are 18.7 at 45 DAS and 28.9 60 DAS). This happened due to the application of Sulphur and boron. Sulphur promotes the production and of leghemoglobin in the roots which leads to increased number root nodules Parry *et al.,* (2018) and Ganie *et al.,* (2014). Boron is essential for the development of both roots and shoots and plays a key role in the functioning in symbiosis of rhizobium bacteria and ensures their proper functioning and proliferation, which are crucial for root nodule formation, aiding in nitrogen fixation Satya, (2025).

Dry matter accumulation (gm^{-2})

The highest dry matter accumulation was observed in treatment T_9, with 13.77 at flowering and 19.50 at harvesting (Table 1). According to Choudhary *et al.,* (2022), sulphur increases the number of leaves and branches, enhancing photosynthetic activity and biomass production, resulting in higher dry matter accumulation. Additionally, boron application significantly contributes to maximum plant dry weight by stabilizing essential components of the cell wall and plasma membrane, promoting cell division, tissue differentiation and the metabolism of vital compounds like nucleic acids, carbohydrates, proteins and auxins as resulted by Sangeetha *et al.,* (2010) and Meshram *et al.,* (2015). The combined effects of sulphur and boron enhanced plant growth and nutrient availability.

Yield attributes

Number of pods plant^{-1}

The results in Table 2 revealed that the highest number of pods plant^{-1} were observed in T_9 (41.1), which was at par with T_{10} (40.0). According to Padbhushan *et al.,* (2014), boron plays a crucial role in flower and pollen formation which is directly impacting pod production by promoting the development and functionality of reproductive organs. Sulphur significantly enhances tissue differentiation, transforming somatic cells into reproductive meristematic activity, leading to the initiation of floral primordia, resulting in increased flower formation and subsequently more pods as suggested by Mazed *et al.,* (2015).

Number of seeds pod^{-1}

The data indicated that the highest number of seeds pod^{-1} were obtained in T_9 *i.e.* 6.9, which was at par to T_{10} *i.e.* 6.6 (Table 2). As resulted by Arunraj *et al.,* (2018) and Kudi *et al.,* (2018) sulphur plays a vital role in enhancing metabolic processes and enzymatic activity in plants. It improves overall plant development by aiding in amino acid, protein, chlorophyll synthesis and better photosynthesis, leading to increased sink potential. Luxmi *et al.,* (2020) highlighted that boron is essential for the development and functioning of reproductive tissues, cell division, tissue differentiation and the metabolism of essential compounds like nucleic acids, carbohydrates and proteins which directly impacting seed production.

Test weight

The results in Table 2 show that the treatments did not have a significant effect on test weight. Devi *et al.,* (2023) reported that the test weight had a high heritability which indicates test weight is genetically controlled trait and demonstrated that test weight is a trait that is largely determined by additive gene action and less influenced by environmental and nutritional factors like sulphur and boron.

Table 2: Effect of different treatments on yield attributes of black gram (*Vigna mungo* L.).

Treatments	No. of pods per plant	No. of seeds per pod	Test weight (g)	Seed yield	Stover yield	Harvest index
T_1: Control	26.5	4.7	36.00	6.17	17.37	26.21
T_2: RDF + 0.1% Boron	32.5	5.7	36.20	7.33	19.47	27.36
T_3: RDF + 0.2% Boron	37.6	6.1	36.10	8.37	21.00	28.49
T_4: RDF + 0.3% Boron	39.3	6.4	36.13	9.27	21.60	30.02
T_5: RDF + 17.5 kg ha^{-1} Sulphur	33.4	6.2	36.23	7.50	19.60	27.68
T_6: RDF + 35 kg ha^{-1} Sulphur	39.0	6.5	36.60	9.97	22.37	30.82
T_7: RDF + 52.5 kg ha^{-1} Sulphur	38.5	6.3	36.57	9.03	21.43	29.66
T_8: RDF + 0.1% Boron + 17.5 kg ha^{-1} Sulphur	38.0	6.2	36.10	8.90	21.03	29.75
T_9: RDF + 0.2% Boron + 35 kg ha^{-1} Sulphur	41.1	6.9	36.87	10.95	24.03	31.30
T_{10}: RDF + 0.3% Boron + 52.5 kg ha^{-1} Sulphur	40.0	6.6	36.73	10.23	23.17	30.60
F test	S	S	NS	S	S	S
SEM±	1.0	0.1	-	0.33	0.45	0.87
CD (p<0.05)	2.0	0.3	NS	0.72	0.94	1.83

Yield

Seed yield

The data on grain yield is presented in Table 2 which shows that the highest seed yield (10.95 q ha^{-1}) was observed in treatment T_9, which was at par with T_{10} (10.23 q ha^{-1}). This increase in yield can be attributed to the combined effect of sulphur and boron. According to Raj *et al.,* (2023), sulphur plays a crucial role in promoting cell division, photosynthesis, chlorophyll formation and root nodule development, leading to enhanced vegetative growth, metabolic activities and better biomass accumulation ultimately resulting in increased seed yield. Meanwhile, Boron regulates important cellular processes, metabolic activities, and nucleic acid synthesis, Boron is essential for cell differentiation, physiological processes, and overall plant growth Kumar *et al.,* (2018). Adequate boron nutrition is vital for improving crop yield and quality Banoth *et al.,* (2022).

Stover yield

Table 2 presents data on stover yield, showing significantly higher stover yield in T_9 (24.03 q ha^{-1}), which was observed at par to T_{10} (23.17 q ha^{-1}). The increase in yield can be attributed to the essential roles of sulphur and boron in metabolic processes related to growth, nodulation, pod setting, carbohydrate, and protein synthesis, as reported by Arora *et al.,* (2012). Sulphur aids in nitrogen absorption and promotes better vegetative growth Jat *et al.,* (2013). Boron plays a crucial role in regulating cellular processes and metabolic activities essential for cell differentiation in meristematic tissues, and aids in the synthesis of phenolic compounds involved in chlorophyll production, ultimately leading to increased stover yield Renukadevi *et al.,* (2002).

Harvest index

The harvesting index was significantly higher in T_9 (31.30%) and found at par to T_{10} (30.60 %), T_6 (30.82%) and T_4 (30.02%) as shown in Table 2. As supported by Arunraj *et al.,* (2018) sulphur is crucial for protein synthesis as it is a component of certain amino acids and chlorophyll. Sulphur also activates enzymes that drive metabolic processes, enhancing nutrient utilization and grain formation, resulting in increased biomass production and a higher proportion of biomass dedicated to grain yield. As reported by Padbhushan *et al.,* (2014) boron plays a role in maximizing the harvest index by influencing cell division, carbohydrate metabolism, and cell wall synthesis, which are essential for the development of reproductive tissues and efficient energy allocation for seed production.

CONCLUSION

The study results indicate that growth and yield attributes improved when applying 35 kg/ha of sulphur + 0.2% boron in addition to the RDF (12: 25 kg NP ha^{-1}). Significant enhancements in plant height, number of leaves, branches and root nodules were observed with this application. The number of pods plant^{-1} and seeds per pod are crucial factors contributing to yield. The highest increase in seed and stover yield was achieved with the application of 35 kg/ha of sulfur and 0.2% boron along with RDF.

ACKNOWLEDGEMENT

The authors wish to sincerely acknowledge Lovely Professional University, Punjab, India for providing facility of using research area and lab facilities for research purpose.

Conflict of interest

All authors declare that they have no conflict of interest.

REFERENCES

Akila, G., Thiyageshwari, S., Selvi, D., Anandham, R. and Djanaguiraman, M. (2024). Antioxidant status of black gram in response to bio sulphur granules developed with *Methylobacterium thiocyanatum* in sulphur deficient calcareous vertisol. *Agricultural Science Digest.* **44(4):** 639-644. doi: 10. 18805/ag.D-5676.

Anonymous. (2021). Directorate of Economics and Statistics. "Ministry of agriculture and farmers welfare department of agriculture, cooperation and farmers welfare," in Third Advance Estimates of Production of Food grains for 2020-21 (Government of India).

Anonymous. (2024). Yearly and monthly weather-Phagwara, India, 2024, August 2. Weather Atlas.

Anonymous. (2025a). Phagwara Junction railway station. In Wikipedia, The Free Encyclopedia. Retrieved June 15, 2025.

Anonymous. (2025b). Climate Data.org. (n.d.). Phagwara climate: Weather Phagwara and temperature by month. Retrieved June 15, 2025, from Climate Data.org database: en. climate-data.org/asia/india/punjab/phagwara-14981.

Arora, A.S., Umer, S. and Mishra, S.N. (2012). Boron and zinc response on growth in [*Vigna radiata* (L.) Wilczek var.] Pusa Vishal under salinity. *International Journal of Plant, Animal and Environmental Sciences.* **2(4):** 131-138.

Arunraj, M., Vasanthi, D. and Mansingh, M.D.I. (2018). Effect of sulphur on growth and yield of green gram (*Vigna radiata). International Journal of Science, Environment and Technology*. **7(5):** 1861-1867.

Banoth, M.K., Kumar, S.H., Priyanka, G., Malavath, V.N. and Umesha, C. (2022). Influence of boron and zinc on growth and yield of green gram (*Vigna radiata* L.). *The Pharma Innovation Journal*. **11(3):** 1674-1678.

Becana, M., Wienkoop, S. and Matamoros, M.A. (2018). Sulfur transport and metabolism in legume root nodules. *Frontiers in Plant Science.* **9:** 1434.

Bolanos, L., Abreu, I., Bonilla, I., Camacho-Cristobal, J.J. and Reguera, M. (2023). What can boron deficiency symptoms tell us about its function and regulation. *Plants*. **12(4):** 777.

Choudhary, R., Pandey, I.B., Singh, R.S., Singh, S.K., Meena, H. and Singh, K. (2022). Effect of phosphorus and sulphur levels on growth and yield of summer greengram (*Vigna radiata* L.) in the middle indo-gangetic zone. *Legume Research-An International Journal.* **46(2):** 186-190. doi: 10.18805/LR-4685.

Day, S. and Aasim, M. (2020). Role of boron in growth and development of plant: Deficiency and toxicity perspective. *Plant Micronutrients: Deficiency and Toxicity Management*. pp: 435-453.

Devi, K.N., Singh, L.N.K., Singh, M.S., Singh, S.B. and Singh, K.K. (2012). Influence of sulphur and boron fertilization on yield, quality, nutrient uptake and economics of soybean (*Glycine max*) under upland conditions. *Journal of Agricultural Science*. **4(4):** 1.

Devi, S.M., Jayamani, P. and Kumar, M. (2023). Genetic analysis of seed traits in pre-breeding lines of blackgram [*Vigna mungo* (L.) Hepper]. *Legume Research*. **46(10):** 1314-1318. doi: 10.18805/LR-4813.

Ganie, M.A., Akhter, F., Bhat, M.A. and Najar, G.R. (2014). Growth, yield and quality of French bean (*Phaseolus vulgaris* L.) as influenced by sulphur and boron application on inceptisols of Kashmir. *The Bioscan*. **9(2):** 513-518.

Hedayetullah, M. and Zaman, P. (2018). URD BEAN (BLACK GRAM). In Forage Crops of the World, Volume II: Minor Forage Crops. *Apple Academic Press*. 175-188.

Herrera-Rodríguez, M.B., González-Fontes, A., Rexach, J., Camacho-Cristobal, J.J., Maldonado, J.M. and Navarro-Gochicoa, M.T. (2010). Role of boron in vascular plants and response mechanisms to boron stresses. *Plant Stress*. **4(2):** 115-122.

Jat, S.R., Patel, B.J., Shivran, A.C. and Kuri, B.R. (2013). Effect of phosphorus and sulphur levels on growth and yield of cowpea under rainfed conditions. *Annals of Plant and Soil Research*. **15(2):** 114-117.

Kudi, S., Swaroop, N., David, A.A., Thomas, T., Hasan, A. and Rao, S. (2018). Effect of different levels of sulphur and zinc on soil health and yield of green gram (*Vigna radiata* L.) var. Patidar-111. *Journal of Pharmacognosy and Phytochemistry*. **9(3):** 50-55.

Kumar, S., Phogat, M. and Lal, M. (2018). Response of pulse and oilseed crops to boron application: a review. *International Journal of Current Microbiology and Applied Sciences.* **7(3):** 669-675.

Lewis, D.H. (2019). Boron: The essential element for vascular plants that never was. *New Phytologist*. **221(4):** 1685-1690.

Longvah, T., Ananthan, R., Bhaskarachary, K. and Venkaiah, K. (2017). Indian Food Composition Tables 2017. National Institute of Nutrition, Indian Council of Medical Research. 2-58.

Luxmi, S., Patel, R., Singh, S., Choudhary, B., Gadhwal, R., Meena, R. and Singh, Y.V. (2020). Growth and yield response of mung bean as influenced by sulphur and boron application. *International Journal of Current Microbiology and Applied Sciences*. **9(3):** 2788-2794.

Manna, P., Kumar, R., Rana, N., Ghosh Bag, A., Manna, A. and Nandi, T. (2024). Effect of phosphorus and bioinoculants on nutrient uptake and available soil nutrients by black gram (*Vigna mungo* L.). *International Journal of Plant and Soil Science.* **36(7):** 290-296.

Mazed, H.E.M.K., Moonmoon, J.F., Haque, M.N., Pulok, M.A.I. and Rahman, M.H. (2015). Growth and yield of mung bean as influenced by potassium and sulphur. *Annals of Biological Research.* **6(1):** 6-10.

Meshram, M.R., Dwivedi, S.K. and Ransing, D.M. (2015). Response of customized fertilizer on productivity, nutrient uptake and energy use of rice (*Oryza sativa* L.). *The Ecoscan*. **9(1 and 2):** 373-376.

Movalia, D.J., Donga, S. and Parmar, K.B. (2020). Effect of boron and molybdenum on summer green gram (*Vigna radiata* L.) (GM-4) under medium black calcareous soils: A review. *Proceedings of the National Conference on Innovations in Biological Sciences* (NCIBS).

Nair, R.M., Chaudhari, S., Devi, N., Shivanna, A., Gowda, A., Boddepalli, V.N. and Somta, P. (2024). Genetics, genomics and breeding of black gram (*Vigna mungo* L.). *Frontiers in Plant Science*. **14:** 1273363.

Padbhushan, R. and Kumar, D. (2014). Influence of soil and foliar applied boron on green gram in calcareous soils. *International Journal of Agriculture, Environment and Biotechnology*. **7(1):** 129-136.

Parashar, A. and Tripathi, L. (2020). Effect of phosphorus and sulphur on the growth and yield of black gram (*Vigna mungo* L.). *Journal of Pharmacognosy and Phytochemistry*. **9(5):** 2585-2588.

Parry, S.A., Jaiswal, P.C., Parry, F.A., Ganie, S.A. and Masood, A. (2018). Effect of different levels of nitrogen and sulphur on growth, nodulation and yield of green gram (*Vigna radiata* L.). *Legume Research-An International Journal*. **41(5):** 767-770. doi: 10.18805/LR-3428.

Phogat, M., Rai, A.P. and Kumar, S. (2020). Interaction effect of phosphorus and sulphur application on nutrient uptake, yield and yield attributing parameters of black gram [*Vigna mungo* (L.) *Hepper*]. *Legume Research-An International Journal*. **43(2):** 212-220. doi: 10.18805/LR-3963.

Phogat, M., Rai, A.P., Kumar, S. and Angmo, P. (2021). Effect of phosphorus and sulphur application on their dynamics and nodulation in soil under black gram [*Vigna mungo* (L.) Hepper] crop. *Legume Research-An International Journal*. **44(3):** 315-321. doi: 10.18805/LR-4085.

Prasad, R. and Shivay, Y.S. (2018). Sulphur in soil, plant and human nutrition. *Proceedings of the National Academy of Sciences, India Section B: Biological Sciences.* **88:** 429-434.

Raj, V.A., Debbarma, V. and Nikhitha, K. (2023). Impact of sulphur and boron levels on growth, yield and economics of summer green gram (*Vigna radiata* L.*). International Journal of Environment and Climate Change*. **13(6):** 56-63.

Reddy, B.V.R.P., Dikshit, H.K., Aski, M.S. and Mishra, G.P. (2023). Comparative analysis of root system architectural traits in genotypes of *Vigna radiata* (L.) and *Vigna mungo* (L.) *Bangladesh Journal of Botany.* **52(1):** 61-69.

Reddy, K.G.H. and Kumar, R. (2023). Effect of organic, inorganic and biofertilizers on growth and yield of blackgram (*Vigna mungo* L.). *Ecology, Environment and Conservation.* **29(4):** 1611-1615.

Renukadevi, A., Savithri, P. and Andi, K. (2002). Evaluation of boron fertilizers for a sunflower (*Helianthus annuus* L.) green gram (*Vigna radiata* L.) cropping sequence in inceptisols. *Acta Agronomica Hungarica*. **50(2):** 163-168.

Saha, B., Saha, S., Roy, P.D., Padhan, D., Pati, S. and Hazra, G.C. (2018). Microbial transformation of sulphur: An approach to combat the sulphur deficiencies in agricultural soils. *Role of Rhizospheric Microbes in Soil: Nutrient Management and Crop Improvement*. **2:** 77-97.

Sangeetha, S.P., Balakrishnan, A. and Bhuvaneswari, J. (2010). Organic nutrient sources on growth and yield of rice. *CABI (Centre for Agriculture and Biosciences International).* **97:** 251-253

Satya, M.S.S.C. (2025). Interactive effect of phosphorus and boron on their temporal soil availability under black gram [*Vigna mungo* (L.) Hepper] cultivation and nodulation in acid inceptisol. *Legume Research: An International Journal.* **48(3):** 444-449. doi: 10.18805/LR-4877.

Singh, A.K., Khan, M.A. and Srivastava, A.S. (2014). Effect of boron and molybdenum application on seed yield of mung bean. *CABI (Centre for Agriculture and Biosciences International).* **9(2):** 169-172.

Singh, B. and Kaur, G. (2021). Black gram: Bioactive components for human health and their functions. *Handbook of Cereals, Pulses, Roots and Tubers.* pp: 377-392.