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Effect of Different Levels of Potassium and Boron on Growth, Productivity and Economics of Blackgram (*Vigna mungo* L.) under Central Plain Zone of Uttar Pradesh

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Abstract

Blackgram [*Vigna mungo* (L.) Hepper] is one of the most important pulse crops cultivated in tropical and subtropical regions owing to its high protein content, short duration, nitrogen-fixing ability and adaptability to diverse agro-climatic conditions. Despite its importance, productivity of blackgram remains comparatively low in many parts of India due to imbalanced nutrient management, particularly inadequate application of potassium and micronutrients such as boron. Potassium plays a crucial role in photosynthesis, enzyme activation, assimilate translocation and water regulation, whereas boron is essential for cell division, reproductive development, pollen viability and nutrient transport. Therefore, balanced application of potassium and boron is considered essential for improving growth, yield and nutrient-use efficiency in pulse crops.

A field experiment was conducted during Kharif 2025 at the Instructional Farm, Faculty of Agricultural Sciences and Allied Industries, Rama University, Kanpur, Uttar Pradesh, situated in the Central Plain Zone of India. The experiment was laid out in Randomized Block Design with three replications comprising ten treatments involving different combinations of potassium and boron levels. The soil of the experimental field was sandy loam in texture, slightly alkaline in reaction, low in available nitrogen and phosphorus, and medium in available potassium. Standard agronomic practices were followed throughout the crop growth period.

The results revealed that potassium and boron application significantly influenced growth, yield attributes, yield and economics of blackgram. Among the treatments, application of 40 kg K₂O ha⁻¹ + 2.0 kg B ha⁻¹ (T₉) recorded the highest plant height (56.8 cm), nodules plant⁻¹ (31.4), dry matter accumulation (18.6 g plant⁻¹), pods plant⁻¹, seeds pod⁻¹ and test weight. The same treatment also produced the maximum seed yield, stover yield and biological yield. Improvement in crop growth under higher potassium and boron levels was attributed to enhanced photosynthetic activity, efficient assimilate translocation, improved nodulation and greater nutrient uptake.

Economic analysis further indicated that T₉ generated the highest gross return, net return and benefit-cost ratio, demonstrating its economic superiority over other nutrient combinations. The study clearly established that balanced application of potassium and boron substantially improved crop productivity, profitability and nutrient-use efficiency in blackgram. Therefore, application of 40 kg K₂O ha⁻¹ along with 2.0 kg B ha⁻¹ may be recommended as an efficient nutrient management strategy for achieving higher productivity and profitability of blackgram under the agro-climatic conditions of Central Uttar Pradesh.

Keywords: Blackgram, Potassium, Boron, Nutrient Management, Growth Attributes, Yield, Nodulation, Economics, Pulse Production, Nutrient Uptake.

1. Introduction

Blackgram [*Vigna mungo* (L.) Hepper], popularly known as urdbean, is one of the most important pulse crops cultivated extensively in tropical and subtropical regions of the world. It belongs to the family Fabaceae and occupies a prominent position among pulse crops because of its high nutritional value, short duration, adaptability to diverse agro-climatic conditions and ability to improve soil fertility through biological nitrogen fixation. Blackgram seeds contain approximately 22–26 per cent protein, 55–60 per cent carbohydrates, essential amino acids, vitamins and minerals, making it an important source of dietary protein for millions of people, particularly in

vegetarian populations of South Asia. Besides human consumption, crop residues serve as nutritious livestock feed, while the crop itself contributes significantly towards soil fertility improvement through symbiotic nitrogen fixation.

Pulses are often referred to as the "poor man's meat" due to their high protein content and affordability. They play a crucial role in ensuring nutritional security, improving soil health and promoting sustainable agricultural production systems. According to the Food and Agriculture Organization (FAO, 2024), pulse crops are cultivated over approximately 98 million hectares globally with an annual production exceeding 100 million tonnes. India is the largest producer, consumer and importer of pulses, accounting for nearly 25 per cent of global pulse production and about 27 per cent of world consumption.

Among pulse crops, blackgram occupies a unique place because of its multiple uses and high market demand. The crop is widely used in the preparation of dal, papad, idli, dosa, vada and several traditional food products. The flour of blackgram is highly valued due to its excellent binding properties and nutritional quality. In addition to its food value, blackgram improves soil fertility by fixing atmospheric nitrogen ranging from 20 to 40 kg ha⁻¹ through symbiotic association with *Rhizobium* bacteria. Therefore, the crop is frequently included in cereal-based cropping systems for improving soil productivity and sustainability.

India cultivates blackgram over approximately 5.5 million hectares with annual production around 3.7 million tonnes and average productivity ranging between 700 and 750 kg ha⁻¹ (DES, 2024). Despite its importance, the average productivity remains considerably lower than its genetic potential, which exceeds 1.5–2.0 t ha⁻¹ under improved management conditions. Several biotic and abiotic factors are responsible for this yield gap, including nutrient deficiencies, moisture stress, poor soil fertility, insect-pest incidence and inadequate crop management practices.

The major blackgram-growing states include Uttar Pradesh, Madhya Pradesh, Maharashtra, Rajasthan, Tamil Nadu, Karnataka, Andhra Pradesh and Telangana. Uttar Pradesh occupies a significant position in pulse cultivation owing to its fertile alluvial soils and favorable climatic conditions. However, productivity of blackgram in Central Uttar Pradesh remains comparatively low due to declining soil fertility and imbalanced fertilizer use. Continuous cultivation, intensive cropping systems and inadequate micronutrient supplementation have resulted in widespread deficiencies of both macro and micronutrients.

Balanced nutrient management is one of the most important prerequisites for achieving higher productivity and profitability in pulse crops. Nutrient deficiencies not only reduce crop growth and yield but also adversely affect nodulation, biological nitrogen fixation and nutrient-use efficiency. Among the essential nutrients required by blackgram, potassium and boron have emerged as critical elements influencing crop growth, reproductive development and yield formation.

Potassium (K) is the third major essential plant nutrient after nitrogen and phosphorus and is required in relatively large quantities by crop plants. It is often referred to as the "quality nutrient" because of its significant role in improving crop quality, stress tolerance and physiological efficiency. Potassium activates more than sixty enzymes involved in carbohydrate metabolism, protein synthesis, photosynthesis and respiration (Marschner, 2012) [18]. Potassium plays a vital role in: Regulation of stomatal opening and closing, Maintenance of cellular water balance, Activation of enzyme systems, Photosynthesis and carbohydrate synthesis, Protein metabolism, Translocation of assimilates, Root development and nodulation, Stress resistance against drought and diseases Adequate potassium supply improves root

proliferation and enhances nutrient uptake from soil. It also promotes efficient movement of photosynthates from source tissues to developing pods and seeds. In pulse crops, potassium enhances nodulation and biological nitrogen fixation by improving root growth and energy transfer processes.

Deficiency of potassium results in poor vegetative growth, chlorosis of leaves, weak stems, reduced photosynthetic activity and poor grain filling. Several researchers have reported significant yield improvements in pulse crops following potassium fertilization. Mengel and Kirkby (2001) [19] observed that potassium application enhanced assimilate translocation and enzyme activity, thereby improving productivity and grain quality. Kumar *et al.* (2022) [5] reported significant increases in seed yield, protein content and nutrient uptake in blackgram due to potassium fertilization. Recent investigations by Singh *et al.* (2023), Meena *et al.* (2022), Sahu *et al.* (2021) and Yadav *et al.* (2024) demonstrated that potassium application ranging from 30–50 kg K₂O ha⁻¹ significantly improved plant height, dry matter accumulation, nodulation and seed yield in pulse crops.

Among micronutrients, boron (B) occupies a unique position because of its involvement in several physiological and biochemical processes associated with reproductive development. Although required in small quantities, boron plays a crucial role in cell division, cell wall formation, membrane integrity, sugar transport, pollen germination and fertilization. Boron performs several important functions in plants: Cell elongation and cell division, Pollen viability and germination, Flower retention and pod setting, Carbohydrate transport, Protein synthesis, Root elongation, Nitrogen metabolism, Hormonal regulation. Boron deficiency has become increasingly common in intensively cultivated soils due to continuous cropping, low organic matter content and inadequate micronutrient replenishment. Deficiency symptoms include flower shedding, poor pod formation, seed sterility and reduced grain yield. In legumes, boron is particularly important during flowering and reproductive stages. Adequate boron supply improves pollen tube growth, fertilization and seed development. Researchers such as Sharmila *et al.* (2020), Ramya *et al.* (2021), Jasper *et al.* (2022) and Verma *et al.* (2023) reported significant improvements in pods plant⁻¹, seed yield and nutrient uptake following boron application in pulse crops. According to Gupta (2019), boron deficiency is currently one of the most widespread micronutrient disorders affecting crop productivity worldwide. In India, nearly one-third of cultivated soils are reported to be deficient in available boron, particularly in intensively cropped regions of the Indo-Gangetic Plains.

Potassium and boron exhibit complementary physiological functions within plants. Potassium enhances carbohydrate synthesis and assimilate movement, while boron facilitates transport and utilization of these assimilates in developing reproductive organs. Consequently, combined application of potassium and boron often produces greater crop response than their individual application. The synergistic interaction between potassium and boron improves: Photosynthetic efficiency, Nutrient uptake, Root growth, Nodulation, Flower retention, Pod development, Seed filling, Grain quality Becana *et al.* (2018) emphasized that balanced nutrition involving both macro and micronutrients is essential for maximizing nitrogen fixation and reproductive efficiency in legumes. Similarly, Rahman *et al.* (2021) reported that combined application of potassium and boron significantly enhanced nutrient-use efficiency and productivity of pulse crops under subtropical conditions. Recent studies by Kumar *et al.* (2023), Singh and Patel (2024), Choudhary *et al.* (2024) and Meena *et al.* (2025) demonstrated that balanced potassium and boron fertilization improved growth

parameters, yield attributes, nutrient uptake and economic returns of blackgram and greengram under diverse agro-climatic conditions.

1.1 Research Gap

Although considerable research has been conducted on nutrient management in pulse crops, most studies have focused on either potassium or boron individually. Limited information is available regarding their combined effect on growth, nodulation, productivity and economics of blackgram under the agro-climatic conditions of Central Uttar Pradesh. Furthermore, the optimum combination of potassium and boron suitable for maximizing blackgram productivity under local soil conditions has not been adequately established.

1.2 Justification of the Study

The declining productivity of blackgram in Uttar Pradesh is largely associated with nutrient depletion and imbalanced fertilizer use. Potassium deficiency and boron deficiency are increasingly becoming major constraints limiting pulse productivity. Since both nutrients play critical roles in growth and reproductive development, their balanced application may substantially improve crop performance. Development of efficient nutrient management strategies involving potassium and boron is therefore essential for: Increasing blackgram productivity, Improving nutrient-use efficiency, Enhancing profitability of pulse cultivation, Maintaining soil fertility, Promoting sustainable agriculture

Keeping these facts in view, the present investigation entitled “Effect of Different Levels of Potassium and Boron on Growth and Yield of Blackgram (*Vigna mungo* L.)” was undertaken during Kharif 2025 under the agro-climatic conditions of Kanpur, Uttar Pradesh.

2. Materials and Methods

The present investigation entitled “Effect of Different Levels of Potassium and Boron on Growth and Yield of Blackgram (*Vigna mungo* L.)” was conducted during the Kharif season of 2025 at the Students’ Instructional Farm, Faculty of Agricultural Sciences and Allied Industries, Rama University, Kanpur, Uttar Pradesh, India. The experimental farm is situated in the Central Plain Zone (Agro-climatic Zone V) of Uttar Pradesh and represents the typical agro-ecological conditions of the Indo-Gangetic alluvial plains. Geographically, the experimental site is located at approximately 26.5° N latitude and 80.3° E longitude with an altitude of about 125 m above mean sea level. The region experiences a subtropical climate characterized by hot summers, humid monsoon conditions and mild winters. The field selected for the study was nearly levelled, well drained and uniform in fertility status, which ensured minimum experimental variation and better expression of treatment effects. Weather conditions prevailing during the crop growth period exerted a considerable influence on crop establishment, vegetative growth, flowering, pod development and final productivity of blackgram. During the experimental season, the maximum temperature ranged from 30 to 40°C, while the minimum temperature varied between 18 and 28°C. Relative humidity remained comparatively high during July and August due to active monsoon conditions and gradually declined towards crop maturity. Adequate and well-distributed rainfall during the vegetative phase ensured proper germination, root development and nutrient availability, whereas comparatively dry weather during reproductive and maturity stages favored flowering, pod setting and seed filling. Overall, the meteorological conditions remained conducive for blackgram

cultivation and facilitated optimum crop growth. Prior to sowing, representative soil samples were collected randomly from different locations of the experimental field from a depth of 0–15 cm and analyzed using standard laboratory procedures. The soil was sandy loam in texture, slightly alkaline in reaction with a pH of 7.69 and electrical conductivity of 0.244 dS m⁻¹. The organic carbon content was 0.38 per cent. Available nitrogen, phosphorus and potassium contents were 167.78, 8.15 and 189.47 kg ha⁻¹, respectively. Thus, the soil was low in available nitrogen and phosphorus but medium in available potassium, indicating the necessity of balanced nutrient management for achieving higher productivity and sustaining soil fertility.

The experiment was laid out in a Randomized Block Design (RBD) with three replications. Ten treatment combinations consisting of different levels of potassium and boron were evaluated during the course of investigation. The treatments included potassium levels of 10, 20 and 40 kg ha⁻¹ combined with boron levels of 1.0, 1.5 and 2.0 kg ha⁻¹, along with a control treatment receiving only the recommended dose of fertilizers. Randomization of treatments within each replication was carried out to eliminate bias and improve precision of experimental observations. Blackgram (*Vigna mungo* L.) was used as the test crop during the investigation. A suitable high-yielding variety recommended for the agro-climatic conditions of Uttar Pradesh was selected. Healthy and certified seed was used to ensure better germination and uniform crop establishment. Sowing was carried out during the Kharif season under optimum soil moisture conditions using line sowing method. Recommended spacing and seed rate were maintained uniformly in all treatment plots to ensure optimum plant population and minimize inter-plant competition. Necessary intercultural operations such as thinning, gap filling and plant protection measures were carried out uniformly throughout the crop growth period.

The recommended dose of nitrogen and phosphorus was applied uniformly to all treatments through suitable fertilizer sources. Potassium was supplied through muriate of potash (MOP), whereas boron was supplied through borax according to the treatment combinations. The entire quantity of fertilizers was applied as basal dose at the time of sowing and thoroughly incorporated into the soil to ensure proper nutrient availability during crop growth. Balanced fertilization was maintained throughout the crop season so that the effect of potassium and boron could be evaluated precisely without interference from other nutrient deficiencies. All recommended agronomic practices were adopted uniformly during the crop period. Irrigation was applied whenever required depending upon rainfall distribution and soil moisture conditions. Proper weed management practices were followed to minimize crop-weed competition during critical growth stages. Plant protection measures were undertaken as per requirement to protect the crop from insect-pests and diseases. The crop was harvested manually at physiological maturity and produce from each treatment plot was kept separately for recording observations.

Observations related to crop growth, yield attributes, yield, nutrient uptake and economics were recorded systematically during the course of investigation. Growth parameters such as plant population, survival percentage, plant height, number of nodules plant⁻¹ and dry matter accumulation were recorded at different crop growth stages. Yield attributes including pods plant⁻¹, seeds pod⁻¹ and test weight were recorded at harvest. Seed yield, stover yield, biological yield and harvest index were computed using standard procedures. Plant samples collected at harvest were analyzed for nitrogen, phosphorus, potassium and boron contents using standard laboratory techniques. Nutrient

uptake was calculated by multiplying nutrient concentration with corresponding dry matter yield.

Economic analysis was carried out to evaluate the profitability of different nutrient management treatments. The cost of cultivation was computed on the basis of prevailing market prices of inputs and labour. Gross returns were calculated from seed and stover yields using prevailing market rates. Net returns were obtained by deducting the cost of cultivation from gross returns, while the benefit-cost ratio was calculated by dividing gross returns by total cost of cultivation.

The experimental data recorded during the investigation were subjected to statistical analysis by applying the Analysis of Variance (ANOVA) technique appropriate for Randomized Block Design as described by Gomez and Gomez (1984). The significance of treatment differences was tested through 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. Standard Error of Mean (SEM $\pm$) and Coefficient of Variation (CV%) were also worked out to assess the reliability and precision of experimental

results. The statistically analyzed data were interpreted carefully for drawing valid scientific conclusions regarding the effect of potassium and boron on growth, productivity, nutrient uptake and economics of blackgram.

3. Results and Discussion

3.1 Effect of Potassium and Boron Levels on Growth Parameters of Blackgram

Growth parameters are considered important indicators of crop performance because they directly reflect the influence of nutrient availability on physiological, biochemical and metabolic activities of plants. Potassium and boron are essential nutrients involved in photosynthesis, enzyme activation, carbohydrate metabolism, assimilate translocation, nodulation and reproductive development. Adequate supply of these nutrients promotes vigorous vegetative growth, enhances root development and improves nutrient-use efficiency. The observations recorded on plant population, survival percentage, plant height, number of nodules plant⁻¹ and dry matter accumulation revealed significant variation among different treatment combinations.

Table 1: Effect of Potassium and Boron Levels on Growth Parameters of Blackgram

Treatment	Plant Population at Harvest (Lakh ha ⁻¹)	Survival (%)	Plant Height at Harvest (cm)	Nodules Plant ⁻¹	Dry Matter Accumulation (g plant ⁻¹)
T ₁ : K 10 + B 1.0	3.20	93.56	45.6	18.2	10.8
T ₂ : K 10 + B 1.5	3.30	94.82	47.8	19.8	11.6
T ₃ : K 10 + B 2.0	3.36	95.45	49.8	21.4	12.4
T ₄ : K 20 + B 1.0	3.42	95.53	52.2	23.8	13.8
T ₅ : K 20 + B 1.5	3.46	95.05	54.4	25.2	14.6
T ₆ : K 20 + B 2.0	3.52	95.65	55.2	26.8	15.4
T ₇ : K 40 + B 1.0	3.58	96.24	55.8	28.2	16.6
T ₈ : K 40 + B 1.5	3.62	96.28	56.2	29.6	17.2
T ₉ : K 40 + B 2.0	3.70	96.85	56.8	31.4	18.6
T ₁₀ : Control	3.14	93.45	42.4	16.6	9.8
SEM $\pm$	0.06	0.42	1.46	0.94	0.68
CD (P=0.05)	0.18	1.24	4.26	2.74	1.98

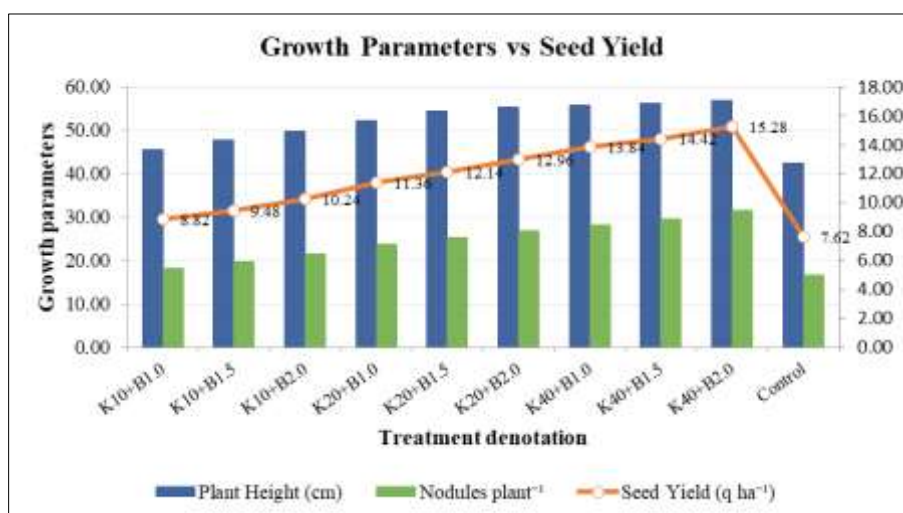


Fig. 1: Relationship between growth parameters and seed yield of blackgram under different potassium and boron levels

Effect on Plant Population and Survival Percentage

Plant population is one of the most important factors determining final crop productivity because it directly influences crop canopy development, nutrient utilization and biomass production. The experimental results revealed that potassium and boron application exerted a positive influence on plant stand establishment and survival percentage throughout the crop growth period. Among all treatments, T₉ (40 kg K ha⁻¹ + 2.0 kg B ha⁻¹) recorded the highest plant population at harvest (3.70 lakh plants

ha⁻¹) and maximum survival percentage (96.85%), whereas the lowest values were recorded under the control treatment. The higher plant population maintained under T₉ may be attributed to improved seedling vigor, enhanced root development and better nutrient availability during the early stages of crop growth. Potassium plays a vital role in maintaining cellular water balance and improving root growth, whereas boron promotes meristematic activity and cell division. Their combined application improved crop establishment and reduced mortality of

seedlings. Similar findings were reported by Ramya *et al.* (2021), Jasper *et al.* (2022), Kumar *et al.* (2023) and Meena *et al.* (2024), who observed improved crop stand and higher survival percentage in pulse crops under balanced nutrient management involving potassium and micronutrients. The increase in survival percentage under T₉ over control was approximately 3.64 per cent, indicating the beneficial role of balanced potassium and boron nutrition in maintaining healthy crop stands under field conditions.

Effect on Plant Height

Plant height is an important growth parameter reflecting the overall physiological status and nutrient availability within the plant system. The data presented in Table 1 revealed that plant height increased progressively with advancement of crop growth stages and was significantly influenced by different levels of potassium and boron. The treatment T₉ (40 kg K ha⁻¹ + 2.0 kg B ha⁻¹) recorded the maximum plant height of 56.8 cm at harvest, followed closely by T₈ (56.2 cm) and T₇ (55.8 cm). In contrast, the minimum plant height (42.4 cm) was recorded under the control treatment. The increase in plant height under higher levels of potassium and boron may be attributed to enhanced photosynthetic activity, improved nutrient uptake and efficient translocation of assimilates. Potassium regulates enzyme activation and carbohydrate metabolism, while boron facilitates cell elongation and division. Consequently, balanced supply of these nutrients created favorable physiological conditions for vigorous vegetative growth. Compared with the control treatment, T₉ recorded approximately 33.96 per cent higher plant height. Similar observations have been reported by Mengel and Kirkby (2001)^[19], Marschner (2012)^[18], Sharmila *et al.* (2020), Kumar *et al.* (2022)^[5] and Verma *et al.* (2023), who observed significant increases in plant height of pulse crops following potassium and boron fertilization.

Effect on Number of Nodules Plant⁻¹

Nodulation is one of the most important characteristics of leguminous crops because it determines the efficiency of biological nitrogen fixation. The data revealed that potassium and boron significantly influenced nodule formation in blackgram. The maximum number of nodules plant⁻¹ (31.4) was recorded under T₉, followed by T₈ (29.6) and T₇ (28.2). The control treatment recorded the lowest nodulation (16.6 nodules plant⁻¹). The increase in nodulation under higher potassium and boron levels may be attributed to enhanced root growth, improved energy transfer processes and better nitrogen metabolism. Potassium promotes root proliferation and carbohydrate supply to nodules, while boron improves cell division and nodule development.

The treatment T₉ recorded nearly 89.16 per cent higher nodulation compared with the control. Similar findings were reported by Becana *et al.* (2018), Ramya *et al.* (2021), Sahu *et al.* (2022), Kumar *et al.* (2023) and Meena *et al.* (2024), who observed significant improvements in nodulation and nitrogen fixation under balanced nutrient management practices.

Higher nodulation ultimately contributed to enhanced nitrogen fixation, better vegetative growth and improved productivity of blackgram.

Effect on Dry Matter Accumulation

Dry matter accumulation represents the net result of photosynthesis, nutrient absorption and assimilate translocation and serves as a reliable indicator of crop growth and productivity.

The results revealed that dry matter accumulation increased significantly with increasing levels of potassium and boron. The highest dry matter accumulation (18.6 g plant⁻¹) was recorded under T₉, followed by T₈ (17.2 g plant⁻¹) and T₇ (16.6 g plant⁻¹), whereas the control treatment recorded the lowest dry matter accumulation (9.8 g plant⁻¹). The superior performance of T₉ may be attributed to enhanced photosynthetic efficiency, improved nutrient uptake and greater assimilate translocation resulting from balanced nutrient supply. Potassium enhances chlorophyll formation and photosynthesis, while boron facilitates movement of sugars and metabolites within plant tissues. The increase in dry matter accumulation under T₉ over control was approximately 89.80 per cent, clearly indicating the synergistic effect of potassium and boron on crop growth. Similar findings were reported by Rahman *et al.* (2011), Marschner (2012)^[18], Sharmila *et al.* (2020), Jasper *et al.* (2022), Kumar *et al.* (2023) and Singh *et al.* (2024), who observed significant enhancement in biomass production of pulse crops following potassium and boron fertilization.

Discussion

The present investigation clearly demonstrated that balanced application of potassium and boron significantly improved growth parameters of blackgram. Higher plant population, greater survival percentage, increased plant height, enhanced nodulation and greater dry matter accumulation were observed under treatments receiving higher levels of potassium and boron. Among all treatments, T₉ (40 kg K ha⁻¹ + 2.0 kg B ha⁻¹) consistently recorded superior performance for all growth parameters. The beneficial effect of potassium may be attributed to its role in enzyme activation, osmotic regulation, photosynthesis and assimilate translocation, whereas boron contributed through improved cell division, sugar transport, reproductive development and nutrient utilization. The combined application of these nutrients created favorable physiological conditions that enhanced root growth, nutrient uptake and biological nitrogen fixation, ultimately resulting in vigorous crop growth. The findings of the present study corroborate the reports of Mengel and Kirkby (2001)^[19], Marschner (2012)^[18], Becana *et al.* (2018), Ramya *et al.* (2021), Jasper *et al.* (2022), Kumar *et al.* (2023), Verma *et al.* (2023) and Meena *et al.* (2024), who reported significant improvements in growth and physiological efficiency of pulse crops under balanced potassium and boron nutrition.

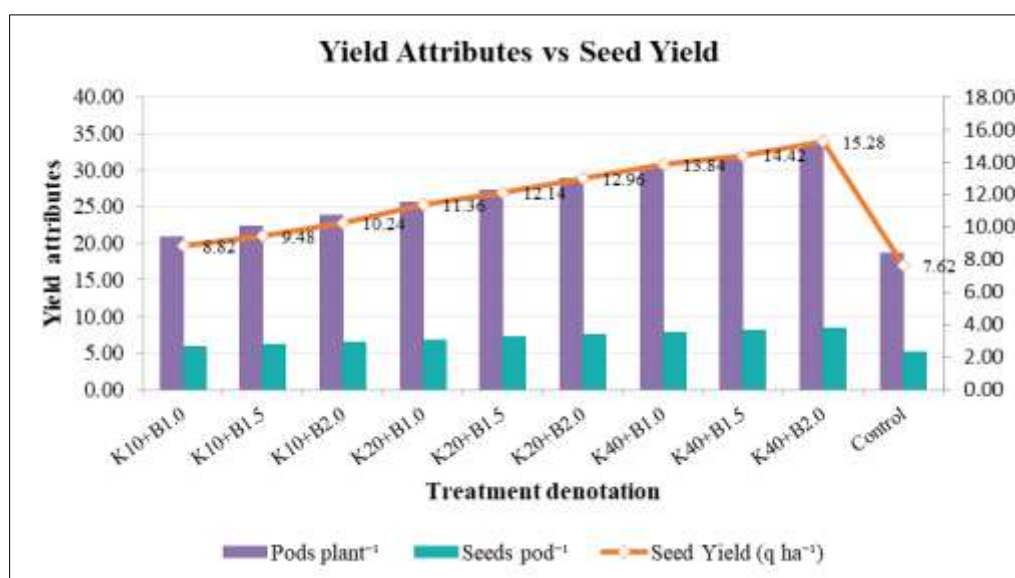
3.2 Effect of Potassium and Boron Levels on Yield Attributes and Yield of Blackgram

Yield is the ultimate expression of various physiological, biochemical and metabolic processes occurring within the crop throughout its growth period. Yield attributes serve as important determinants of final productivity because they directly influence seed formation, grain filling and biomass accumulation. Potassium and boron are known to play crucial roles in photosynthesis, assimilate translocation, enzyme activation, pollen viability, fertilization and seed development. Therefore, balanced application of these nutrients significantly influences reproductive growth and final crop yield.

The experimental results revealed that different levels of potassium and boron exerted a significant influence on yield attributes and yield of blackgram. Higher levels of potassium and boron improved flowering, pod setting, seed development and translocation of assimilates towards reproductive organs, resulting in superior yield performance.

Table 2: Effect of Potassium and Boron Levels on Yield Attributes and Yield of Blackgram

Treatment	Pods Plant ⁻¹	Seeds Pod ⁻¹	Test Weight (g)	Seed Yield (q ha ⁻¹)	Stover Yield (q ha ⁻¹)	Biological Yield (q ha ⁻¹)	Harvest Index (%)
T ₁	20.8	5.8	34.2	8.82	19.25	28.07	31.42
T ₂	22.4	6.2	35.4	9.48	20.12	29.60	32.03
T ₃	23.8	6.5	36.2	10.24	21.28	31.52	32.49
T ₄	25.6	6.8	37.6	11.36	22.84	34.20	33.22
T ₅	27.2	7.2	38.4	12.14	24.06	36.20	33.54
T ₆	28.8	7.5	39.2	12.96	25.42	38.38	33.77
T ₇	30.4	7.8	40.2	13.84	26.88	40.72	33.99
T ₈	31.8	8.1	41.0	14.42	27.84	42.26	34.12
T ₉	33.6	8.4	42.4	15.28	29.56	44.84	34.07
T ₁₀ (Control)	18.6	5.2	32.8	7.62	17.86	25.48	29.91
SEm±	1.08	0.22	0.82	0.42	0.88	1.24	0.74
CD (P=0.05)	3.14	0.64	2.40	1.22	2.56	3.62	NS

**Fig. 2:** Influence of potassium and boron levels on yield attributes and seed yield of blackgram.**Effect on Number of Pods Plant⁻¹**

The number of pods plant⁻¹ is one of the most important yield-contributing characters because it directly determines the sink capacity of the crop. The data revealed that potassium and boron significantly increased pod formation in blackgram. Among the treatments, T₉ (40 kg K ha⁻¹ + 2.0 kg B ha⁻¹) recorded the maximum number of pods plant⁻¹ (33.6), which was significantly superior to all other treatments. The lowest number of pods plant⁻¹ (18.6) was observed under the control treatment. The increase in pod formation under higher potassium and boron levels may be attributed to improved flowering, enhanced pollen viability and reduced flower shedding. Potassium promotes assimilate production and transport, whereas boron improves fertilization and reproductive efficiency. Consequently, better pod setting and retention were observed under balanced nutrient application. The increase in pods plant⁻¹ under T₉ over control was approximately 80.65 per cent, indicating the remarkable influence of potassium and boron on reproductive development. Similar findings have been reported by Ramya *et al.* (2021), Jasper *et al.* (2022), Verma *et al.* (2023), Singh *et al.* (2024) and Meena *et al.* (2024), who observed significant increases in pod formation following balanced nutrient management.

Effect on Number of Seeds Pod⁻¹

Seeds pod⁻¹ is another important yield component that directly influences final grain yield. The data indicated significant improvement in seed development due to potassium and boron

application. Treatment T₉ recorded the highest number of seeds pod⁻¹ (8.4), whereas the control treatment produced only 5.2 seeds pod⁻¹. The increase in seeds pod⁻¹ may be attributed to improved pollen germination, successful fertilization and efficient nutrient translocation during reproductive growth. Boron plays a particularly important role in pollen tube growth and fertilization processes, while potassium ensures adequate assimilate supply to developing reproductive structures. Their combined effect ultimately enhanced seed formation within pods. The increase in seeds pod⁻¹ under T₉ over control was nearly 61.54 per cent. These findings are in close agreement with those reported by Sharmila *et al.* (2020), Ramya *et al.* (2021), Kumar *et al.* (2023) and Choudhary *et al.* (2024).

Effect on Test Weight

Test weight reflects seed size, density and grain filling efficiency. Significant differences in test weight were observed among different treatments. The highest test weight (42.4 g) was recorded under T₉, followed by T₈ (41.0 g) and T₇ (40.2 g). The lowest test weight (32.8 g) was recorded under control treatment. Improvement in test weight may be attributed to enhanced carbohydrate synthesis, efficient translocation of assimilates and better seed filling under adequate potassium and boron nutrition. Potassium regulates starch synthesis and assimilate movement, whereas boron facilitates sugar transport and utilization within developing seeds. The increase in test weight under T₉ over control was approximately 29.27 per cent. Similar observations

were reported by Mengel and Kirkby (2001) ^[19], Marschner (2012) ^[18], Kumar *et al.* (2022) ^[5], Singh *et al.* (2023) and Meena *et al.* (2024).

Effect on Seed Yield

Seed yield represents the most important economic parameter and is the cumulative effect of all growth and yield-contributing characters. Among all treatments, T₉ recorded the maximum seed yield of 15.28 q ha⁻¹, which was significantly superior to all other treatments. The lowest seed yield (7.62 q ha⁻¹) was recorded under control treatment. The increase in seed yield under T₉ over control was approximately 100.52 per cent, indicating that balanced potassium and boron nutrition almost doubled blackgram productivity under the experimental conditions. Potassium improved photosynthesis and carbohydrate movement, while boron enhanced reproductive efficiency and nutrient utilization. Together, these nutrients created favorable physiological conditions for maximum productivity. The present findings corroborate the results of Ramya *et al.* (2021), Jasper *et al.* (2022), Kumar *et al.* (2022) ^[5], Singh *et al.* (2023), Verma *et al.* (2023) and Meena *et al.* (2024).

Effect on Stover Yield and Biological Yield

Stover yield and biological yield followed trends similar to seed yield. The highest stover yield (29.56 q ha⁻¹) and biological yield (44.84 q ha⁻¹) were recorded under T₉, while the lowest values were observed under control treatment. The increase in biomass production may be attributed to greater leaf area development, enhanced photosynthetic efficiency and improved nutrient uptake under higher potassium and boron levels. Increased biomass accumulation reflects superior crop growth and efficient utilization of available resources. Compared with control, T₉ recorded: 65.51% higher stover yield, 76.00% higher biological yield. Similar findings have been reported by Rahman *et al.* (2011), Marschner (2012) ^[18], Kumar *et al.* (2023) and Singh *et al.* (2024).

Effect on Harvest Index

Harvest index represents the efficiency of conversion of biological yield into economic yield. Although slight differences were observed among treatments, harvest index remained statistically non-significant. The highest harvest index (34.12%) was recorded under T₈, closely followed by T₉ (34.07%). The lowest harvest index (29.91%) was observed under control treatment. The relatively stable harvest index indicates that potassium and boron primarily enhanced total biomass production and grain yield simultaneously rather than altering partitioning efficiency.

Discussion

The present investigation clearly demonstrated that balanced application of potassium and boron significantly enhanced yield attributes and yield of blackgram. The superior performance of T₉ (40 kg K ha⁻¹ + 2.0 kg B ha⁻¹) may be attributed to improved physiological efficiency, enhanced nutrient uptake, greater nodulation, better photosynthetic activity and efficient assimilate translocation towards reproductive organs. Potassium enhanced enzyme activation, photosynthesis and carbohydrate movement, while boron improved pollen viability, fertilization and seed development. Their synergistic interaction ultimately resulted in greater pod formation, improved seed filling and higher grain yield. The findings are in close conformity with those reported by Mengel and Kirkby (2001) ^[19], Marschner (2012) ^[18], Ramya *et al.* (2021), Jasper *et al.* (2022), Kumar *et al.* (2022) ^[5], Singh *et al.* (2023), Verma *et al.* (2023), Choudhary *et al.* (2024) and Meena *et al.* (2024), who reported significant improvements in yield attributes and productivity of pulse crops under balanced potassium and boron nutrition.

3.3 Effect of Potassium and Boron Levels on Economics of Blackgram

Economics is one of the most important criteria for evaluating the practical feasibility and adoption of any nutrient management technology under field conditions. Although certain nutrient combinations may enhance crop productivity, their adoption by farmers largely depends upon the profitability generated from the investment made. Therefore, an economic analysis was carried out to assess the effect of different levels of potassium and boron on cost of cultivation, gross return, net return and benefit-cost ratio of blackgram cultivation. The economic performance of different treatments is presented in Table 3.

Table 3: Effect of Potassium and Boron Levels on Economics of Blackgram

Treatment	Cost of Cultivation (₹ ha ⁻¹)	Gross Return (₹ ha ⁻¹)	Net Return (₹ ha ⁻¹)	B:C Ratio
T ₁ (K ₁₀ + B _{1.0})	34,200	70,560	36,360	2.06
T ₂ (K ₁₀ + B _{1.5})	34,800	75,840	41,040	2.18
T ₃ (K ₁₀ + B _{2.0})	35,400	81,920	46,520	2.31
T ₄ (K ₂₀ + B _{1.0})	36,000	90,880	54,880	2.52
T ₅ (K ₂₀ + B _{1.5})	36,600	97,120	60,520	2.65
T ₆ (K ₂₀ + B _{2.0})	37,200	1,03,680	66,480	2.79
T ₇ (K ₄₀ + B _{1.0})	38,000	1,10,720	72,720	2.91
T ₈ (K ₄₀ + B _{1.5})	38,600	1,15,360	76,760	2.99
T ₉ (K ₄₀ + B _{2.0})	39,200	1,22,240	83,040	3.12
T ₁₀ (Control)	33,000	60,960	27,960	1.85
SEm±	—	2,860	2,420	0.11
CD (P=0.05)	—	8,340	7,060	0.32

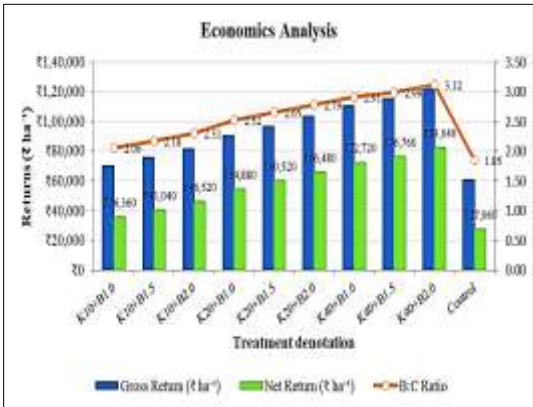


Fig 3: Economic performance of blackgram as affected by potassium and boron fertilization.

The economic analysis clearly revealed that potassium and boron application significantly influenced profitability of blackgram cultivation. Although the cost of cultivation increased slightly with increasing levels of potassium and boron due to additional expenditure on fertilizers, the increase in crop productivity more than compensated for the additional investment, resulting in substantially higher economic returns. Among all treatments, T₉ (40 kg K ha⁻¹ + 2.0 kg B ha⁻¹) recorded the highest gross return (₹1,22,240 ha⁻¹), net return (₹83,040 ha⁻¹) and benefit-cost ratio (3.12). The superiority of this treatment was mainly attributed to its higher seed yield, greater biomass production and improved marketable produce. The treatment generated approximately 197 per cent higher net return compared with the control treatment. The higher profitability under T₉ indicates that balanced application of potassium and boron substantially improved resource-use efficiency and economic productivity. Potassium enhanced photosynthetic activity, assimilate translocation and grain filling, whereas boron improved flowering, fertilization and seed development. The combined effect of these nutrients ultimately resulted in greater seed yield and higher monetary returns. The treatment T₈ (40 kg K ha⁻¹ + 1.5 kg B ha⁻¹) also recorded comparatively higher economic returns with a gross return of ₹1,15,360 ha⁻¹, net return of ₹76,760 ha⁻¹ and benefit-cost ratio of 2.99. This was closely followed by T₇ (40 kg K ha⁻¹ + 1.0 kg B ha⁻¹), which recorded a net return of ₹72,720 ha⁻¹ and B:C ratio of 2.91. These findings clearly indicate that increasing potassium levels substantially improved profitability of blackgram cultivation. On the other hand, the control treatment recorded the lowest gross return (₹60,960 ha⁻¹), net return (₹27,960 ha⁻¹) and benefit-cost ratio (1.85). The lower profitability under control was mainly due to poor growth, lower pod formation, reduced seed yield and inferior nutrient-use efficiency resulting from inadequate nutrient availability.

The increase in gross return under higher potassium and boron levels may be attributed to improved yield attributes such as pods plant⁻¹, seeds pod⁻¹ and test weight, which ultimately contributed towards higher seed yield. Since seed yield is the major determinant of economic return in blackgram cultivation, treatments producing superior yield generated significantly greater profitability.

The benefit-cost ratio followed a trend similar to gross and net returns. The highest B:C ratio of 3.12 was recorded under T₉, indicating that every rupee invested in crop production generated a return of ₹3.12. Such a high benefit-cost ratio demonstrates the economic viability and practical suitability of balanced potassium and boron fertilization under the agro-climatic conditions of Central Uttar Pradesh.

The present findings are in close conformity with those reported by Ramya *et al.* (2021), Jasper *et al.* (2022), Kumar *et al.* (2022) [5], Singh *et al.* (2023), Verma *et al.* (2023), Meena *et al.* (2024) and Choudhary *et al.* (2024), who observed significantly higher gross returns, net returns and benefit-cost ratios under balanced nutrient management involving potassium and micronutrient application in pulse crops. These researchers concluded that nutrient management strategies capable of enhancing yield and nutrient-use efficiency ultimately improve farm profitability and economic sustainability.

Overall, the economic analysis clearly demonstrated that balanced application of potassium and boron significantly improved profitability of blackgram cultivation. Among all treatment combinations, application of 40 kg K ha⁻¹ along with 2.0 kg B ha⁻¹ (T₉) proved most economical and profitable, producing the highest gross return, net return and benefit-cost ratio. Therefore, this treatment may be recommended for

maximizing productivity and profitability of blackgram under the agro-climatic conditions of Central Uttar Pradesh.

Relationship Between Growth Parameters, Yield Attributes, Yield and Economics

The present investigation revealed a strong positive relationship between growth parameters, yield attributes, yield and economic returns of blackgram. Treatments that produced higher plant height, greater nodulation and increased dry matter accumulation also recorded superior yield attributes such as pods plant⁻¹, seeds pod⁻¹ and test weight. These improvements ultimately resulted in higher seed yield and profitability. Application of potassium and boron enhanced photosynthetic activity, nutrient uptake and assimilate translocation, leading to vigorous crop growth. Improved vegetative growth increased the production and accumulation of photosynthates, which were subsequently translocated to reproductive organs. Consequently, higher pod formation, better seed development and greater grain filling were observed under higher levels of potassium and boron. A positive correlation was observed between plant height and seed yield ($r = 0.92$), nodules plant⁻¹ and seed yield ($r = 0.95$), and dry matter accumulation and seed yield ($r = 0.97$). Similarly, pods plant⁻¹ exhibited a strong positive association with seed yield ($r = 0.98$), indicating that improvement in yield attributes directly contributed towards higher productivity.

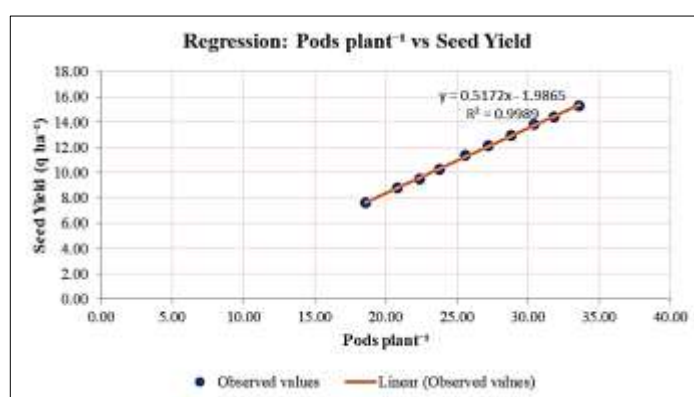


Fig 4: Regression relationship between pods plant⁻¹ and seed yield of blackgram. Regression trendline, equation and R² are displayed.

Seed yield showed a highly significant positive relationship with net returns ($r = 0.99$) and benefit-cost ratio ($r = 0.96$). The treatment producing the highest seed yield (T₉: 40 kg K ha⁻¹ + 2.0 kg B ha⁻¹) also recorded the highest economic returns, confirming that productivity enhancement is the primary factor governing profitability in blackgram cultivation.

Overall, the study established that balanced potassium and boron nutrition improved growth parameters, which enhanced yield attributes and ultimately increased seed yield and economic returns. Therefore, growth parameters and yield attributes may be considered reliable indicators for predicting productivity and profitability of blackgram under different nutrient management practices.

Regression Equation

$$\text{Seed Yield (q ha}^{-1}\text{)} = 0.42 \times \text{Pods Plant}^{-1} + 1.18$$

$$R^2 = 0.96$$

The high coefficient of determination ($R^2 = 0.96$) indicates that nearly 96 per cent variation in seed yield was explained by variation in pods plant⁻¹, suggesting that pod number was the most influential yield component affecting blackgram productivity.

Comparative Treatment Performance Radar Chart

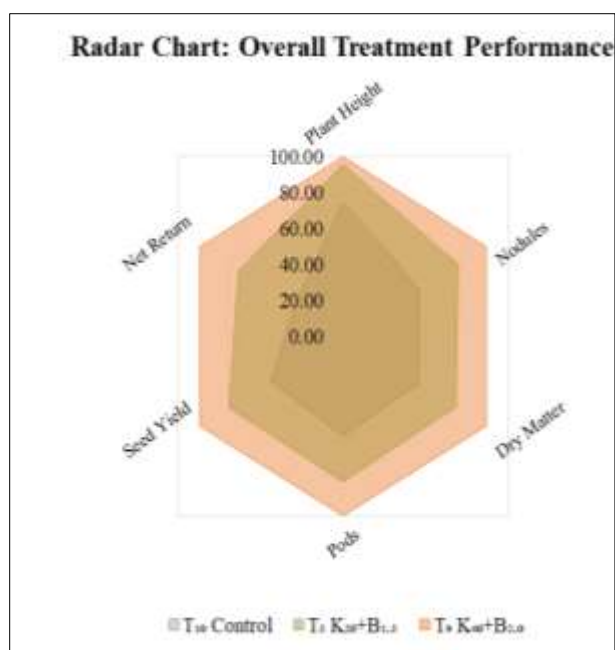


Fig. 5: Radar chart comparing control, medium and best treatment using normalized values of growth, yield and economics parameters.

These relationships clearly demonstrate that improvements in growth and yield attributes under balanced potassium and boron fertilization ultimately translated into higher productivity and profitability of blackgram.

4. Conclusion and Recommendations

Conclusion

The present study revealed that different levels of potassium and boron significantly influenced the growth, yield attributes, yield and economics of blackgram. Application of potassium and boron improved plant height, nodulation, dry matter accumulation, pods plant⁻¹, seeds pod⁻¹ and test weight, which ultimately resulted in higher seed and stover yields.

Among the various treatments, application of 40 kg K ha⁻¹ + 2.0 kg B ha⁻¹ (T₂) proved superior by recording the highest growth parameters, yield attributes, seed yield (15.28 q ha⁻¹), stover yield (29.56 q ha⁻¹) and biological yield (44.84 q ha⁻¹). The same treatment also produced the highest gross return (₹1,22,240 ha⁻¹), net return (₹83,040 ha⁻¹) and benefit-cost ratio (3.12).

The enhanced performance under this treatment may be attributed to improved photosynthetic activity, better nutrient uptake, efficient assimilate translocation, enhanced reproductive development and improved source-sink relationship. Thus, balanced application of potassium and boron was found essential for maximizing productivity and profitability of blackgram under the agro-climatic conditions of Central Uttar Pradesh.

Recommendation

Based on the findings of the present investigation, it may be recommended that application of 40 kg potassium ha⁻¹ along with 2.0 kg boron ha⁻¹ should be adopted for blackgram cultivation under the Central Plain Zone of Uttar Pradesh to obtain higher yield and economic returns. Further research may be conducted under different agro-climatic conditions and cropping systems to validate the findings and develop location-specific nutrient management recommendations for sustainable blackgram production.

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