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

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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 field experiment was conducted during fall season of 2020–21 at Mahatma Gandhi Gramodaya Vishwavidyalaya Chitrakoot, Satna (M.P.) to evaluate the effect of sulphur and boron on growth parameters, yield attributes and yield of mustard (*Brassica juncea* L.) under rainfed condition of Chitrakoot area. The experimental soil is sandy loam in texture having medium status of available sulphur and available boron. The experiment consists of 9 treatments combinations in factorial randomized block design with three replications consisted of three levels of sulphur (0, 30 and 40 kg ha^{-1}), three boron levels (0, 2 ppm one spray and 2 ppm two spray). Mustard variety *Pusa Mahak* was grown with the recommended agronomic practices. On the basis of the results emanated from present investigation, it could be concluded that application of 40 kg S ha^{-1} + Two spray (2ppm boron) 40 DAS applied on mustard significantly increases growth parameter i.e. plant

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height, no. of leaves and no. of branches; yield attributes i.e. number of pods per plant, number of seeds per pod and 1000 seed weight (gm). Results showed that among the different fertility levels, application of 40 kg S ha^{-1} + Two spray (2ppm boron) 40 DAS significantly enhanced productivity parameter i.e. seed yield (kg ha^{-1}) and stalk yield over the control.

Keywords: Boron; mustard; sulphur; yield.

1. INTRODUCTION

Globally, India is the fourth largest oilseed crops producing country after the United States, China and Brazil. However, it secures first position in sesame, 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^{-1} productivity (Department of Agriculture Cooperation and Farmers Welfare, 2020).

"Rapeseed-mustard is second most important edible oilseed crop in our country after soybean, among all the nine oilseed crops" [2]. "India occupies the third position in area and production of rapeseed-mustard after Canada and China" [3]. Globally, the area and production of rapeseed-mustard is 36.81 million ha and 72.61 million ton, respectively [3]. India is having 6.23 million ha area under rapeseed-mustard and 9.34 million tonnes production with average productivity of 1499 kg ha^{-1}, which is about three forth of the world's average productivity (1960 kg ha^{-1}) [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^{-1}) of rapeseed-mustard. Uttar Pradesh secured third position in country in respect of both acreage (0.75 million ha) and production (1.12 million ton) of rapeseed-mustard with 1483 kg ha^{-1} productivity [2]. Bundelkhand region covers 121.58 thousand ha area under rapeseed-mustard crop with the production of 92.80 thousand ton. The average productivity of rapeseed-mustard crop in Bundelkhand region is very low (763 kg ha^{-1}) 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 of UP Bundelkhand region (Banda, Chitrakoot, Hamirpur, Jalaun, Jhansi, Lalitpur and Mahoba district) are flat, swallow in nature, alluvial, sandy texture with mixture of black and red soil with low to very low in available N and P, medium to high in available K, low to medium in available S, and medium in available Zn. However, in MP Bundelkhand region (Datia, Tikamgarh, Newari, Sagar, Damoh, Panna and Chattarpur), undulating land with deep to very deep heavy texture with low fertility status mainly 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]. Low fertility status in this region is mainly due to poor attention of farmers towards soil degradation beside indiscriminate use of fertilizers comprises mainly of primary nutrients N, P and K, which leads to multi-nutrient deficiency in Bundelkhand region *viz.* S, Zn and B. Thus, balanced and adequate amount of macronutrient and micro-nutrients is the need of hour to improve soil fertility and crop productivity.

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]. It is also an essential component for chlorophyll formation, activation of various enzymes and sulfhydryl (SH-) linkages, protein and oil synthesis [8]. Sulphur is also a constituent of glucosinolate and glycosidase enzyme, which are responsible for pungency in mustard oil [9]. 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) [10]. Sulphur application enhances mustard yield both under irrigated and rainfed conditions by 12–48% and 17–24%, respectively [11].

Boron is the second most essential micronutrient in mustard after Zn [12]. It plays an important role in the cell division, differentiation, and elongation of meristemic region [13]. 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 [14]. 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% [15].

The objective of this present study is to examine the effect of sulphur and boron in relation to growth characteristics, yield components and yield of mustard.

2. MATERIALS AND METHODS

2.1 Study Place and Weather Condition

The experiment was conducted at the Research farm of at Agriculture farm of Mahatma Gandhi Gramodaya Vishwavidyalaya Chitrakoot, Satna (M.P.) during October, 2020 to March 2021 to examine effect of sulphur and boron on mustard (*Brassica juncea* L.). It is located on $24^{0}31'$ N latitude, $81^{0}15'$ E longitude and at an altitude of 306 meters above mean sea level. Experimental site area is situated in Bundelkhand Zone of northern Madhya Pradesh and have typically sub-tropical and semi-arid with monsoon commencing by the third week of June and with drawing by end of September. Total rainfall received during the crop growing period was 264 mm.

2.2 Experimental Soil

The experimental field is sandy loam in texture, neutral in reaction (pH 7.78), low in organic carbon (0.33%), available N (222.36 kg ha^{-1}), medium in available P (11.36 kg ha^{-1}), high in available K (342.22 kg ha^{-1}) and medium in available S (10.88 kg ha^{-1}).

2.3 Study Design

The experiment was laid 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 nitrogen, phosphorus, potassium and sulphur were applied to all the plots. Recommended dose of nitrogen, phosphorus and potassium were applied through Urea, DAP and MOP (60:20:20 kg ha^{-1}) whereas sulphur was applied through wet table powder (15, 30 kg S ha^{-1}).

2.4.1 Observation recorded

Height of the plant (cm): The height of the plant was measured by metre scale from ground level to tip of the plants.

Number of branches per plant: The number of branches per plant of the selected five tagged plants from each plot was counted and their average was calculated.

2.5 Yield Attributing Characteristics

Number of pods per plant: The pods were picked from all the five tagged plants of each plot. After counting the pods of each plant, their average was recorded.

Number of seeds per pods: Ten pods were taken from five tagged plants. Pods were shallow carefully by hand. Seeds were separated from stover and then they were counted and an average was worked out.

1000 seeds weight (g): Seed samples from each treatment of every plot were taken. Later on counting of 1000 seeds was carried out for each treatment separately and was weighed on an electric balance. The weight was recorded in gram.

Seed yield (kg ha^{-1}): From the recorded data of seed yield per plot, seed yields were computed per hectare on multiplying the yield per plot by conversion factor.

Table 1. Treatment details

Levels of sulphur			Levels of boron		
S_0	-	Control	B_0	-	Control
S_1	-	30 kg ha^{-1}	B_1	-	One spray (2 ppm) 30 days after sowing
S_2	-	40 kg ha^{-1}	B_2	-	Two spray (2 ppm) 40 days after sowing

Stover yield (kg ha^{-1}): From the recorded data of straw yield per plot, straw yields were computed per hectare on multiplying the yield per plot by conversion factor.

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. The significant differences between the means were tested against the critical difference at 5% probability level" Chandel [16].

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 40 kg ha^{-1} increased the plant height significantly at of 30 DAS 20.35 cm to 23.58 cm, 60 DAS 74.08 to 85.13 and 90 DAS 81.55 cm to 93.20 cm. In the similar way due to the increasing levels of boron application plant height was recorded in the range of 30 DAS 20.35 cm to 23.58 cm, 60 DAS 74.08 cm to 85.13 cm and 90 DAS 81.55 cm to 93.20 cm under different level of boron Control, 1 spray 2 ppm and 2 spray 2 ppm at 30, 60, 90 DAS, respectively. The interaction effect due to sulphur control, 30 kg ha^{-1} and 40 kg ha^{-1} and boron control,1 spray 2 ppm and 2 spray 2 ppm on plant height was found statistically non-significant at all the observation stages. The conclusions of this analysis concur]with those made by Öztürk [17], Solanki et al. [18] and Negi et al. [19].

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 from30 DAS 8.36 cm to 9.84, and 60 DAS 15.08 to 18.84 cm under different level of sulphur Control, 30 kg ha^{-1} and 40 kg ha^{-1} at 30and 60 DAS, respectively. Number of leaves plant^{-1} ranged from 8.42 to 10.11 cm, and 15.62 to 18.53 cm under different level of boron (Control, 2 ppm one spray, 2 ppm 2 spray) at 30 and 60 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 insignificant. The consequences of the current investigation are additionally in concurrence with the investigation of Jamal et al. [20], Rajput et al. [21] and Singh et al. [22].

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	30 DAS	60 DAS	90 DAS	Harvest
S_0: 0 kg ha^{-1}	22.40	75.40	83.04	8.36	15.08	1.97	9.36	13.07	13.27
S_1: 30 kg ha^{-1}	21.80	78.22	86.02	9.48	17.81	2.24	10.81	14.88	15.61
S_2: 40 kg ha^{-1}	22.47	88.17	94.73	9.84	18.84	2.34	12.93	16.52	17.34
S.E. (m)±	1.01	2.48	2.96	0.35	0.71	0.03	0.12	0.07	0.12
C.D. (5%)	NS	7.51	8.95	1.07	2.15	0.09	0.39	0.21	0.38
B_0: Control	20.35	74.08	81.55	8.42	15.62	2.04	10.70	14.55	14.42
B_1 : 1 Spray (2ppm)	22.74	82.57	89.04	9.16	17.58	2.19	10.90	14.83	15.61
B_2 : 2 Spray (2ppm)	23.58	85.13	93.20	10.11	18.53	2.33	11.51	15.09	16.18
S.E. (m) ±	1.01	2.48	2.96	0.35	0.71	0.03	0.12	0.07	0.12
C.D. (5%)	NS	7.51	8.95	1.07	2.15	0.09	0.39	0.21	0.38
S X B (Interactions)	NS	NS	NS	NS	NS	0.16	0.67	NS	0.66

3.1.3 No. of branches plant^{-1}

It is visualized from the data given in Table 2 that number of branches plant^{-1} observed in the range of 1.97 to 2.34 cm, 9.36 to 12.93 cm, 13.07 to 16.52 cm and 13.27 to 17.34 cm under different level of sulphur control, 30 kg ha^{-1} and 40 kg ha^{-1} at 30, 60, 90 DAS and harvest stage, respectively. Number of branches plant^{-1} ranged from 2.04 to 2.33 cm under different level of boron control, 1 spray 2 ppm and 2 sprays 2 ppm at different observation stage of present study. The interaction effect due to sulphur control, 30 kg ha^{-1} and 40 kg ha^{-1} and boron control, one spray 2 ppm and 2 spray 2 ppm on number of branches plant^{-1} was found statistically non-significant at all the observation stages except harvest stage. Comparative findings were detailed by Singh et al*.* [23], Upadhyay et al*.* [24] and Rajput et al*.* [21].

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 silique plant^{-1} mustard observed in the range of 114.87 to 159.96 under different level of sulphur control, 30 kg ha^{-1} and 40 kg ha^{-1} at harvest stage. Maximum number of siliqua plant^{-1} was observed with application of 40 kg S ha^{-1} (S_2) which was significantly higher to 0 and 30 kg S ha^{-1} but statistically at par with 40 kg S ha^{-1}. Number of siliqua plant^{-1} mustard observed in the range of 129.38 to 140.90 no. under different level of boron control, 1 spray 2 ppm and 2 spray 2 ppm at harvest stage. Application of two spray of boron (2ppm each) resulted significantly higher number of siliqua plant^{-1} as compared to control and one spray 2 ppm treatments. The interaction effect due to sulphur control, 30, 40 kg ha^{-1} and boron Control, 1 spray 2 ppm 135.32 and 2 spray 2 ppm 140.90 on number of siliqua plant^{-1} was found statistically significant. Additionally, the results of the current analysis are in agreement with those of Ray et al*.* [15], Dhruw et al*.* [26] and Masum et al*.* [27].

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 are presented in Table 4. Number of seeds per siliqua mustard noted in the range of 10.56 to 12.30 under different level of sulphur control, 30 kg ha^{-1} and 40 kg ha^{-1}. The increasing level of sulphur up to 40 kg ha^{-1} increased the number of seeds per siliqua mustard significantly. Number of seeds per siliqua mustard observed in the range of 10.94 to12.05 under different level of boron control, 1 spray 2 ppm 11.64 and 2 spray 2 ppm 12.05 at harvest stage. The interaction effect due to sulphur control, 30 kg ha^{-1}, 40 kg ha^{-1} and boron control, 1 spray 2 ppm 11.94 and 2 spray 2 ppm 12.05 on number of seeds per siliqua mustard was found statistically non-significant at harvest stage. Similar findings was also reported by Yadav et al*.* [28], Ray et al*.* [25] and Rana et al*.* [29] 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 3.91-4.40 g ha^{-1} under different treatments of sulphur control, 30 kg ha^{-1}, 40 kg ha^{-1}. Maximum test weight (4.44 g ha^{-1}) was observed with the application of 30 kg S ha^{-1} (S_1) which was significantly higher to 0, 30 and 40 kg S ha^{-1}. 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. Application of

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_0: 0 kg ha^{-1}	114.87	10.56	3.91
S_1: 30 kg ha^{-1}	130.76	11.77	4.44
S_2: 40 kg ha^{-1}	159.96	12.30	4.40
S.E. (m)±	0.47	0.08	0.11
C.D. (5%)	1.44	0.25	0.35
B_0: Control	129.38	10.94	4.08
B_1 : 1 Spray (2 ppm)	135.32	11.64	4.45
B_2 : 2 Spray (2 ppm)	140.90	12.05	4.21
S.E. (m) ±	0.47	0.08	0.11
C.D. (5%)	1.44	0.25	NS
S X B (Interactions)	S	NS	S

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

Treatments	Yield (kg ha^{-1})	
	Seed Yield	**Stover Yield**
S_0: 0 kg ha^{-1}	1008.48	1258.81
S_1: 30 kg ha^{-1}	1154.00	1443.43
S_2: 40 kg ha^{-1}	1326.32	1551.17
S.E. (m)±	10.09	4.04
C.D. (5%)	30.51	12.22
B_0: Control	1129.47	1387.20
B_1 : 1 Spray (2 ppm)	1157.84	1434.62
B_2 : 2 Spray (2 ppm)	1201.48	1431.59
S.E. (m) ±	10.09	4.04
C.D. (5%)	30.51	12.22
S X B (Interactions)	52.85	7.00

two spray of boron (1 ppm each) 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, 30 kg ha^{-1}, 40 kg ha^{-1} and boron control, 1 spray 2 ppm and 2 spray 2 ppm on test weight of mustard seeds was found statistically significant. Comparative findings were detailed by Singh et al*.* [30], Awal et al*.* [31] and Rana et al*.* [29].

3.3 Productivity Parameters

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

It is clear from Table 4 Mustard Seed yield varied from 1008.48 -1326.32 kg ha^{-1} under different levels of sulphur control, 30 kg ha^{-1}, 40 kg ha^{-1}. Increasing level of sulphur increase the mustard seed yield significantly up to 40 kg ha^{-1}. Maximum yield (1326.32 kg ha^{-1}) was observed with the application of 40 kg S ha^{-1} (S_2). Mustard seed yield observed in the range of 1129.47 to 1201.48 kg ha^{-1} under different level of boron control, 1 spray 2 ppm and 2 spray 2 ppm. Maximum yield (1201.48 kg ha^{-1}) was observed with two sprays of boron which was 26.22, and 9.33 percent significantly higher over to control and one spray 2 ppm of boron treatments, respectively. The interaction effect due to sulphur control, 30 kg ha^{-1}, 40 kg ha^{-1} and boron control, 1 spray 2 ppm and 2 spray 2 ppm 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. [32], Sahoo et al*.* [33] and Singh et al*.* [34] and Sachan et al*.* [35].

3.3.2 Stover yield (kg ha^{-1})

Table 4, indicated that there was a significant response in mustard stover yield due to different levels of sulphur control, 30 kg ha^{-1}, 40 kg ha^{-1} and boron control, 1 spray 2 ppm and 2 spray 2 ppm and boron as compared to respective control. Increasing level of sulphur increases the mustard stover yield significantly up to 40 kg ha^{-1}. Stover yield varied from 1258.81 to 1551.17 kg ha^{-1} under different levels of sulphur control, 30 kg ha^{-1}, 40 kg ha^{-1} and Maximum mustard yield (1551.17 kg ha^{-1}) was observed with the application of 40 kg S ha^{-1} (S_2) which was significantly higher to 0 and 30 kg S ha^{-1} but statistically at par with 40 kg S ha^{-1} treatments, respectively. Stover yield mustard observed in the range of 1387.20 to 1431.59 kg ha^{-1} under different level of boron control, 1 spray 2 ppm and 2 spray 2 ppm. Maximum yield (1563.53 kg ha^{-1}) was observed with two sprays of boron 2 ppm which was significantly higher over to control but statistically at par with one spray 2 ppm of boron, respectively. The interaction effect due to sulphur control, 30 kg ha^{-1}, 40 kg ha^{-1} and boron control, 1 spray 2 ppm and 2 spray 2 ppm on mustard Stover yield was found statistically non-significant. The results of the present investigation are also in agreement with the findings of Nath et al*.* [36], Yadav et al*.* [14] and Singh et al*.* [22].

4. CONCLUSION

Based on the findings of the current investigation, it can be said that application of sulphur @ 40 kg ha^{-1} and two spray of boron (2 ppm) 40 DAS 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 @ 40 kg ha-1 and two spray of boron (2 ppm) 40 DAS along with recommended dose of fertilizers (N:P:K 60:20:20).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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