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Influence of potassium and boron on growth and yield components of mustard (*Brassica juncea* L.)

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Abstract
A field experiment was carried out during the *Rabi season of 2024-25* at the Crop Research Farm, Department of Agronomy, Naini Agricultural Institute, SHUATS, Prayagraj, to study the "Effect of Potassium and Boron on growth and yield of mustard (*Brassica juncea* L.)". The experiment was laid out in a Randomized Block Design with ten treatments comprising three levels of potassium (30, 40 and 50 kg/ha), three levels of boron (1.0, 2.0 and 3.0 kg/ha), a control (80:40:40 NPK kg/ha) along with recommended fertilizer dose, and replicated thrice. The results indicated that the application of 50 kg/ha Potassium with 2.0 kg/ha Boron (T_8) produced significantly superior growth and yield performance, reflected in maximum plant height (184.24 cm), dry weight (27.33 g), branches/plant (18.13), siliquae/plant (295.87), seeds/siliqua (17.13), seed yield (2.54 t/ha), and stover yield (6.24 t/ha). Overall, the study suggests that balanced application of potassium and boron in combination enhances both growth and productivity of mustard under the agro-climatic conditions of Prayagraj.

Keywords: Rabi season, mustard, potassium, boron, growth and yield

Introduction
Indian mustard (*Brassica juncea* L.), belonging to the family Brassicaceae (Cruciferae), is one of the most important oilseed crops cultivated predominantly during the *Rabi* season in India. The Brassicaceae family includes several economically significant crops such as *B. juncea* (Indian mustard), *B. rapa*, and *B. nigra* (Kaur *et al.*, 2022). Among these, *B. juncea* is the most widely grown in India owing to its adaptability to diverse agro-climatic conditions, drought tolerance, and relatively low input requirements, making it well-suited for dryland farming systems (Kumar *et al.*, 2023). Globally, Indian mustard ranks as the third most important oilseed crop in terms of both area and production. During 2024-25, the global area under rapeseed-mustard was 43.5 million hectares with a total production of 89.54 million metric tonnes, recording an average productivity of 2.08 t/ha. India contributes 11.7-12.6 million tonnes annually, which accounts for about 13-14% of global rapeseed-mustard production. In India, rapeseed-mustard is the second most important annual oilseed crop after soybean, with a total production of 12.67 million tonnes from 8.63 million hectares, and an average productivity of 1.46 t/ha (USDA, 2024) [24]. In Uttar Pradesh alone, rapeseed-mustard covers 1.42 million hectares, producing 1.56 million tonnes with a productivity of 1.6 t/ha (GOI, 2024) [7].

Among various plant nutrients, potassium (K) is a crucial macronutrient influencing mustard growth and productivity. It regulates stomatal activity, photosynthesis, water balance, enzyme activation, and carbohydrate-protein metabolism (Marschner, 2012) [12]. Potassium deficiency hampers plant growth, seed development, and oil quality, while adequate supply enhances photosynthetic efficiency, water-use efficiency, stem strength, assimilate translocation, seed weight, and oil content (Singh *et al.*, 2017; Sharma *et al.*, 2020) [21, 18]. Generally, a recommended dose of 40-60 kg K_2O/ha is suggested depending on soil fertility (Kumar & Singh, 2002). Moreover, integrated use of potassium with organic manures or potassium-solubilizing microbes has been shown to further improve nutrient availability and efficiency (Patra *et al.*, 2021).

Similarly, boron (B) is an essential micronutrient required in trace amounts, but it plays a vital role in reproductive growth, cell wall development, membrane stability, and sugar transport in mustard (Shorrocks, 1997).

Boron deficiency is widespread in calcareous, coarse-textured, and sandy soils, resulting in brittle leaves, poor flowering, reduced siliquae formation, hollow seeds, and ultimately lower yields (Havlin *et al.*, 2013). Mustard is particularly responsive to boron application, with yield improvements ranging from 21% to 31% reported (Shekhawat *et al.*, 2012). Since boron is relatively immobile in plants, continuous and adequate supply is critical. Its availability is influenced by soil pH, moisture, texture, organic matter, and mineral composition (Goldberg *et al.*, 2000). Both soil and foliar applications of boron have been found to significantly increase siliquae per plant, seeds per siliqua, test weight, seed yield, and oil content (Chand & Rana, 2006; Cara *et al.*, 2002).

Thus, the balanced application of potassium and boron is essential for sustaining high productivity and quality of mustard under Indian conditions.

Materials and Methods

A field experiment was conducted during the *Rabi* season of 2024 at the Crop Research Farm, Department of Agronomy, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj. The experimental site is located at 25°39′42″N latitude, 81°67′56″E longitude, and an altitude of 98 meters above mean sea level (MSL). The objective of the study was to assess the effect of potassium and boron on the growth and yield of mustard (*Brassica juncea* L.).

The soil of the experimental plot was sandy loam in texture, with a neutral reaction (pH 7.0), organic carbon content of 0.79%, and available nutrient status of 184.54 kg/ha nitrogen, 34.2 kg/ha phosphorus, 247.5 kg/ha potassium, and 0.41 mg/kg boron.

The experiment was laid out in a Randomized Block Design (RBD) with ten treatment combinations, replicated three times. The treatments were as follows:

- T_1: Potassium 30 kg/ha + Boron 1.0 kg/ha
- T_2: Potassium 30 kg/ha + Boron 2.0 kg/ha
- T_3: Potassium 30 kg/ha + Boron 3.0 kg/ha
- T_4: Potassium 40 kg/ha + Boron 1.0 kg/ha
- T_5: Potassium 40 kg/ha + Boron 2.0 kg/ha
- T_6: Potassium 40 kg/ha + Boron 3.0 kg/ha
- T_7: Potassium 50 kg/ha + Boron 1.0 kg/ha
- T_8: Potassium 50 kg/ha + Boron 2.0 kg/ha
- T_9: Potassium 50 kg/ha + Boron 3.0 kg/ha
- T_{10}: Control (RDF: 80-40-40 NPK kg/ha)

The recommended dose of fertilizers (RDF) for mustard was 80:40:40 kg $N:P_2O_5:K_2O$/ha, which served as the standard. Nitrogen and phosphorus were applied through urea and DAP, respectively, while potassium was applied as muriate of potash (MOP) according to the treatments. At sowing, the full dose of phosphorus and treatment-wise potassium, along with 50% of nitrogen, were applied as basal. The remaining 50% nitrogen was top-dressed at 30 days after sowing (DAS) with the first irrigation to ensure sufficient supply during the active growth stage.

Boron was applied as Di-Sodium Octaborate Tetrahydrate (20%) at three levels (1.0, 2.0, and 3.0 kg/ha), broadcast uniformly at sowing and incorporated into the soil to enhance availability. Sowing was done at a seed rate of 5 kg/ha, maintaining a spacing of 30 cm between rows and 10 cm between plants.

Observations on growth parameters were recorded at 20, 40, 60, and 80 DAS. The parameters included plant height (cm), number of branches/plant, plant dry weight (g), crop growth rate (g/m²/day), and relative growth rate (g/g/day). Yield attributes such as number of siliquae/plant, seeds/siliqua, seed yield, and stover yield were recorded at harvest. Plant height was measured from five randomly selected plants per plot using a meter scale, while seed and stover yields were computed from net plot produce and expressed on a hectare basis.

Result and Discussion

Growth and Yield attributes

Plant Height (cm)

The data revealed that significantly higher plant height (184.24 cm) was recorded in T_8 (Potassium 50 kg/ha + Boron 2.0 kg/ha). However, treatments T_6 (Potassium 40 kg/ha + Boron 3.0 kg/ha), T_9 (Potassium 50 kg/ha + Boron 3.0 kg/ha), and T_7 (Potassium 50 kg/ha + Boron 1.0 kg/ha) were found to be statistically at par with T_8.

The significant increase in plant height with the application of potassium @ 50 kg/ha may be attributed to its role in improving the turgidity of plant cells, which facilitates better cell expansion and elongation, thereby enhancing vertical growth. Potassium also regulates stomatal activity, photosynthesis, and enzyme activation, ultimately improving vegetative development in mustard. Similar results were reported by Ray and Singh (2016), who observed that higher potassium application increased plant growth due to its influence on metabolic activities. The positive effect of boron @ 2.0 kg/ha on plant height could be ascribed to its crucial role in cell division, cell wall formation, and the proper functioning of meristematic tissues. Boron also facilitates the transport of sugars and synthesis of growth hormones, which stimulate stem elongation. These findings are in close agreement with the results of Singh *et al.* (2022), who reported that boron application significantly enhanced growth attributes of mustard.

Number of branches/plant

The data indicated that the significantly maximum number of branches per plant (18.13) was recorded in T_8 (Potassium 50 kg/ha + Boron 2.0 kg/ha). Treatments T_6 (Potassium 40 kg/ha + Boron 3.0 kg/ha), T_9 (Potassium 50 kg/ha + Boron 3.0 kg/ha), T_4 (Potassium 40 kg/ha + Boron 1.0 kg/ha), and T_7 (Potassium 50 kg/ha + Boron 1.0 kg/ha) were found to be statistically at par with T_8.

The significant increase in branching with the application of potassium @ 50 kg/ha may be attributed to its vital role in several physiological and biochemical processes, including enzyme activation, protein synthesis, assimilate translocation, maintenance of cell turgor, and enhanced photosynthetic efficiency. These processes promote lateral shoot initiation and growth, leading to higher numbers of both primary and secondary branches. Improved plant vigor under adequate potassium nutrition provides favorable conditions for better branching. Similar findings were reported by Kumar *et al.* (2021) [10], who also noted that potassium application enhanced branching and vegetative growth in mustard. Likewise, the significant improvement in the number of branches per plant with boron @ 2.0 kg/ha may be explained by its role in stimulating apical and lateral bud development. Boron enhances cell division and elongation in growing tissues and contributes to the regulation of hormonal balance, which collectively promote branching. These results are in close agreement with Singh *et al.* (2022), who highlighted that boron application improved growth traits and branching in mustard.

Plant dry weight (g/plant)

The the data revealed that significantly higher plant dry weight (27.33 g) was recorded in T_8 (Potassium 50 kg/ha + Boron 2.0 kg/ha). Treatments T_6 (Potassium 40 kg/ha + Boron 3.0 kg/ha), T_7 (Potassium 50 kg/ha + Boron 1.0 kg/ha), T_9 (Potassium 50 kg/ha + Boron 3.0 kg/ha), T_4 (Potassium 40 kg/ha + Boron 1.0 kg/ha), and T_5 (Potassium 40 kg/ha + Boron 2.0 kg/ha) were found to be statistically at par with T_8.

The significant increase in plant dry weight with the application of potassium @ 50 kg/ha may be ascribed to its role in enhancing photosynthetic efficiency, enzyme activation, and efficient translocation of assimilates, which together contribute to greater biomass accumulation. Higher potassium availability promotes structural development and stronger shoot systems, thereby supporting overall plant growth and higher dry matter production. These observations are consistent with the findings of Choudhary *et al.* (2021), who reported that adequate potassium supply significantly enhanced biomass accumulation in mustard. Similarly, the significant improvement in dry weight with boron @ 2.0 kg/ha may be attributed to its role in promoting cell division, cell wall development, and nutrient absorption, particularly nitrogen, which supports better plant development. Adequate boron availability ensures proper metabolic functioning and assimilate partitioning, resulting in greater accumulation of dry matter. These results are in line with the findings of Bhavana *et al.* (2022), who confirmed the positive influence of boron on biomass production in mustard

Crop Growth Rate (g/m²/day)

The data indicated that between 60-80 DAS, there was no significant difference in crop growth rate (CGR) among the treatments. However, the statistically highest CGR was recorded in T_4 (Potassium 40 kg/ha + Boron 1.0 kg/ha).

Relative growth rate (g/g/day)

Between 60-80 DAS, no significant difference was recorded among all the treatments. Statistically highest relative growth rate was recorded in treatment 4 [Potassium 40 kg/ha + Boron 1.0 kg/ha].

Yield attributes and Yield

Number of Seeds per Siliqua

The data revealed that the significantly maximum number of seeds per siliqua (17.13) was recorded in T_8 (Potassium 50 kg/ha + Boron 2.0 kg/ha), which was statistically superior over all other treatments. Treatments T_9 (Potassium 50 kg/ha + Boron 3.0 kg/ha), T_7 (Potassium 50 kg/ha + Boron 1.0 kg/ha), and T_6 (Potassium 40 kg/ha + Boron 3.0 kg/ha) were found to be statistically at par with T_8.

The significant improvement in seeds per siliqua with potassium @ 50 kg/ha may be attributed to its vital role in enhancing reproductive efficiency by improving pollination, fertilization, and grain filling. Potassium also facilitates efficient assimilate translocation towards developing siliquae, thereby ensuring better seed set and filling. Similar observations were reported by Bhavana *et al.* (2022), who noted that higher potassium application significantly increased seed set and yield attributes in mustard. Likewise, the positive effect of boron @ 2.0 kg/ha on seeds per siliqua may be explained by its role in maintaining pollen viability, enhancing fertilization efficiency, and supporting the development of reproductive organs. Boron also promotes the translocation of assimilates to sink organs, which improves seed development within siliquae. These findings are in agreement with Meena *et al.* (2021), who reported that boron application significantly improved siliqua filling and seed set in mustard.

Number of Siliquae per Plant

The data indicated that the significantly maximum number of siliquae per plant (295.87) was recorded in T_8 (Potassium 50 kg/ha + Boron 2.0 kg/ha), which was statistically superior over all other treatments. Treatments T_9 (Potassium 50 kg/ha + Boron 3.0 kg/ha), T_7 (Potassium 50 kg/ha + Boron 1.0 kg/ha), T_4 (Potassium 40 kg/ha + Boron 1.0 kg/ha), and T_2 (Potassium 40 kg/ha + Boron 3.0 kg/ha) were found to be statistically at par with T_8.

Application of potassium @ 50 kg/ha significantly enhanced the number of siliquae per plant in mustard. This improvement may be attributed to potassium's vital role in enzyme activation, assimilate translocation, and maintenance of osmotic regulation, which collectively promote efficient flowering, minimize pod abortion, and ensure better siliqua development. Similar findings were reported by Verma *et al.* (2021), who observed a positive influence of potassium on siliqua formation and yield attributes in mustard. Further, boron @ 2.0 kg/ha also contributed to an increase in siliquae per plant. This may be due to its role in enhancing the pollen-producing capacity of anthers, improving fertilization, and boosting photosynthetic efficiency. Boron influences phosphorylation processes, thereby reducing the respiratory consumption of assimilates and accelerating the translocation of photosynthates towards reproductive organs. These observations are consistent with the results of Kumar *et al.* (2023), who highlighted the importance of boron in improving siliqua initiation and setting in mustard.

Test weight (g): The data showed that no significant difference was recorded among all the treatments. Statistically highest test weight (5.1 g) was recorded in treatment 5 [Potassium 40 kg/ha + Boron 2.0 kg/ha].

Seed Yield (t/ha)

The data revealed that the significantly highest seed yield (2.54 t/ha) was recorded in T_8 (Potassium 50 kg/ha + Boron 2.0 kg/ha), which was statistically superior over all other treatments. Treatments T_9 (Potassium 50 kg/ha + Boron 3.0 kg/ha), T_5 (Potassium 40 kg/ha + Boron 2.0 kg/ha), T_6 (Potassium 40 kg/ha + Boron 3.0 kg/ha), T_4 (Potassium 40 kg/ha + Boron 1.0 kg/ha), and T_7 (Potassium 50 kg/ha + Boron 1.0 kg/ha) were found to be statistically at par with T_8.

The significant increase in seed yield with potassium @ 50 kg/ha may be attributed to its role in enhancing photosynthetic efficiency, assimilate translocation, and nutrient and water uptake. Improved vegetative growth and better pod filling under adequate potassium supply contributed to higher seed production. These observations are in accordance with Verma *et al.* (2015) [25], who reported a positive influence of potassium on seed yield in mustard. Similarly, boron @ 2.0 kg/ha enhanced seed yield by supporting reproductive growth. Boron plays a vital role in cell wall formation, sugar transport, and development of reproductive tissues, which improves flowering, pod setting, and ultimately seed output. These findings are consistent with Sahu *et al.* (2020), who noted that boron application significantly increased mustard seed yield by improving reproductive efficiency.

Stover yield (t/ha):

The data revealed that the significantly highest stover yield (6.24 t/ha) was recorded in T_8 (Potassium 50 kg/ha + Boron 2.0 kg/ha), which was statistically superior over all other treatments. Treatments T_9 (Potassium 50 kg/ha + Boron 3.0 kg/ha), T_7 (Potassium 50 kg/ha + Boron 1.0 kg/ha), T_5 (Potassium 40 kg/ha + Boron 2.0 kg/ha), T_6 (Potassium 40 kg/ha + Boron 3.0 kg/ha), and T_4 (Potassium 40 kg/ha + Boron 1.0 kg/ha) were found to be statistically at par with T_8.

The significant increase in stover yield with potassium @ 50 kg/ha may be attributed to its role in enhancing nutrient translocation, water regulation, and photosynthetic efficiency, which collectively improve plant structure and promote higher straw accumulation. These observations are consistent with Verma *et al.* (2021) [26], who reported that higher potassium application improved vegetative growth and biomass in mustard. Similarly, boron @ 2.0 kg/ha contributed to higher stover yield by supporting cell elongation, tissue differentiation, and efficient translocation of photosynthates, which enhanced vegetative growth and overall biomass accumulation. These results are in close agreement with Meena *et al.* (2020), who highlighted the positive influence of boron on mustard vegetative growth and stover production.

Harvest index

The data showed that no significant difference was recorded among all the treatments. Statistically highest harvest index (31.15%) was recorded in treatment 3 [Potassium 30 kg/ha + Boron 3.0 kg/ha].

Table 1: Effect of Potassium and Boron on growth and growth attributes of Mustard.

S. No.	Treatment Combinations	Plant Height (cm, 80 DAS)	No. of Branches/Plant	Plant Dry Weight (g)	CGR (g/m²/day, 60-80 DAS)	RGR (g/g/day, 60-80 DAS)
1	Potassium 30 kg/ha + Boron 1.0 kg/ha	165.27	14.87	23.78	16.86	0.028
2	Potassium 30 kg/ha + Boron 2.0 kg/ha	167.79	15.53	24.65	17.66	0.028
3	Potassium 30 kg/ha + Boron 3.0 kg/ha	162.56	14.93	25.50	18.53	0.029
4	Potassium 40 kg/ha + Boron 1.0 kg/ha	167.89	16.87	25.59	19.96	0.032
5	Potassium 40 kg/ha + Boron 2.0 kg/ha	176.81	15.40	24.87	16.96	0.026
6	Potassium 40 kg/ha + Boron 3.0 kg/ha	183.11	17.73	27.05	18.37	0.026
7	Potassium 50 kg/ha + Boron 1.0 kg/ha	181.29	16.67	26.14	18.21	0.027
8	Potassium 50 kg/ha + Boron 2.0 kg/ha	184.24	18.13	27.33	18.33	0.026
9	Potassium 50 kg/ha + Boron 3.0 kg/ha	183.07	17.40	25.89	18.28	0.028
10	Control (RDF-80:40:40 NPK kg/ha)	160.53	14.80	22.79	15.47	0.026
	F test	S	S	S	NS	NS
	SEm±	5.19	0.46	0.87	1.55	0.002
	CD (p = 0.05)	15.44	1.37	2.60	-	-

Table 2: Effect of Potassium and Boron on yield and yield attributes of Mustard.

S. No.	Treatment Combinations	No. of Seeds/Siliqua	No. of Siliquae/Plant	Test Weight (g)	Seed Yield (t/ha)	Stover Yield (t/ha)	Harvest Index (%)
1	Potassium 30 kg/ha + Boron 1.0 kg/ha	14.80	242.07	4.71	2.08	5.14	28.79
2	Potassium 30 kg/ha + Boron 2.0 kg/ha	15.33	268.33	4.63	2.19	5.19	29.74
3	Potassium 30 kg/ha + Boron 3.0 kg/ha	15.13	264.53	5.04	2.35	5.27	31.15
4	Potassium 40 kg/ha + Boron 1.0 kg/ha	15.00	268.13	4.88	2.36	5.68	29.44
5	Potassium 40 kg/ha + Boron 2.0 kg/ha	15.20	251.00	5.21	2.40	6.06	28.45
6	Potassium 40 kg/ha + Boron 3.0 kg/ha	16.13	265.00	5.06	2.37	5.79	29.02
7	Potassium 50 kg/ha + Boron 1.0 kg/ha	16.47	270.60	4.84	2.34	6.08	27.83
8	Potassium 50 kg/ha + Boron 2.0 kg/ha	17.13	295.87	4.88	2.54	6.24	28.84
9	Potassium 50 kg/ha + Boron 3.0 kg/ha	16.80	276.20	5.20	2.44	6.14	28.38
10	Control (RDF-80:40:40 NPK kg/ha)	14.40	239.53	4.60	1.96	4.05	27.88
	F test	S	S	NS	S	S	NS
	SEm±	0.51	9.04	0.23	0.09	0.29	0.92
	CD (p = 0.05)	1.52	28.05	-	0.27	0.87	-

Conclusion

The present study demonstrated that the application of Potassium @ 50 kg/ha in combination with Boron @ 2.0 kg/ha (soil application) was most effective in improving the growth, yield attributes, and overall productivity of mustard (*Brassica juncea* L.). These findings suggest that the integrated use of potassium and boron at these levels can be recommended as an efficient nutrient management strategy to maximize both yield and profitability in mustard cultivation under the agro-climatic conditions of Prayagraj.

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