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Research Article

Growth and Yield Response of Soybean to Sulphur and Boron Application

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ABSTRACT

Soybean is a prospective oilseed crop in Bangladesh. Yield of soybean is lower than other countries due to proper dose and unplanned nutrient management. An experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh to evaluate the influence of sulphur and boron on the growth and yield of soybean (cv. Binasoybean-1). The experiment comprised three levels of sulphur (S) viz. 0, 20, and 40 kg ha^{-1} and four levels of boron (B) viz. 0, 1.0 kg B ha^{-1} as basal application, 0.5 kg B ha^{-1} as basal application + 0.5 kg B ha^{-1} as foliar application at pre-flowering stage and 0.5 kg B ha^{-1} as foliar application at 30 days after sowing (DAS) + 0.5 kg B ha^{-1} as foliar application at pre-flowering stage. The experiment was laid out in a randomized complete block design with three replications. At 75 days after sowing, the tallest plant (43.93 cm), maximum branches $plant^{-1}$ (3.43), SPAD value (28.70), number of nodules (18.80) and dry weight of nodules $plant^{-1}$ (0.17 g) were recorded in 20 kg S ha^{-1} with boron 0.5 kg ha^{-1} as basal application + 0.5 kg ha^{-1} as foliar application at pre-flowering stage while nodule fresh weight $plant^{-1}$ (1.65 g), plant fresh weight (42.73 g) and plant dry weight (6.89 g) were recorded in 40 kg S ha^{-1} with boron 1.0 kg ha^{-1} as basal application. Sulphur 20 kg ha^{-1} produced the highest seed (1.33 t ha^{-1}) and stover (2.14 t ha^{-1}) yields while control treatment provided the lowest yields. The highest number of branches $plant^{-1}$ (3.20), pods $plant^{-1}$ (30.52), seeds pod^{-1} (3.44), seed (1.27 t ha^{-1}) and stover (2.15 t ha^{-1}) yields were obtained at 0.5 kg B ha^{-1} as basal + 0.5 kg B ha^{-1} as foliar application at pre-flowering stage while the lowest values were found in control treatment. In interaction, the highest seed (1.63 t ha^{-1}) and stover (3.15 t ha^{-1}) yields were obtained with 20 kg S ha^{-1} and 0.5 kg B ha^{-1} as basal + 0.5 kg B ha^{-1} as foliar application at pre-flowering stage while the worst yield performance was observed in control treatment. Therefore, application of sulphur @ 20 kg ha^{-1} along with 0.5 kg B ha^{-1} as basal + 0.5 kg B ha^{-1} as foliar application at pre-flowering stage could be applied for Binasoybean-1 for higher seed yield.

Introduction

Soybean (*Glycine max* L.), belongs to the family Leguminosae is one of the leading oil and protein-containing crops of the world. Soybean produced worldwide 333.67 million tons with an area of 120.30 million ha in 2019 (FAO, 2021). Brazil, USA, Argentina, China and India are the top five soybean producers in the world. In Bangladesh, out of the total cropped areas of 15.60 million ha, oil seed crops occupy about 0.44 million ha with the total production of 0.95 million tones. Out of the total oil cropped area, soybean occupies 0.051 million ha and produced 0.091 million tones (BBS, 2019). It has become the miracle crop of the twentieth century on account of getting excessive protein and oil content material and is regarded as "Golden Bean". Soybean is now parent out as "protein wish of the future" for its dietary price in Bangladesh. Recently it is widely used as fish meal (Phumee et al., 2011; Kader et al., 2012) and poultry feed (Serrano et al., 2013). Soybean seed is a crucial source of food having 40-45% protein, 20-22% oil, 20-26% carbohydrate and an excessive quantity of Ca, P and vitamins (Rahman et al., 2011; Vorobyev et al., 2019). Soybean is a good source of isoflavones and therefore it helps in preventing heart diseases and cancer (Kumar, 2007).

Fertilizer applications have to be balanced with the specified nutrients for attaining its potential yield. Unless soybean is supplied with the specified nutrient enter to provide enough biomass it would not yield high (Singh et al., 2006). Micronutrients are required in relatively smaller quantities for plant growth, they are

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as important as macronutrients for the plants and if any element is lacking in the soil or not adequately balanced, growth suppression or even complete inhibition may result (Mengel et al., 2001). Sulphur is involved in the synthesis of fatty acids and also increases protein quality through the synthesis of certain amino acids such as cysteine, cysteine and methionine (Havlin et al., 1999). Soybean plant's positive response to sulphur fertilization has been reported elsewhere (Morshed et al., 2009; Farhad et al., 2010; Pable and Patil, 2011). Boron also plays an important role in cell wall integrity, cell division, plasma membranes, phenol metabolism in plants and is considered to be an essential element for the nitrogen fixation and in the reproductive growth of plants (Ahmad et al., 2009). Boron deficiency is the second most widespread micronutrients problem globally (Alloway, 2008). Bellaloui et al. (2013) proven foliar B-fertilization of soybean accelerated B accumulation in leaves and seed and rehabilitated seed protein and fatty acid content. The interaction of S and B is quite expected in soil and plant systems as both of these are crucial elements for plant growth and metabolism. Soybean plants need sulphur to complete their life cycle because it’s a key component of amino acid and deficiency can affect soybean concentration and grain yield (Singh et al., 2014). Boron deficiency is accountable to flower drop and poor podding in soybean plants (Hajiboland et al., 2012). The above discussion indicates that sulphur and boron increase the growth, yield and quality of soybean. Still a lack of available information on the basal application of sulphur, and basal along with foliar application of boron on soybean under Bangladesh condition. Considering the above issues, the study has been undertaken to investigate the effect of sulphur and boron on growth and seed yield with related traits of soybean.

Materials and Methods

Experimental duration and site

The experiment was conducted during November 2019 to April 2020 at the Agronomy Field Laboratory of Bangladesh Agricultural University (24° 75' N latitude and 90° 50' E longitude and at an altitude of 18 meter above the sea level), Mymensingh, Bangladesh. The experimental area belongs to the non-calcareous dark grey soil under the Agro-ecological Zone of the Old Brahmaputra Floodplain (AEZ-9) (UNDP and FAO, 1988). The land was medium high with a silty-loam texture. The soil of the experimental field was more or less neutral in reaction having pH 6.9, EC (electrical conductivity) 0.4 ds/m, organic carbon 1.00%, N 0.09%, P 1.60 ppm, K 0.10% meq/100g soil, Ca 8.30 meq/100 g soil, Mg 3.29 meq/100 g soil, S 2.98 ppm, Zn 0.21 ppm and B 0.23 ppm (Bithy et al., 2020).

Experimental Treatments and Design

The experiment comprised three levels of sulphur viz. 0 (S_0), 20 (S_1), and 40 (S_2) kg ha^{-1} and four levels of boron viz. 0 kg B ha^{-1} (B_0), 1.0 kg B ha^{-1} as basal application (B_1), 0.5 kg B ha^{-1} as basal application + 0.5 kg B ha^{-1} as foliar application at pre-flowering stage (B_2) and 0.5 kg B ha^{-1} as foliar application at 30 days after sowing (DAS) + 0.5 kg B ha^{-1} as foliar application at pre-flowering stage (B_3). The experiment was laid out in a randomized complete block design with three replications. Thus the total number of plots was 36. Each plot size was 2.5 × 2.0 m.

Crop Husbandry

The experimental field was prepared by ploughing and cross ploughing followed by laddering by a power tiller. Then plots were laid out in the field and fertilized with N-P-K @ 28-37-60 kg ha^{-1} as urea, triple super phosphate (TSP) and muriate of potash (MoP), respectively (BARI, 2019). One third urea and full dose of TSP and MoP were applied at the time of final land preparation. The remaining urea was top dressed in two equal installments at 25 days after sowing (DAS) and 40 DAS, respectively. Sulphur and boron were applied as gypsum and boric acid, respectively as per treatment specification. The seeds of soybean (cv. Binasoybean-1) were sown, on 25 November 2019 in 2-3 cm deep furrows made by hand rake keeping with 30 cm × 10 cm spacing where row to row distance was 30 cm and plant to plant distance was 10 cm. The first weeding and thinning were done manually at 20 DAS while the second and third weeding were done at 45 and 65 DAS, respectively. Three irrigations were given at 25 DAS, 55 DAS (maximum flowering stage) and 75 DAS (seed formation stage). The crop was infested with aphids (*Lipaphis erysimi*) at the time of pod filling and was controlled successfully by spraying Malathion 50 EC @ 2 ml L^{-1} water thrice. The crop was kept under constant observations from sowing to harvesting. The crop was harvested on 7th April 2020 when maximum pods were matured and turned to brown in color.

Data collection

At 75 DAS, five plants were randomly selected excluding border rows to record the data on plant height, number of branches plant^{-1}, chlorophyll content (SPAD value), number of nodules plant^{-1}, nodules dry weight plant^{-1}, shoot fresh weight plant^{-1}, and shoot dry weight plant^{-1}. Chlorophyll content of five fully expanded young leaves from each five plants was measured by using a portable SPAD meter (model SPAD-502, Minolta crop, Ramsey, NJ). To determine the dry matter production plant^{-1}, two plants were randomly uprooted from each plot excluding border rows and central 1.5 m × 1.5 m. Number of nodules plant^{-1} was counted and removed and then shoot dry weight and nodules dry weight plant^{-1} were taken by using an electric balance after proper drying in an oven at 70°C until constant weight was reached.

Prior to harvest five plants from each plot were collected at random excluding border plants and central 1.5 m × 1.5 m and tagged for the data collection. Data on crop characters and yield components were collected from these samples. Central 1.5 m × 1.5 m was harvested and dried properly. After threshing and cleaning, the yields of seed and straw were recorded and converted to t ha^{-1}.

Data Analysis

The recorded data were compiled and tabulated in proper form for statistical analysis. Analysis of variance was done following the RCBD with the help of computer package MSTAT (Power, 1985). The mean differences were judged by Duncan's Multiple Range Test (Gomez and Gomez, 1984).

Results and Discussion

Growth characters at 75 DAS

Growth characters were significantly influenced by various levels of sulphur (Table 1). The tallest plant (38.63 cm) was recorded in 20 kg S ha^{-1} while the maximum number of branches plant^{-1} (2.69) was recorded in 40 kg S ha^{-1} which was at par with 20 kg S ha^{-1} and lowest values of plant height and number of branches plant^{-1} were found in control. The increase in plant height and branches plant^{-1} may be due to the advantageous effects of sulphur on N-metabolism and consequently on the vegetative growth of soybean plant. This observation was in close conformity with the observations of Farhad et al. (2010) and Akter et al. (2013) who noticed that sulphur significantly influence on plant height and branching of soybean plant. Likewise the application of sulphur 20 kg ha^{-1} gave the highest SPAD value (26.38), number of nodules plant^{-1} (15.70), dry weight of nodules (0.117 g), fresh weight of plants (39.17 g) and dry weight of plants (4.80 g) while the highest fresh weight of nodules plant^{-1}was found in 40 kg S ha^{-1} whereas all parameters shows the lowest values in control (Table 1). Significant influences of sulphur on vegetative characters of soybean were also reported elsewhere (Parry et al., 2016; Longkumer et al., 2017; Minz et al., 2017; Sharma and Sharma, 2018). Singh et al. (2014) and Minz et al. (2017) also documented that without sulphur fertilization the reduced vegetative growth of soybean.

Various levels of boron application significantly influenced the vegetative characters (Table 1). The tallest plant (36.56 cm) was recorded in B_2 which was at par with B_1 while the shortest plant was found in control. The highest number of branches plant^{-1}(2.78), SPAD value (27.12) and dry weight of nodules (0.10 g) were recorded in B_2. The increase in plant height and number of primary branches plant^{-1} may be due to favorable effects of boron on hormonal balance that helped proper growth and development of the soybean plant. Similar results were reported elsewhere (Schon and Blevins 1990; Kappes et al., 2008). The highest number of nodules plant^{-1} (13.89) which was found in B_1 which was at par with control and the lowest one was recorded in B_3 while highest fresh weight (37.39 g) and highest dry weight (4.65 g) of plants were recorded in B_1, and the lowest values were found in control. Application of boron significantly influence the vegetative characters of soybean were reported by Kappes et al. (2008), Chaturvedi et al. (2012) and Bellaloui et al. (2013). The poor growth of soybean from the control (0 kg B ha^{-1}) treatment was also found by Chaturvedi et al. (2012) and Bellaloui et al. (2013).

All the studied vegetative parameters were significantly influenced by the interaction effect between sulphur and boron fertilizations (Table 2). The tallest plant (43.93 cm) was recorded in $S_1 \times B_2$ which was at par with $S_1 \times B_3$. Maximum branches plant^{-1} (3.43), SPAD value (28.70), number of nodules plant^{-1} (18.80) and dry weight of nodules plant^{-1} (0.170 g) were recorded with $S_1 \times B_2$. However, the highest fresh (42.73 g) and dry weights (6.89 g) plant^{-1} were found with $S_2 \times B_1$. Comparable results were reported by Longkumer et al. (2017) and Singh et al. (2012). The shortest plant (30.67 cm), lowest branches (1.80) and fresh weight (26.67 g) plant^{-1} were found in $S_0 \times B_0$. However, lowest number of nodules (7.33), lowest fresh weight of nodules (0.71 g) and lowest dry weight of nodules (0.043 g) plant^{-1} were found from $S_0 \times B_2$. The lower growth of soybean without sulphur and boron fertilization was reported by Singh et al. (2012) and Devi et al. (2012).

Table 1. Effect of levels of sulphur and boron on vegetative characters of soybean (cv. Binasoybean-1)

Treatments	Plant height (c) at 75 DAS	Number of branches plant^{-1}	Chlorophyll content (SPAD)	Number of nodules plant^{-1}	Fresh weight of nodules plant^{-1}	Dry weight of nodules plant^{-1}	Fresh weight (g) plant^{-1}	Dry weight (g) plant^{-1}
Level of sulphur (kg S ha^{-1})								
S_0	30.78b	1.85b	25.39b	9.95c	0.94c	0.058c	29.57c	3.08c
S_1	38.63a	2.57ab	26.38a	15.70a	1.21b	0.117a	39.17a	4.80a
S_2	32.65b	2.69a	24.12c	14.00b	1.29a	0.101b	34.8b	4.50b
Level of significance	**	**	**	**	**	**	**	**
Level of boron (kg B ha^{-1})								
B_0	31.02c	1.96c	23.47c	13.50ab	1.146b	0.08bc	31.08c	3.63c
B_1	33.62b	2.43b	25.03b	13.89a	1.302a	0.09ab	37.39a	4.65a
B_2	36.56a	2.78a	27.12a	13.04bc	1.037c	0.10a	35.37b	4.15b
B_3	34.88ab	2.31b	25.57b	12.44c	1.116b	0.08c	34.31b	4.08b
Level of significance	**	**	**	**	**	**	**	**
CV (%)	7.19	8.19	3.63	5.64	3.52	11.27	4.92	4.43

Figures in a column under each factor and treatment having the same letter or without letter do not differ significantly whereas figures with dissimilar letter(s) different significantly

** = Significant at 1% level of probability

S_0 = 0 kg ha^{-1}, S_1 = 20 kg ha^{-1}, S_2 = 40 kg ha^{-1}

B_0 = 0 kg ha^{-1}, B_1 = 1kg ha^{-1} (basal application), B_2 = 0.5 kg ha^{-1} (basal application) + 0.5 kg ha^{-1} (foliar application at pre-flowering stage), B_3 = 0.5 kg ha^{-1} (foliar application at 30 days after sowing) + 0.5 kg ha^{-1} (foliar application at pre-flowering stage)

Table 2. Interaction effect of levels of sulphur and levels of boron on vegetative characters of soybean (cv. Binasoybean-1)

Level of sulphur × level of boron	Plant height (c) at 75 DAS	Number of branches plant^{-1}	Chlorophyll content (SPAD)	Number of nodules plant^{-1}	Fresh weight of nodules plant^{-1}	Dry weight of nodules plant^{-1}	Fresh weight plant^{-1} (g)	Dry weight plant^{-1} (g)
$S_0 \times B_0$	30.67c	1.80e	25.53bc	11.50e	1.033d	0.067d	26.67f	3.26fg
$S_0 \times B_1$	32.93bc	1.86de	23.77d	10.33e	1.02d	0.060de	29.87de	2.24h
$S_0 \times B_2$	34.07bc	2.00de	26.70b	7.33f	0.71e	0.043e	30.60de	3.26fg
$S_0 \times B_3$	25.47d	1.76e	25.57bc	10.67e	1.02d	0.063d	31.13de	3.56ef
$S_1 \times B_0$	31.60bc	2.20d	23.80d	15.00bc	1.19bc	0.097c	38.13bc	4.53cd
$S_1 \times B_1$	35.27bc	2.60c	26.60b	15.67b	1.24b	0.107bc	39.57b	4.83bc
$S_1 \times B_2$	43.93a	3.43a	28.70a	18.80a	1.27b	0.170a	39.80b	4.93b
$S_1 \times B_3$	43.70a	2.06de	26.43bc	13.33d	1.14c	0.093c	39.20b	4.93b
$S_2 \times B_0$	30.80bc	1.90de	21.07e	14.00cd	1.21bc	0.100c	28.43ef	3.10g
$S_2 \times B_1$	32.67bc	2.83bc	24.73cd	15.67b	1.65a	0.120b	42.73a	6.89a
$S_2 \times B_2$	31.67bc	2.93bc	25.97bc	13.00d	1.13c	0.090c	35.70c	4.26d
$S_2 \times B_3$	35.47b	3.10b	24.70cd	13.33d	1.19bc	0.093c	32.60d	3.76e
Level of significance	**	**	**	**	**	**	**	**
CV (%)	7.19	8.19	3.63	5.64	3.52	11.27	4.92	4.43

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT

** = Significant at 1% level of probability

S_0 = 0 kg ha^{-1}, S_1 = 20 kg ha^{-1}, S_2 = 40 kg ha^{-1}

B_0 = 0 kg ha^{-1}, B_1 = 1 kg ha^{-1} (basal application), B_2 = 0.5 kg ha^{-1} (basal application) + 0.5 kg ha^{-1} (foliar application at pre-flowering stage), B_3 = 0.5 kg ha^{-1} (foliar application at 30 days after sowing) + 0.5 kg ha^{-1} (foliar application at pre-flowering stage

Crop characters, yield components and yield

Crop characters, yield components and yield were significantly influenced by sulphur fertilization in soybean (Table 3, Figure 1A). The tallest plant (43.12 cm) and maximum number of branches plant^{-1} (3.08) were recorded when the crop was fertilized with 20 kg S ha^{-1} followed by 40 kg S ha^{-1} and the lowest values were found in control. This result was in conformity with the reports of Farhad et al. (2010) who found that application of sulphur 20 kg ha^{-1} produced the highest plant height and maximum branches plant^{-1} of soybean. Application of sulphur 40 kg ha^{-1}prodeced the maximum number of pods (29.96) plant^{-1}which was as good as 20 kg ha^{-1}and the lowest pods (25.33) found in control. The highest number of seeds pod^{-1} (3.32), weight of 1000-seed (139.4 g), seed yield (1.33 t ha^{-1}), stover yield (2.14

t ha^{-1}) and biological yield (3.48 t ha^{-1}) were obtained with 20 kg ha^{-1} followed by 40 kg ha^{-1} and the lowest values were found in control. Similar results were obtained by Akter et al. (2013) who reported that application of sulphur 20 kg S ha^{-1} maximize yield components seed and stover yield of soybean. Sulphur fertilization significantly influences the seed and stover yields of soybean was also reported elsewhere (Chandra and Pandey, 2016; Anil et al., 2017; Longkumer et al., 2017; Minz et al., 2017; Sisodiya et al., 2017; Sharma and Sharma, 2018). Singh et al. (2012) and Longkumer et al. (2017) depicted that control sulphur reduced seed and stover yields of soybean.

Different levels of boron application exerted significant effects crop characters, yield components and yield of soybean (Table 3, Figure 1B). The tallest plant (42.91 cm) was recorded in B_3 which was at par with B_2 while the shortest one was found in B_0. The highest number of branches plant^{-1} (3.20), pods plant^{-1} (30.52), number of seeds pod^{-1} (3.44), weight of 1000-seed (141.0 g), seed yield (1.27 t ha^{-1}), stover yield (2.15 t ha^{-1}) and biological yield (3.42 t ha^{-1}) were recorded in B_2. The findings of the present study were in close agreement with the observations of previous studies (Crak et al., 2006; Ross et al., 2006; Kappes et al., 2008; Chaturvedi et al., 2012). The lowest number of branches plant^{-1}(2.38), the lowest 1000-seed weight (134.0g), the lowest seed yield (1.09 t ha^{-1}) and the lowest stover yield (1.35 t ha^{-1}) was found in control treatment (0 kg B ha^{-1}). However, the lowest pods plant^{-1}(26.38) and seeds pod^{-1} (2.47) were obtained from B_3 treatment. However, the highest (44.48) and lowest (37.31) harvest index were recorded in B_0 and B_3, respectively.

All the studied parameters were significantly influenced by the interaction effect between sulphur and boron fertilizations (Table 4, Figure 1C). The tallest plant (46.88 cm) was recorded in $S_1 \times B_2$ which was at par with $S_1 \times B_3$ while the shortest one was recorded in $S_0 \times B_0$. The maximum branches plant^{-1} (3.50) was found in $S_1 \times B_2$ and $S_2 \times B_3$ and the lowest number was found in $S_0 \times B_3$. The highest number of pods plant^{-1} (37.10), seeds pod^{-1} (4.70), 1000-seed weight (146.0 g), seed yield (1.63 t ha^{-1}), stover yield (3.15 t ha^{-1}) and biological yield (4.78 t ha^{-1}) were recorded from the interaction of $S_1 \times B_2$. The highest seed yield was the resultant of cumulative performance by the yield components such as pods plant^{-1}, seeds pod^{-1} and 1000-seed weight of soybean. This could have been due to some synergistic properties of combined use of sulphur and boron fertilization up to certain levels as reported by previous studies (Singh et al., 2012; Devi et al., 2012; Longkumer et al., 2017). The lowest seed (1.03 t ha^{-1}) and stover (1.32 t ha^{-1}) yields were found with $S_0 \times B_0$. The lower yield of soybean with no sulphur and boron fertilization was also observed in other studies (Singh et al., 2012; Devi et al., 2012). The deficiency of one or more essential plant nutrients i.e. sulphur and boron could be responsible for the poor performance of the yield attributes which, in turn, hastened the lowest seed yield and stover yield of soybean. However, the highest harvest index (46.24) was obtained from $S_1 \times B_0$.

Table 3. Effect of levels of sulphur and boron on crop characters, yield components and yield of soybean (cv. Binasoybean-1)

Treatment	Plant height (cm) at harvest	Number of branches plant^{-1} at harvest	Number of pods plant^{-1}	Number of seeds pod^{-1}	1000- seed weight (g)	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
S_0	38.76b	2.43c	25.33b	2.53c	134.8b	1.56c	2.63c	40.96a
S_1	43.12a	3.08a	29.29a	3.32a	139.4a	2.14a	3.48a	39.11ab
S_2	39.20b	2.98b	29.96a	2.89b	137.6a	1.69b	2.76b	38.78b
Level of significance	**	**	**	**	**	**	**	**
B_0	38.07b	2.38c	29.00b	2.82b	134.0c	1.35d	2.45d	44.48a
B_1	38.88b	2.91b	26.87c	2.92b	137.3b	1.92b	3.16b	38.84b
B_2	41.58a	3.20a	30.52a	3.44a	141.0a	2.15a	3.42a	37.85b
B_3	42.91a	2.83b	26.38c	2.47c	136.7bc	1.75c	2.80c	37.31b
Level of significance	**	**	**	**	**	**	**	**
CV (%)	4.79	3.10	4.52	3.99	2.24	2.99	4.09	5.89

Figures in a column under each factor and treatment having the same letter or without letter do not differ significantly whereas figures with dissimilar letter(s) different significantly

** = Significant at 1% level of probability

S_0 = 0 kg ha^{-1}, S_1 = 20 kg ha^{-1}, S_2 = 40 kg ha^{-1}, B_0 = 0 kg ha^{-1}, B_1 = 1 kg ha^{-1} (basal application), B_2 = 0.5 kg ha^{-1} (basal application) + 0.5 kg ha^{-1} (foliar application at pre-flowering stage), B_3 = 0.5 kg ha^{-1} (foliar application at 30 days after sowing) + 0.5 kg ha^{-1} (foliar application at pre-flowering stage)

Table 4. Interaction effect of levels of sulphur and levels of boron on crop characters, yield components and yield of soybean (cv. Binasoybean-1)

Interaction Level of sulphur × level of boron	Plant height (cm) at harvest	Number of branches plant^{-1} at harvest	Number of pods plant^{-1}	Number of seeds pod^{-1}	1000- seed weight (g)	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
$S_0 \times B_0$	37.70c	2.20h	28.80cd	2.86bcd	129.7c	1.32e	2.34f	43.81ab
$S_0 \times B_1$	38.67c	2.40g	18.20h	2.83bcd	134.3bc	1.62d	2.74de	40.95bcd
$S_0 \times B_2$	40.10c	2.93 de	24.67f	2.73cd	137.8b	1.64d	2.73de	39.75bcd
$S_0 \times B_3$	38.57c	2.16 h	29.63c	1.70e	137.4b	1.64d	2.72de	39.33cd
$S_1 \times B_0$	39.67c	2.66f	25.33ef	2.70d	135.5b	1.36e	2.53ef	46.24a
$S_1 \times B_1$	39.17c	3.33b	32.40b	3.00b	139.7b	2.12b	3.64b	41.58bcd
$S_1 \times B_2$	46.88a	3.50a	37.10a	4.70a	146.0a	3.15a	4.78a	34.05e
$S_1 \times B_3$	46.77a	2.83e	22.33g	2.86bcd	136.4b	1.93c	2.95cd	34.58e
$S_2 \times B_0$	36.83c	2.26gh	32.87b	2.90bcd	136.9b	1.40e	2.47f	43.39abc
$S_2 \times B_1$	38.80c	3.00d	30.00c	2.93bc	138.1b	2.04b	3.10c	33.97e
$S_2 \times B_2$	37.77c	3.16c	29.80c	2.90bcd	139.1b	1.64d	2.73de	39.75bcd
$S_2 \times B_3$	43.40b	3.50a	27.17de	2.83bcd	136.5b	1.69d	2.72de	38.03de
Level of significance	**	**	**	**	**	**	**	**
CV (%)	4.79	3.10	4.52	3.99	2.24	2.99	4.09	5.89

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT
** = Significant at 1% level of probability
S_0 = 0 kg ha^{-1}, S_1 = 20 kg ha^{-1}, S_2 = 40 kg ha^{-1}, B_0 = 0 kg ha^{-1}, B_1 = 1kg ha^{-1} (basal application), B_2 = 0.5 kg ha^{-1} (basal application) + 0.5 kg ha^{-1} (foliar application at pre-flowering stage), B_3 = 0.5 kg ha^{-1} (foliar application at 30 days after sowing) + 0.5 kg ha^{-1} (foliar application at pre-flowering stage)

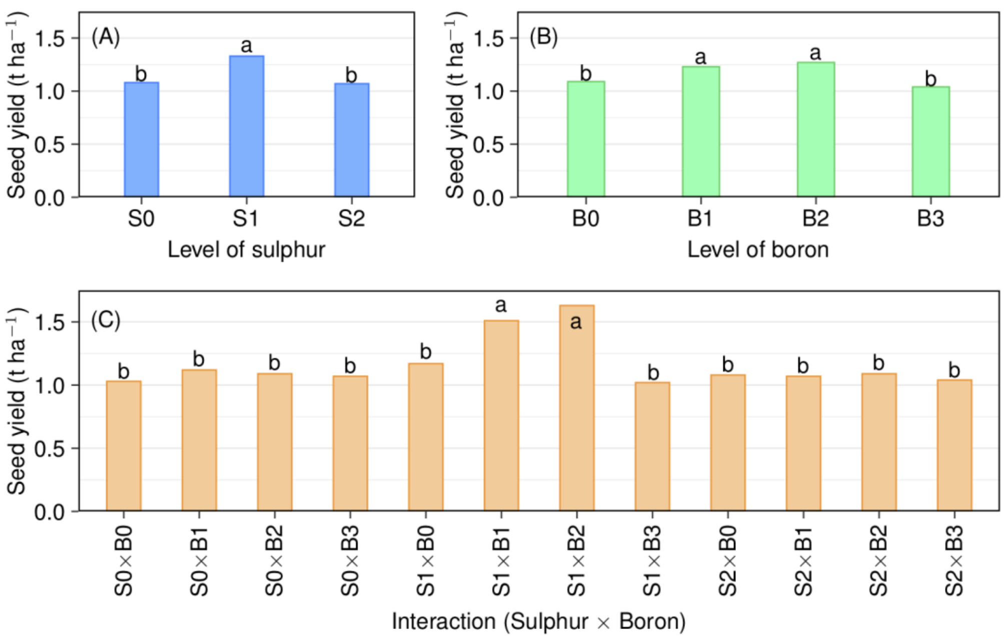

Figure 1. Effects of (A) levels of sulphur, (B) levels of boron, and (C) interaction between sulphur and boron on seed yield of soybean (cv. Binasoybean-1). S_0 = 0 kg ha^{-1}, S_1 = 20 kg ha^{-1}, S_2 = 40 kg ha^{-1}, B0 = 0 kg ha^{-1}, B_1 = 1 kg ha^{-1} (basal application), B_2 = 0.5 kg ha^{-1} (basal application) + 0.5 kg ha^{-1} (foliar application at pre-flowering stage), B_3 = 0.5 kg ha^{-1} (foliar application at 30 days after sowing) + 0.5 kg ha^{-1} (foliar application at pre-flowering stage).

Conclusion

Results revealed that application of sulphur @ 20 kg ha^{-1} produced the highest seed and stover yields. Boron application 0.5 kg ha^{-1} as basal followed by application of 0.5 kg ha^{-1}as foliar at pre-flowering stage gave the highest seed and stover yields. Compare to other combinations sulphur 20 kg ha^{-1}along with 0.5 kg ha^{-1} as basal + 0.5 kg ha^{-1} as foliar application at pre-flowering stage produced the highest seed and stover yields. The present study suggested that sulphur and boron played a significant role in increasing growth and seed yield of soybean. Therefore, sulphur and boron at the rate of 20 kg ha^{-1} along with 0.5 kg ha^{-1} as basal application + 0.5 kg ha^{-1} as foliar application at pre-flowering stage appears as the promising combination in terms of seed and stover yields of soybean (cv. Binasoybean-1).

Author's contribution

SD conducted the field experiments, took data, and wrote the report for his degree requirement, SKP designed the research project, supervised the research work, and wrote the final manuscript, MRR helped in the statistical analysis of data, SR took data and downloaded related literature, FMJU made tables and figure, MHR revises and improved the quality of the manuscript.

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Conflict of Interest

The authors declare that there is no conflict of interests regarding the publication of this paper.

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