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Effect of Sulphur and Boron on Growth Characterstics, Yield Components and Productivity Parameters of Mustard (*Brassica juncea* L.) under Rainfed Condition of Chitrakoot Region, Madhya Pradesh, India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The current field experiment was carried out at Mahatma Gandhi Gramodaya Vishwavidyalaya Chitrakoot, Satna (M.P.) during the Kharif season of 2021–2022 in order to assess the impact of sulphur and boron on growth parameters, yield attributes, and yield of mustard (*Brassica juncea* L.) under the rainfed conditions of the Chitrakoot area. The sandy loam texture of the experimental soil has a medium availability of boron and sulphur. The experiment used a factorial randomised block

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design with nine treatment combinations and three replications. The *Pusa Mahak* mustard variety was grown using the advised agronomic methods. Based on the findings of the experiment, it was possible to draw the conclusion that applying 35 kg S ha^{-1} + 2.5 kg B ha^{-1} 40 DAS to mustard greatly boosts the plant's growth parameter i.e. plant height, no. of leaves and no. of branches and yield attributes i.e. number of pods per plant, number of seeds per pod and 1000 seed weight (gm The application of 35 kg S ha^{-1} + 2.5 kg B ha^{-1} 40 DAS considerably increased productivity parameter, i.e. seed yield (q ha^{-1}), above the control, according to the results.

Keywords: Boron; mustard; sulphur; yield.

1. INTRODUCTION

Globally, India is the fourth largest oilseed crops producing country after United States, China and Brazil. However, it secures first position in sesame, niger, castor and safflower production and second position in groundnut production after China [1,2]. In India, the oilseeds are grown on 14.4% of total gross cropped area (25.50 million ha), which produced 32.26 million tonnes oilseeds with 1265 kg/ha productivity [2].

Out of the nine edible oilseed crops in our country, rapeseed-mustard is the second-most significant after soybean [2]. After Canada and China, India is third in terms of area and rapeseed-mustard productivity [3]. Rapeseed-mustard production covers 36.81 million hectares and 72.61 million tonnes worldwide, respectively [3]. With an average productivity of 1499 kg/ha, India produces 9.34 million tonnes of rapeseed-mustard, or nearly one-third of the average output for the entire world (1960 kg/ha) [2]. Among the different states and union territories, Rajasthan, Haryana, Uttar Pradesh and Madhya Pradesh contribute 74% acreage and 81% production of total rapeseed-mustard. Rajasthan ranks first in area (38.1%) and production (43.7%) while Haryana ranks first in productivity (2058 kg/ha) of rapeseed-mustard. Uttar Pradesh secured third position in country in respect of both acreage (0.75 million ha) and production (1.12 million tonnes) of rapeseed-mustard with 1483 kg/ha productivity [2]. Bundelkhand region covers 121.58 thousand ha area under rapeseed-mustard crop with the production of 92.80 thousand tonnes. The average productivity of rapeseed-mustard crop in Bundelkhand region is very low (763 kg/ha) as compared to national productivity [4].

Indian mustard (*Brassica juncea* L. Czernj & Cosson*)* belongs to the family *Brassicaceae* and commonly called as *rai* or Indian mustard. It contain good amount of oil usually 30–38% [5]. The mustard oil contains low amount of saturated fatty acids among vegetable oils.

The soils in the UP Bundelkhand region (Banda, Chitrakoot, Hamirpur, Jalaun, Jhansi, Lalitpur, and Mahoba district) are flat, swallow-shaped, alluvial, sandy in texture, with a mixture of black and red soil and low to very low levels of readily available N and P, medium to high levels of readily available K, low to medium levels of readily available S, and medium levels of readily available Zn. However, in the MP Bundelkhand region (Datia, Tikamgarh, Newari, Sagar, Damoh, Panna, and Chattarpur), undulating land with deep to very deep heavy texture and low fertility status is present. This land is particularly low in available N, low to medium in available P, low to high in available K, deficient in sulphur, and 40–80% deficient in available Zn [6]. Poor care is primarily to blame for this region's low fertility rate.

Sulphur is the fourth most important nutrient in crop production to increase quality and productivity of mustard next to N, P and K. It is essential for synthesis of cystine (27% S), cysteine (26% S) and methionine (21% S) amino acids which contain 90% of total sulphur [7-10]. It is also an essential component for chlorophyll formation, activation of various enzymes and sulfhydryl (SH-) linkages, protein and oil synthesis [11]. Sulphur is also a constituent of glucosinolate and glycosidase enzyme, which are responsible for pungency in mustard oil [12]. Oilseeds require more amount of sulphur (12 kg) to produce one tonne of economic yield as compared to pulses (8 kg) and cereals (3-4 kg) [13]. Sulphur application enhances mustard yield both under irrigated and rainfed conditions by 12–48% and 17–24%, respectively [14].

Boron is the second most essential micronutrient in mustard after Zn [15]. It plays an important role in the cell division, differentiation, and elongation of meristemic region [16]. It also helps regulation of various physiological and metabolic reactions

of the plant such as nucleic acid synthesis, cell wall synthesis, glucose synthesis, root elongation and carbohydrate transportation [17]. It is essential for reproductive growth of plant and increases flower production, pollen viability, seed and fruit development in crop plant [7]. Mustard crop responded well to B application with the average response ranging from 21-31% [18].

2. MATERIALS AND METHODS

2.1 Area and Location

The test was performed at the research farm of Agriculture farm of Mahatma Gandhi Gramodaya Vishwavidyalaya Chitrakoot, Satna (M.P.) throughout October, 2021 to March 2022 to observe impact of Sulphur and boron on Mustard (*Brassica juncea* L.) below rainfed situation of Chitrakoot area. Its latitude is $25^0$14' N range, $80^0$85' E longitude and at an altitude of 190-210 meters above mean sea level. "Experimental site location is located in Bundelkhand sector of northern Madhya Pradesh and feature generally sub-tropical and semi-arid with monsoon starting off through the 1/3 week of June and with drawing through quit of September. Overall rainfall acquired throughout the crop growing duration became 264 mm" [19].

2.2 Edaphic Condition

"The experimental field is sandy loam in texture, neutral in pH 7.3, low in organic carbon (0.20%), available N (94.68 kg ha^{-1}), medium in available P (16.00 kg ha^{-1}), high in available K (308.90 kg ha^{-1}) and high in available S (26.41 kg ha^{-1})" [19].

2.3 Study Design

The experiment was carried out in a factorial randomized block design (FRBD) assigning treatment combinations.

2.4 Application of Manures and Fertilizers

FYM was applied @ 10 q ha^{-1} as basal dose. After the layout of experimental plot, the fertilizers were weighed and applied in the plots and thoroughly mixed with soil. As per the experimental recommended doses of N, P, K and S have been implemented to all the plots. Recommended dose of N, P, K were applied through Urea, DAP and MOP (80:40:40 kg ha^{-1}) whereas Sulphur and Boron were implemented through wettable powder (15, 25, 35 kg S ha^{-1} and 1.5, 2.5 kg B ha^{-1})

2.5 Data Collection

2.5.1 Plant growth parameters

Plant height (cm): Heights of crop plants under different of combination treatments were recorded at 30, 60 and 90 DAS. For this, five plants were randomly selected from each plot and tagged for observation to be recorded. Height of plant in cm was taken from ground level up to the base of the last fully opened leaf of the main shoot.

No. of leaves per plant: Number of leaves per plant was recorded at 30, 60 and 90 days after sowing in the five tagged plants only.

No. of branches per plant: The total numbers of branches per plant in the five tagged plants were counted and then the average numbers of branches per plant were worked out.

2.5.2 Yield attributing characters

Number of siliqua plant: The number of Siliqua was counted from the five sample plants and the average was worked out.

Number of seeds per siliqua: The number of seeds per Siliqua was counted from the five sample plants and the average was calculated.

Seed index: The weight of 1000- seeds from the produce of each treatment was recorded and subjected to statistical computation.

Seed yield (q ha^{-1}): The seed yield from the net plot area was recorded in kg $plot^{-1}$ and figure converted into q/ha.

Table 1. Treatment details

Levels of sulphur			Levels of boron		
S_1	-	0 kg ha^{-1}	B_0	-	0 kg ha^{-1}
S_2	-	15 kg ha^{-1}	B_1	-	1.5 kg ha^{-1}
S_3	-	25 kg ha^{-1}	B_2	-	2.5 kg ha^{-1}
S_4	-	35 kg ha^{-1}			

2.6 Statistical Analysis

"The data recorded during the course of investigation was subjected to statistical analysis by Analysis of variance technique. The significant and non-significant treatment effects were judged with the help of 'F' (variance ratio) table" Chandel [20]. "The significant differences between the means were tested against the critical difference at 5% probability level". Chandel [20].

3. RESULTS AND DISCUSSION

3.1 Growth Parameters

3.1.1 Plant height

At a glance over the data given in the Table 2 clearly shows that the increasing level of sulphur up to 35 kg ha^{-1} increased the plant height significantly at of 30 DAS 14.70 cm to 19.23 cm, 60 DAS 110.26 to 119.16 cm and 90 DAS 179.60 cm to 195.76 cm. In the similar way due to the increasing levels of boron application plant height was recorded in the range of 30 DAS 16.50 cm to 17.85 cm, 60 DAS 114.15 cm to 116.97 cm and 90 DAS 186.05 cm to 190.82 cm under different level of boron control, 1.5 kg B ha^{-1} and 2.5 kg B ha^{-1} at 30, 60, 90 DAS, respectively. The interaction effect due to sulphur (control, 15 kg ha^{-1}, 25 kg ha^{-1} and 35 kg ha^{-1}) and boron (control, 1.5 kg B ha^{-1} and 2.5 kg B ha^{-1}) on plant height was found statistically non-significant at all the observation stages. The results of the present investigation are also in agreement with the findings of Öztürk [21], Solanki et al. [22] and Negi et al. [23].

3.1.2 No. of leaves $plant^{-1}$

A critical perusal of the data given in Table 2 clearly reflected that the number of leaves $plant^{-1}$ ranged from 30 DAS 4.96 to 6.10, 60 DAS 16.96 to 19.13 and 90 DAS 33.20 to 37.00 under different level of sulphur (control, 15 kg ha^{-1}, 25 kg ha^{-1} and 35 kg ha^{-1}) at 30, 60 and 90 DAS respectively. Number of leaves $plant^{-1}$ ranged from 5.47 to 5.75, 17.67 to 18.45 and 34.05 to 35.40 under different level of boron (control, 1.5 kg B ha^{-1} and 2.5 kg B ha^{-1}) at 30, 60 and 90 DAS, respectively. At all observational stages, it was determined that the interaction impact of sulphur and boron on the number of leaves in plant-1 mustard was statistically significant. The findings of the current analysis also agree with those of Rajput et al. [24], Singh et al. [25], and Jamal et al. [26].

3.1.3 No. of branches $plant^{-1}$

It is visualized from the information given in Table 2 that number of branches $plant^{-1}$ observed in the range of 1.93 to 2.76, 8.46 to 10.63 and 11.06 to 12.30 under different level of sulphur (control, 15 kg ha^{-1}, 25 kg ha^{-1} and 35 kg ha^{-1}) at 30, 60 and 90 DAS, respectively. Number of branches $plant^{-1}$ ranged from 2.25 to 2.52, 9.20 to 9.92 and 11.42 to 11.90 under different level of boron (control, 1.5 kg B ha^{-1} and 2.5 kg B ha^{-1}) at different observation stage of present study. The interaction effect due to sulphur and boron on number of branches $plant^{-1}$ was found statistically significant at all the observation stages except harvest stage. Comparative findings were detailed by Singh et al. [25], Upadhyay et al. [27] and Rajput et al. [24].

3.2 Yield Components and Yield

3.2.1 Number of siliqua $plant^{-1}$

An appraisal of the data given in Table 3 that number of siliquae $plant^{-1}$ mustard observed in the range of 304.43 to 321.06 under different level of sulphur control, 30 kg ha^{-1} and 40 kg ha^{-1} at harvest stage. Maximum number of siliquae $plant^{-1}$ was observed with application of 35 kg S ha^{-1} (S_2) which was significantly higher to 0, 15 and 25 kg S ha^{-1} but statistically at par with 25 kg S ha^{-1}. Number of siliquae $plant^{-1}$ mustard observed in the range of 311.55-315.87 no. under different level of boron (control, 1.5 kg B ha^{-1} and 2.5 kg B ha^{-1}) at harvest stage. Application of 2.5 kg B ha^{-1} resulted significantly higher number of siliquae $plant^{-1}$ as compared to control and 1.5 kg B ha^{-1}. The interaction effect due to sulphur (control, 15 kg ha^{-1}, 25 kg ha^{-1} and 35 kg ha^{-1}) and boron (control, 1.5 kg B ha^{-1} and 2.5 kg B ha^{-1}) on number of siliquae $plant^{-1}$ was found statistically significant. Additionally, the results of the current analysis are in agreement with those of Ray et al. [28], Dhruw et al. [29], and Masum et al. [30].

3.2.2 Number of seed $siliqua^{-1}$

It is inferred from Table 3 that the number of seeds per siliqua was significantly influenced by

different treatments. Number of seeds per siliqua mustard noted in the range of 10.00 to 11.26 under different level of sulphur (control, 15 kg ha^{-1}, 25 kg ha^{-1} and 35 kg ha^{-1}). The increasing level of sulphur up to 35 kg ha^{-1} increased the number of seeds per siliqua mustard significantly. Number of seeds per siliqua mustard observed in the range of 10.45 to 10.90 under different level of boron (control, 1.5 kg B ha^{-1} and 2.5 kg B ha^{-1}) at harvest stage. The interaction effect due to sulphur (control, 15 kg ha^{-1}, 25 kg ha^{-1} and 35 kg ha^{-1}) and boron (control, 1.5 kg B ha^{-1} and 2.5 kg B ha^{-1}) on number of seeds per siliqua mustard was found statistically non-significant at harvest stage. Similar findings was also reported by Yadav et al. [31], Ray et al. [28] and Rana et al. [32]

3.2.3 1000 Seed weight (gm)

It is evident from Table 3 that significant increase was noted in 1000 seed weight under different levels of sulphur as compared to the control. It is observed in the range of 7.30-8.13 g under different treatments of sulphur (control, 15 kg ha^{-1}, 25 kg ha^{-1} and 35 kg ha^{-1}). Maximum test weight (8.13 g ha^{-1}) was observed with the application of 35 kg S ha^{-1} (S_1) which was significantly higher to 0, 15 and 25 kg S ha^{-1}. Test weight of seeds observed in the range of 7.55 to 7.85 g under different level of boron at harvest stage. Application of 2.5 kg B ha^{-1} resulted significantly highest weight of mustard seeds as compared to control but statistically at par with one spray treatments. Test weight of seeds observed in the range of 4.08 to 4.21 g ha^{-1} under different level of boron at harvest stage. The interaction effect due to sulphur (control, 15 kg ha^{-1}, 25 kg ha^{-1} and 35 kg ha^{-1}) and boron (control, 1.5 kg B ha^{-1} and 2.5 kg B ha^{-1}) on test weight of mustard seeds was found statistically significant. Comparative findings were detailed by Singh et al. [33], Awal et al. [34] and Rana et al. [32].

3.3 Productivity Parameters

3.3.1 Seed yield (kg ha^{-1})

It is clear from Table 4 Mustard Seed yield varied from 9.90 to 11.30 q ha^{-1} under different levels of sulphur (control, 15 kg ha^{-1}, 25 kg ha^{-1} and 35 kg ha^{-1}). Increasing level of sulphur increase the mustard seed yield significantly up to 35 kg ha^{-1}. Maximum yield (11.30 q ha^{-1}) was observed with the application of 35 kg S ha^{-1} (S_2). Mustard Seed yield observed in the range of 10.42 to 10.74 q ha^{-1} under different level of boron Control, 1 spray 2 ppm and 2 spray 2 ppm. Maximum yield (10.74 q ha^{-1}) was observed with 2.5 kg B ha^{-1}. The interaction effect due to sulphur (control, 15 kg ha^{-1}, 25 kg ha^{-1} and 35 kg ha^{-1}) and boron (control, 1.5 kg B ha^{-1} and 2.5 kg B ha^{-1}) on mustard seed yield was found statistically significant. The consequences of the current investigation are additionally in concurrence with the investigation of Singh et al. [33], Sahoo et al. [35], Singh et al. [36] and Sinha et al. [37]

Table 2. Effect of different level of sulphur and boron on growth parameters of mustard at different growth intervals

Treatments	Plant height (cm)			No. of leaves plant^{-1}			No. of branches		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
S_1: 0 kg ha^{-1}	14.70	110.26	179.60	4.96	16.96	32.20	1.93	8.46	11.06
S_2: 15 kg ha^{-1}	16.60	115.36	186.50	5.46	17.80	33.80	2.31	9.20	11.46
S_3: 25 kg ha^{-1}	18.36	117.83	192.30	5.93	18.46	35.73	2.56	9.90	11.86
S_4: 35 kg ha^{-1}	19.23	119.16	195.76	6.10	19.13	37.00	2.76	10.63	12.30
S.E. (m)±	0.14	1.12	1.59	0.04	0.13	0.28	0.09	0.08	0.10
C.D. (5%)	0.43	3.32	4.71	0.13	0.39	0.83	0.28	0.25	0.30
B_0: 0 kg ha^{-1}	16.50	114.15	186.05	5.47	17.67	34.05	2.25	9.20	11.42
B_1 : 1.5 kg ha^{-1}	17.32	115.85	188.75	5.62	18.15	34.60	2.40	9.52	11.70
B_2 : 2.5 kg ha^{-1}	17.85	116.97	190.82	5.75	18.45	35.40	2.52	9.92	11.90
S.E. (m) ±	0.12	0.97	1.38	0.04	0.11	0.24	0.08	0.07	0.08
C.D. (5%)	0.37	2.92	4.13	0.11	0.34	0.72	0.25	0.22	0.26
S X B (Interactions)	NS	S	S	S	S	S	S	S	S

Table 3. Effect of different level of sulphur and boron on yield components of mustard

Treatments	Yield attribute character's		
	No. of siliquae plant^{-1}	**No. of seeds siliqua^{-1}**	**1000 seed weight (g)**
S_1: 0 kg ha^{-1}	304.43	10.00	7.30
S_2: 15 kg ha^{-1}	311.66	10.50	7.50
S_3: 25 kg ha^{-1}	318.00	10.93	7.86
S_4: 35 kg ha^{-1}	321.06	11.26	8.13
S.E. (m)±	2.61	0.10	0.06
C.D. (5%)	7.71	0.31	0.20
B_0: 0 kg ha^{-1}	311.55	10.45	7.55
B_1 : 1.5 kg ha^{-1}	313.95	10.67	7.70
B_2 : 2.5 kg ha^{-1}	315.87	10.90	7.85
S.E. (m) ±	2.26	0.09	0.05
C.D. (5%)	6.79	0.28	0.17
S X B (Interactions)	S	NS	S

Table 4. Effect of different level of sulphur and boron on productivity of mustard

Treatments	Yield (q ha^{-1})
S_1: 0 kg ha^{-1}	9.90
S_2: 15 kg ha^{-1}	10.43
S_3: 25 kg ha^{-1}	10.78
S_4: 35 kg ha^{-1}	11.30
S.E. (m)±	0.10
C.D. (5%)	0.31
B_0: 0 kg ha^{-1}	10.42
B_1 : 1.5 kg ha^{-1}	10.66
B_2 : 2.5 kg ha^{-1}	10.74
S.E. (m) ±	0.09
C.D. (5%)	0.28
S X B (Interactions)	S

4. CONCLUSION

The result showed that application of sulphur @ 35 kg ha^{-1} and 2.5 kg B ha^{-1} can increased growth characters of mustard as well as yield component and yield of mustard. Therefor it can be suggested that farmers of Bundelkhand zone can achieved higher yield of mustard with the application of sulphur @ 35 kg ha^{-1} and 2.5 kg B ha^{-1}along with recommended dose of fertilizers (N:P:K 80:40:40).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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