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Effect of Agronomic Biofortification of Sulphur and Boron on the Growth and Yield of Mustard (*Brassica campestris* L.) Crop

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Authors' contributions

This work was carried out in collaboration among all authors. Author MAA managed the literature searches and wrote the first draft of the manuscript. Author MHOR conducted field study and performed the statistical analysis. Author MMR wrote the protocol. All authors read and approved the final manuscript.

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ABSTRACT

Background and Objective: Sulphur and boron are found as most critical nutrient elements for the better growth and yield of mustard crop however no such concrete information for their uses in field production of this crop is yet to be reported. Therefore, an experiment was conducted to investigate the effect of agronomic biofortification of sulphur and boron nutrients on the growth and yield of mustard crop.
Study Design: The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replicates.
Place of Study: The experiment was carried out in the Crop Botany Field Laboratory, Bangladesh Agricultural University, Mymensingh.
Methodology: Three doses of sulphur (S) viz. 0, 20 and 40 kg ha^{-1} and three doses of boron (B) viz. 0, 0.5 and 1.0 kg ha^{-1} and their possible combinations were used as basal doses. Field data were collected from periodic destructive samplings on the plant height, number of leaves and branches per plant, total dry matter accumulation and finally yield components and yield.
Results: Sulphur and boron fertilizations significantly influence the plant height, production of branches and leaves per plant, dry matter accumulation and yield attributes and yield of mustard

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crop. The mustard crop fertilized with 40 kg S ha^{-1} in combination with 1 B kg ha^{-1} produced taller plant, higher number of branches and leaves in each plant and higher amount of dry matter per plant while these plant traits were found as minimum when the growing the mustard crops in control plots i.e. the plants received neither sulphur nor boron. Application of sulphur @ 40 kg ha^{-1} along with boron @ 1 kg ha^{-1} produced the highest seed yield (2.73 t ha^{-1}) whereas the lowest seed yield (1.08 t ha^{-1}) was found where no sulphur and boron were applied.

Conclusion: The result conclude that combine application of sulphur and boron @ 40 and 1 kg per hectare, respectively was found to be most effective dose in enhancing growth and yield of mustard crop.

Keywords: Boron; branch; dry matter accumulation; leaves; mustard; plant height; sulphur; seed yield.

1. INTRODUCTION

Mustard (*Brassica* spp.) is a highly responsive crop to fertilizer applications, particularly to sulphur and boron nutrients. Sulphur and boron fertilizations have been reported to increase the seed yield and oil content of mustard crop [1-2]. These are absolutely essential nutrient elements in order to obtain higher yield from improved i.e. high yielding varieties of mustard [3].

Suphur is now recognized as the fourth major plant nutrient along with nitrogen, phosphorus and potassium. Sulphur is immobile, thus cannot move from older leaves to the younger ones in plant. This results in yellowing of the newer leaves towards the tops of the plants when the availability of sulphur in soil is critical. It is involved in protein formation of three sulphur bearing amino acids like cysteine, cystine and methionine. Sulphur is necessary for the synthesis of chlorophyll in plants. Among the nutrient elements used for mustard cultivation, sulphur plays a key role in augmenting the production of oil seed. In general, about 97 percent soils of Bangladesh with deficit in sulphur and this deficit is becoming acute day by day due to intensive cultivation of land for crop production purposes but using sulphur-free fertilizers [4]. In an intensive cropping system, about 30-70 kg sulphur is annually removed from a hectare of land due to the consumption of sulphur nutrient by the growing crops. Therefore, when oil seed crops are included in the crop rotation, the consumption of sulphur from soil increases. The total removal of sulphur from the soil by the different crops is estimated as 64,349 tons and about 7.5 percent of total sulphur is removed by the oil seed crops. Rapeseed and mustard have been reported to remove as much as 17.27 kg sulphur per ton of grain production [5].

The deficiency symptoms of some boron sensitive crops like *Brassica* spp., legumes, beet, celery, grapes and fruit trees are chlorosis and browning of young leaves or growing tips, distortion of blossom development, lesions in pith roots, burning of the tips of leaves and restriction of root growth, and plants etc [6]. Boron plays a vital role in the physiological process of mustard, such as cell elongation, cell maturation, meristematic tissue development and protein synthesis [7]. The boron inclusion in fertilizer schedules can lead to either success or failure of the crops [8]. It is reported that the ranges between the deficiency level and toxicity level of boron fertilization on the yield of agricultural plants are quite narrow and that an application of boron can be extremely toxic to plants at concentration slightly above the optimum level [9]. Thus the judicial use of boron fertilizer is very important. However, information to that end for mustard cultivation is scanty in Bangladesh.

Agronomic biofortification not only increases the targeted minerals in the edible parts of harvested crops but also reported to enhance the growth and yield of crops grown. For example, Haider et al. [10] found better growth and yield of mungbean (*Vigna radiata* (L.) Wilczek) with biorfotification of zinc as foliar spray. Rasheed et al. [11] found increased plant growth and grain production of lentil (*Lens culinaris* Medik) with biofortification of zinc as basal dose in the field. Ramzan et al. [12] found increased plant height, number of tillers, spike length, number of spikelets per spike, number of grains per spike, thousand grain weight, economical yield, biological yield and harvesting index of wheat (*Triticum aestivum* L.) crop with biofortification of iron and zinc as alone or in combination used either in soil and by foliar application. Agronomic biofortification as basal dose is the cheapest way as the targeted minerals can be fertilized in soil with other nutrient elements before seed sowing. Thus, it is very much urgent to test the responsiveness of mustard crop to sulphur and boron biofortification as basal dose for better plant growth leading to increased grain yield to meet the rising demand of edible oils for over increasing population of Bangladesh. Therefore, the present study was conducted to evaluate the effect of agronomic biofortification of sulphur and boron on the growth and yield of mustard crop. The findings would find the suitable doses of sulphur and boron elements for profitable production of mustard in Bangladesh.

2. MATERIALS AND METHODS

The experiment was conducted at the Field Laboratory of the Department of Crop Botany ($24^o72'$N latitude and $90^o42'$E longitude), Bangladesh Agricultural University, Mymensingh. The experimental land was first opened with a power tiller. Then the land was ploughed and cross-ploughed three times followed by laddering to obtain a good tilth. The corners of the land were spaded and larger clods were broken into smaller pieces. All stubbles and weeds were collected and removed from the field. The land was leveled and made ready for seed sowing. Different types of fertilizers @ 150, 40 and 60 kg ha^{-1} respectively for N, P and K were applied in the soil as basal doses. They were applied from the sources of urea, triple super phosphate (TSP) and muriate of potash (MP).

The mustard crop fertilized with sulphur @ 0, 20 and 40 kg ha^{-1} with no use of boron, and that of boron @ 0, 0.5 and 1.0 kg ha^{-1} with no use of sulphur and their combinations. Therefore, it was a 2-factor experiment with a total number of treatments was 9. The experiment was laid out following a Randomized Complete Block Design (RCBD) with three replicates. Gypsum ($CaSO_4.2H_2O$) and Borax (H_3BO_4) were used as the source of sulphur (S) and boron (B), respectively. These S and B fertilizers were mixed in soil of experimental plots with the basal dose fertilizers. All of those fertilizers except urea were mixed with soil during final land preparation as basal doses. Urea was applied in three equal splits, first split as with basal dose, second split at 28 days after sowing (DAS) and third split at 50 percent flowering. Mustard seeds cv. BINAsarisha-3 (*Brassica campestris* L.) were collected from the Bangladesh Institute of Nuclear Agriculture (BINA) and sown in line 20 cm apart with 5 cm interplant distance in a line. Intercultural operations like weeding and thinning, and pest control operations were performed as and when necessary to optimize the growth and development of the crop.

For collecting data, the plants were sampled and harvested with destructive sampling protocol at the rate of five plants per plot starting from 30 DAS with an interval of 15 days till maturity of crop at 85 DAS. The data were recorded on plant height, number of branches and leaves per plant, total dry matter accumulation etc. The dry weight was recorded after drying fresh plant samples in an electronic oven at 80 ± 2^oC until constant weight. At final harvest or physiological maturity, crops of 1 m^2 were harvested for recording data on yield components and yield. Harvest index was determined as seed yield over biological yield where biological yield means total dry matter (TDM) accumulation.

All the recorded data on different variables were statistically analyzed to obtain the level of significance using MSTAT-C Computer Package Programme developed by Russel [13]. The treatment means were compared by Duncan's Multiple Range Test, DMRT [14].

3. RESULTS AND DISCUSSION

3.1 Plant Stature

The effect of different doses of sulphur and boron on the plant height of mustard was significant. Taller plant of mustard was recorded when the crop treated with higher dose of sulphur like 40 kg ha^{-1} as compared to that with no use of sulphur (Table 1). Similar result was recorded for boron. That is taller statured plant was noticed when the crop treated with boron @1.0 kg ha^{-1} as compared to 0.5 kg ha^{-1}. Interaction effect of sulphur and boron on plant height was also found significant. Plant height was gradually increased with the use of higher doses of sulphur and boron. For example, taller plant was observed when the crop grown with sulphur @ 40 kg ha^{-1} and boron @ 1.0 kg ha^{-1} than that the plants grown with lower doses of sulphur and boron. Likewise, shortest plant was found in control plots receiving neither sulphur nor boron. Rashid [15] also observed the taller plant of mustard with higher doses of sulphur like 40 kg ha^{-1}. Similarly, Rahman [16] found taller mustard plant with the use of $B_{1.0}S_{40}$ as compared to their lower doses.

3.2 Number of Branches per Plant

Number of branches per mustard plant was significantly affected due to the use of different doses of sulphur and boron (Table 2). The higher number of branch production per plant was observed with the use of higher doses of sulphur and/or boron either for sole effect or their combined effect. For example, higher number of branches per plant (5.67) was found at final harvest or physiological maturity when the crop grown with sulphur @ 40 kg ha^{-1} and boron @ 1.0 kg ha^{-1} which was about 72 percent higher than the plants grown with no use of sulphur and no use of boron (with 3.30 branches per plant). Hu et al. [17] observed the higher number of branches per mustard plant with the application of boron fertilizer and Hemantarajan et al. [18] also found the similar result for the application of sulphur and boron in soybean crop.

Table 1. Effect of agronomic biofortification of sulphur and boron elements and their interaction effects on plant stature at different growth stages in mustard crop

Treatment	Plant height (cm) at different days after sowing (DAS)				
	30	**45**	**60**	**75**	**85***
Sulphur (S) doses without boron (B)					
$S_{20} \times B_0$	20.2 abc	53.7 ab	75.9 bc	83.8 cde	84.8 cde
$S_{40} \times B_0$	22.0 ab	54.7 ab	76.9 bc	86.5 bcd	88.4 bcd
Boron (B) doses without sulphur (S)					
$S_0 \times B_{0.5}$	19.4 bc	51.9 bc	72.6 cd	82.3 de	84.3 de
$S_0 \times B_{1.0}$	18.6 cd	52.8 ab	73.0 cd	83.8 cde	84.9 cde
S × B interaction					
$S_0 \times B_0$	16.5 d	47.8 c	68.9 d	79.0 e	80.3 e
$S_{20} \times B_{0.5}$	20.2 de	53.5 ab	77.0 bc	86.5 vcd	88.8 bcd
$S_{40} \times B_{0.5}$	24.4 abc	55.4 ab	81.1 ab	88.1 bc	89.5 bc
$S_{20} \times B_{1.0}$	21.7 ab	53.3 ab	77.1 bc	91.0 ab	92.9 ab
$S_{40} \times B_{1.0}$	22.4 a	56.8 a	84.7 a	93.7 a	95.1 a
$S_{\bar{x}}$	0.84	1.38	1.80	1.50	1.52
LSD	2.53	4.16	5.41	4.50	4.58

*In a column, figures having similar letter(s) do not differ significantly at P≤0.05; S_0= No sulphur applied; S_{20}= Sulphur applied @ 20 kg ha^{-1}; S_{40}= Sulphur applied @ 40 kg ha^{-1}; B_0= No Boron applied; $B_{0.5}$= Boron applied @ 0.5 kg ha^{-1}; $B_{1.0}$= Boron applied @ 1.0 kg ha^{-1}; * at final harvest on physiological maturity*

Table 2. Effect of agronomic biofortification of sulphur and boron elements and their interaction effects on branch production at different growth stages in mustard crop

Treatment	Number of branches $plant^{-1}$ at different days after sowing (DAS)				
	30	**45**	**60**	**75**	**85***
Sulphur (S) doses without boron (B)					
$S_{20} \times B_0$	1.80 bc	3.73 cd	4.26 b	4.53 c	4.55 bc
$S_{40} \times B_0$	2.13 a	5.06 a	5.46 a	5.66 a	6.00 a
Boron (B) doses without sulphur (S)					
$S_0 \times B_{0.5}$	1.53 c	3.46 d	3.60 c	3.80 d	4.06 cd
$S_0 \times B_{1.0}$	1.53 c	3.53 d	3.66 c	3.81 d	3.76 de
S × B interaction					
$S_0 \times B_0$	1.60 c	2.93 e	3.00 d	3.19 e	3.30 e
$S_{20} \times B_{0.5}$	2.06 ab	4.10 bc	4.26 b	4.40 c	4.53 bc
$S_{40} \times B_{0.5}$	2.00 ab	4.26 b	4.66 b	4.83 bc	4.89 b
$S_{20} \times B_{1.0}$	2.13 a	4.33 b	4.78 b	5.06 b	5.03 b
$S_{40} \times B_{1.0}$	2.14 a	5.18 a	5.33 a	5.53 a	5.67 a
$S_{\bar{x}}$	0.09	0.12	0.17	0.15	0.20
LSD	0.28	0.37	0.51	0.45	0.61

*In a column, figures having similar letter(s) do not differ significantly at P≤0.05; S_0= No sulphur applied; S_{20}= Sulphur applied @ 20 kg ha^{-1}; S_{40}= Sulphur applied @ 40 kg ha^{-1}; B_0= No Boron applied; $B_{0.5}$= Boron applied @ 0.5 kg ha^{-1}; $B_{1.0}$= Boron applied @ 1.0 kg ha^{-1}; * at final harvest on physiological maturity*

3.3 Number of Leaves per Plant

Number of leaves per mustard plant was increased with season. Maximum number of green leaves was sustained with plant within up to 60 or 75 DAS, and thereafter the leaves were gradually senescence and fallen from the plant. The number of green leaves per plant due to the use of different doses of sulphur and/or boron in sole or combined form was found significant (Table 3) as like for their effects on the plant height and number of branches per plant (Tables 1 and 2). The higher number of leaves per plant (13.2) was found at 60 DAS in the plant grown with 40 kg S ha^{-1} and boron @ 1.0 kg B ha^{-1} which was about 74 percent higher than that at no use of sulphur and no use of boron (with 7.60 leaves per plant). Prakash et al. [19] also observed the higher number of leaves per mustard plant when treated with 40 kg S ha^{-1}.

3.4 Total Dry Matter (TDM) Accumulation

After seedling emergence, there was a little dry matter accumulation per mustard plant. Thereafter, total dry matter accumulation was gradually increased and reached peak at the time of crop harvest at maturity (Table 4). The effect of sulphur and boron on the total dry matter accumulation was significant. The higher TDM production was found from the plants grown with 40 kg S ha^{-1} and 1.0 kg B ha^{-1} as compared to that with lower doses of sulphur and boron application and lower amount of dry matter was accumulated when the crop received neither sulphur nor boron. The result is supported by the findings of Awal et al. [20].

3.5 Yield and Yield Components

The yield components and seed yield of mustard as affected by different levels of sulphur and boron with their sole and combined effects were found significant and the data are shown in the Table 5. All the yield components and seed yield was recorded higher in the plants fertilized with 40 kg S ha^{-1} and/or 1.0 kg B ha^{-1} either in sole or combined form. Dutta et al. [21] and Islam and Sarker [22] observed that boron application increased the number of siliqua per plant and seed set in mustard. Subbaiah and Mitra [23] found higher 1000-seed weight due to boron application in mustard crop. Islam et al. [24] and Haque et al. [25] found positive effect for the use of boron and sulphur on mustard seed yield and seed formation. Mehrotra et al. [26] observed a 16-69 percent increase in mustard seed yield due to boron application. Overall, the seed yield of mustard in this study was found similar as those reported earlier [20,25-32]. The yield components and seed yield of mustard as affected by the application of different levels of sulphur and boron in this study are also supported by Rahman [16], Hossain et al. [33] and Biswas [34].

The higher harvest index was observed from mustard plants fertilized with 40 kg S ha^{-1} along with 0.5-1.0 kg B ha^{-1} whereas lower harvest index was obtained from the mustard crop when it was grown without application of any sulphur and boron (i.e. $S_0 \times B_0$). Similar result was also reported by Rashid [15] and Awal et al. [20].

Table 3. Effect of agronomic biofortification of sulphur and boron elements and their interaction effects on leaf production at different growth stages in mustard crop

Treatment	Number of green leaves $plant^{-1}$ at different days after sowing (DAS)				
	30	45	60	75	85*
Sulphur (S) doses without boron (B)					
$S_{20} \times B_0$	6.00 cd	9.13 c	10.6 d	9.46 d	4.46 a
$S_{40} \times B_0$	7.06 a	10.9 b	11.6 bc	10.8 bc	6.50 a
Boron (B) doses without sulphur (S)					
$S_0 \times B_{0.5}$	6.17 cd	8.06 de	9.57 e	6.53 e	5.93 b
$S_0 \times B_{1.0}$	5.73 d	8.27 cd	8.43 f	6.76 e	3.30 de
S × B interaction					
$S_0 \times B_0$	4.86 e	7.10 e	7.60 g	5.66 f	2.93 e
$S_{20} \times B_{0.5}$	6.80 ab	9.03 cd	10.4 d	10.3 c	2.97 e
$S_{40} \times B_{0.5}$	7.06 a	10.4 b	11.9 b	9.53 d	3.87 c
$S_{20} \times B_{1.0}$	6.43 bc	10.8 b	11.3 c	11.9 a	3.77 cd
$S_{40} \times B_{1.0}$	7.27 a	12.4 a	13.2 a	11.5 ab	3.83 cd
$S\bar{x}$	0.14	0.32	0.17	0.24	0.17
LSD	0.44	0.33	0.51	0.24	0.52

*In a column, figures having similar letter(s) do not differ significantly at P≤0.05; S_0= No sulphur applied; S_{20}= Sulphur applied @ 20 kg ha^{-1}; S_{40}= Sulphur applied @ 40 kg ha^{-1}; B_0= No Boron applied; $B_{0.5}$= Boron applied @ 0.5 kg ha^{-1}; $B_{1.0}$= Boron applied @ 1.0 kg ha^{-1}; * at final harvest on physiological maturity*

Table 4. Effect of agronomic biofortification of sulphur and boron elements and their interaction effects on total dry matter (TDM) accumulation at different growth stages in mustard crop

Treatment	Total dry matter (TDM, g) plant^{-1} at different days after sowing (DAS)				
	30	45	60	75	85*
Sulphur (S) doses without boron (B)					
$S_{20} \times B_0$	1.17 abc	2.45 cd	4.50 bc	6.68 d	7.88 ef
$S_{40} \times B_0$	1.29 a	2.70 bc	5.10 ab	8.08 c	9.87 d
Boron (B) doses without sulphur (S)					
$S_0 \times B_{0.5}$	1.02 cd	2.13 d	3.60 de	5.85 e	7.22 f
$S_0 \times B_{1.0}$	1.06 bc	2.18 d	3.70 cd	6.40 d	8.05 e
S × B interaction					
$S_0 \times B_0$	0.83 d	1.65 e	2.80 e	4.49 f	5.05 g
$S_{20} \times B_{0.5}$	1.20 abc	2.85 b	5.20 ab	9.50 b	10.9 c
$S_{40} \times B_{0.5}$	1.25 ab	3.58 a	5.60 a	9.87 ab	11.8 b
$S_{20} \times B_{1.0}$	1.23 abc	3.00 b	5.45 a	9.91 ab	12.0 ab
$S_{40} \times B_{1.0}$	1.30 a	3.60 a	5.28 ab	10.3 a	12.6 a
$S\bar{x}$	0.06	0.11	0.27	0.16	0.22
LSD	0.19	0.35	0.81	0.48	0.66

*In a column, figures having similar letter(s) do not differ significantly at P≤0.05; S_0= No sulphur applied; S_{20}= Sulphur applied @ 20 kg ha^{-1}; S_{40}= Sulphur applied @ 40 kg ha^{-1}; B_0= No Boron applied; $B_{0.5}$= Boron applied @ 0.5 kg ha^{-1}; $B_{1.0}$= Boron applied @ 1.0 kg ha^{-1}; * at final harvest on physiological maturity*

Table 5. Effect of agronomic biofortification of sulphur and boron elements and their interaction effects on yield contributing characters and yield of mustard crop

Treatment	No. of effective siliqua plant^{-1}	No. of non-effective siliqua plant^{-1}	Siliqua length (cm)	No. of seed siliqua^{-1}	1000-seed weight (g)	Seed weight plant^{-1}	Seed yield (t ha^{-1})	Harvest index (%)
Sulphur (S) doses without boron (B)								
$S_{20} \times B_0$	45.6 e	19.8 d	6.44 a	21.2 bc	3.50 b	3.40 e	1.71 e	30.1 abc
$S_{40} \times B_0$	50.2 de	23.6 b	6.53 a	25.3 a	3.50 b	4.07 cd	2.18 d	29.2 bc
Boron (B) doses without sulphur (S)								
$S_0 \times B_{0.5}$	47.2 e	19.9 d	6.37 a	18.2 de	3.60 ab	3.63 de	1.83 e	33.5 ab
$S_0 \times B_{1.0}$	51.8 de	26.1 a	6.43 a	20.1 cd	3.67 ab	3.58 de	1.69 e	30.8 abc
S × B interaction								
$S_0 \times B_0$	36.5 f	18.3 ef	5.83 b	15.9 e	2.96 c	1.94 f	1.08 f	27.3 c
$S_{20} \times B_{0.5}$	57.1 cd	20.8 c	6.73 a	23.8 ab	3.70 ab	4.87 b	2.33 cd	31.0 abc
$S_{40} \times B_{0.5}$	68.0 ab	18.6 c	6.79 a	23.8 ab	3.93 a	6.13 a	2.63 ab	34.1 a
$S_{20} \times B_{1.0}$	62.8 bc	17.9 f	6.71 a	22.2 bc	3.77 ab	5.39 bc	2.46 bc	30.9 abc
$S_{40} \times B_{1.0}$	70.6 a	13.3 g	6.75 a	24.0 ab	3.86 ab	6.38 a	2.73 a	33.4 ab
$S\bar{x}$	2.48	0.19	0.14	0.96	0.11	0.17	0.07	1.38
LSD	7.43	0.57	0.44	2.88	0.33	0.51	0.21	4.16

In a column, figures having similar letter(s) do not differ significantly at P≤0.05; S_0= No sulphur applied; S_{20}= Sulphur applied @ 20 kg ha^{-1}; S_{40}= Sulphur applied @ 40 kg ha^{-1}; B_0= No Boron applied; $B_{0.5}$= Boron applied @ 0.5 kg ha^{-1}; $B_{1.0}$= Boron applied @ 1.0 kg ha^{-1}

4. CONCLUSION

It was concluded from the present study that agronomic biofortification of sulphur and boron nutrient elements as basal doses have profound effect on growth, yield attributes and yield of mustard crop. Combine application of sulphur and boron at the rate of 40 kg ha^{-1} and 1 kg ha^{-1}, respectively was found to be most effective dose in enhancing growth and yield of mustard crop.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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