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Influence of Foliar Application of Boron on the Growth, Yield and Quality of Sesame (cv. BARI Til-4)

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ABSTRACT

Foliar supplementation may be useful for boron to a crop when its demands are higher compared to the supply from soil. Boron is an important micronutrient which had a substantial impact on oil content, seed yield, and the components of the sesame yield. A field investigation was implemented to determine the impact of foliar application of boron on seed yield, growth and oil content of sesame cv. BARI Til-4. The investigation included four concentrations of boron viz. 0, 25, 50, and 75 ppm and three frequencies of boron application viz. one time at 30 days after sowing (DAS), two times at 30 and 50 DAS, and three times at 30, 50, and 70 DAS. The experiment was conducted following randomized complete block design, which was replicated thrice. At the vegetative stage, the highest plant height (107.3 cm), branches/plant (5.0) and shoot dry weight (45.20 g/plant) resulted in 75 ppm boron spray at 30, 50 and 70 DAS. However, the highest root dry weight (5.80 g/plant) was recorded in 75 ppm with one application of boron at 30 DAS. The plants with the highest plant height (112.1 cm), branches/plant (5.13), pods/plant (44.13), seeds/pod (54.33), seed yield (609.0 kg/ha), harvest index (30.65%), and oil content (42.33%) were also observed with the combination of 75 ppm boron spray with thrice application at 30, 50 and 70 DAS. The lowest seed yield (368.7 kg/ha) resulted in without boron application. Therefore, it can be inferred that the most efficient method for increasing the sesame seed yield and oil content is thrice (30, 50, and 70 DAS) foliar spraying of 75 ppm boron.

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Introduction

One of the oldest oil seed crops is sesame (*Sesamum indicum* L.) under the Pedaliaceae family. It has been farmed for generations and is a valuable ancient oilseed crop cultivated in the tropics and subtropics, particularly in Asia and Africa (FAO, 2013). In terms of global oil crops, it comes in fourth place. Its primary producing regions are in Asia, East, and Central America's tropics and subtropics (Nayar et al., 1970). Sesame production drastically declined over time as a result of intense competition among various high-value crops (Paul et al., 2019). In addition to carbs, protein, and lipids, sesame is a versatile crop that produces excellent edible oil that synthesizes sulphur-containing amino acids and vitamins (Mohsana, 2009). Sesame oil contains 42 to 50 with 25% protein the oil contains 42% essential linoleic acid and 16-18% carbohydrates (Miah et al., 2015). It has lower levels of acetic acid but higher unsaturated fatty acids (more than 80%), particularly oleic and linoleic acids, which are resistant to rancidity. Sesame has noticeable antioxidant properties. It is sometimes referred to as the "seed of immortality" since it has a lengthy shelf life (Sanga, 2013). Sesame plants tolerate drought and can be cultivated in rain-fed highland settings. In Bangladesh, two-thirds of the total sesame is cultivated during the *kharif* season.

The population growth of Bangladesh is 1.22% and there is a severe shortage of edible oil (BBS, 2022). Sesame can also be used to extract high-quality oil for cooking, as well as medicinal and cosmetic uses, all of which have extended shelf lives. The yield of sesame in Bangladesh is lower than other sesame-producing countries. Lower yield might be caused by improper cultivar selection and inadequate management practices. Previous studies have shown that varietal potentiality influences on seed output (Mohsana, 2009; Raja et al., 2007).

One of the elements affecting sesame yield and oil content is boron. During the development of plants, boron is engaged in a number of physiological and biochemical processes. In Bangladesh, some soils and crops have shown evidence of B (Islam et al., 1997) and B, Zn, and Mo deficiencies (Khanam et al., 2001). On some soils and crops, boron shortage is documented in particular (Islam et al., 1997). During the development of plants, boron is engaged in several physiological and biochemical processes. Low yield might be caused by its absence, among other things. According to Ahmed and Hossain (1999), a million hectares of land in Bangladesh has boron deficiencies. A lack of boron leads to a significant decline in grain set and a severe yield drop (Jamjod et al., 2004). This boron shortage is typically found in soils with a light texture and a high pH. Higher production potential and resistance to pests and diseases in improved sesame varieties are indicated to boost yield (Ssekabembe et al., 2002). The most recent high yielding sesame variety developed by Bangladesh Agricultural Research Institute (BARI) is BARI Til-4. This study was conducted to determine the impact of foliar application of boron on sesame growth, seed yield, and oil content.

Materials and Methods

Experimental Site, Soil and Weather

The Agronomy Field Laboratory of Bangladesh Agricultural University hosted the experiment between March and June of 2019. The study area is 18 meters above the nearest sea level and is located at 90° 50' East longitude and 24° 75' North latitude. A piece of land with a silty loam soil texture makes up the experimental plot, which is a little bit elevated and has a pH of 6.10, an electrical conductivity of 233 (μS/cm), organic carbon of 1.00%, nitrogen of 0.117 %, phosphorus of 3.19 ppm, potassium of 0.092 %, calcium of 8.30 g, magnesium of 3.29 g, sulfur of 9.52 ppm, and boron of 0.23 g. The experimental area experiences subtropical weather. The experimental site saw lowest and highest temperatures of 12.16°C and 31.69°C, relative humidity levels of 67.76% and 83%, and total rainfall amounts of 0.00 mm and 66.80 mm, respectively (Source: Department of Irrigation and Water Management, Bangladesh Agricultural University).

Experimentation

The study consisted of four concentrations of boron viz. 0 ppm (B_0), 25 ppm (B_1), 50 ppm (B_2) and 75 ppm (B_3) and three frequencies of boron application viz. one time at 30 DAS (T_1), two times at 30 and 50 DAS (T_2), three times at 30, 50 and 70 DAS (T_3). To set up the experiment, a Randomized Complete Block Design was utilized which comprised three replications. Each block included 12 plots. There were 36 such plots in all. The plot measured 2.5 m × 2.0 m. Blocks were separated from one another by 0.5 cm between each, while plots were separated by 0.25 cm. BARI Til-4 cultivar of sesame was utilized in this investigation.

Crop Husbandry

Using a power tiller, the experimental site was prepared. Laddering was done after using the country plough for ploughing and cross-ploughing to obtain the desirable tilt. There were 5 types of fertilizer used. The rate of urea 120 kg/ha, triple super phosphate (TSP) 145 kg/ha, muriate of potash (MoP) 50 kg/ha was applied to all plots as per recommended by Bangladesh Agricultural Research Institute. There were four concentrations of boron application *viz.* 0 ppm, 25 ppm, 50 ppm and 75 ppm with frequencies of boron application *viz.* once at 30 DAS, twice at 30 and 50 DAS, and thrice at 30, 50, and 70 DAS. Boron was obtained from boronic acid at 0, 147, 294 and 441 mg Boric acid per litre for 0 ppm, 25 ppm, 50 ppm and 75 ppm respectively. TSP, MoP, Gypsum, and 50% of Urea were all fully integrated during the last stage of soil preparation. Sesame seeds (BARI Til-4) were sown in 2-3 cm profound ridges created by manual raking, keeping rows 25 cm apart. After the seeds were planted in the furrow, dirt was added, and then the seeds were lightly pressed by hand. Seed rate was 7 kg/ha. Within three days of seeding, seedling emergence began, and it was finished seven days later. After the establishment of seedlings, healthy seedlings were kept within a distance of 5 cm between two seedlings in a row and the additional seedlings were carefully uprooted by hand pulling.

Data Collection, Harvesting and Post-Harvest Operations

At 60 DAS, to measure plant height, four plants were chosen at random from the core 1.0 m × 1.0 m and border rows, branches/plant, shoot and root dry matter production/plant Plant was uprooted average height and number of branches/plant was measured then shoots and roots were separated and a consistent weight was attained after oven drying. When around 80% of the plant leaves turned straw-yellow in colour then crops were harvested. In order to collect information on plant height, branches/plant, pods/plant, seeds/pod, 1000-seed weight, and oil (%) content of sesame seeds, five randomly chosen plants from each unit plot were uprooted. Border plants and the middle 1.0 m × 1.0 m area were not included in this process. After collection of the sample harvesting of 1.0 m^2 area was done. The harvested crops were tied into bundled, tagged separately, sun dried and threshed by bamboo rods. After separating the seeds from the pods, the yields of both the seeds and the stover were documented. The biological yield was determined using the following formula on a dry weight basis:

Biological yield = Seed yield + Stover yield.

The formula below was used to construct the harvest index (%), which determines the percentage difference between economic yield and biological yield (Gardner et al., 1985).

$$\text{Harvest index (\%)} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100.$$

Seed Oil Content Measurement

By using the Soxhlet apparatus method in accordance with the steps in the oil content was calculated (Singh et al., 1960). Oil content and seed yield were multiplied to determine the oil yield.

Statistical Analysis

The computer program MSTATC-C developed by (Russel, 1986) was employed to conduct the analysis of variance (ANOVA). The mean differences between the treatments were adjusted by DMRT at a 5% level of significance (Gomez and Gomez, 1984).

Results

Vegetative Traits at 60 DAS

Plant Height

The height of the plant was sown a substantial impact by various boron doses concentrations. However, the frequencies of boron application and the interaction between concentration and frequencies did not show any significant effects. Among the different concentrations, 75 ppm resulted in the tallest plants (104.70 cm), which were not significantly different from plants treated with 50 ppm and 25 ppm. The shortest plants (101.10 cm) were observed in the control group (0 ppm) (Table 1). Regarding the frequencies of boron application, plants treated three times at 30, 50, and 70 DAS exhibited the highest height of the plant (104.3 cm), while the lowest height of the plant (101.9 cm) was found when boron was applied only once at 30 DAS (Table 1). Table 2 shows that the combination of 75 ppm boron applied three times at 30, 50, and 70 DAS ($B_3 \times T_3$) resulted in the tallest plants (107.3 cm), whereas the shortest plants (100.7 cm) were observed in the group treated with 0 ppm boron two times at 30 and 50 DAS ($B_0 \times T_2$).

Number of Branches/Plant

Variable boron concentrations had a substantial impact on the quantity of branches/plant, but the frequencies of boron treatment and the relationship between the two did not. In the experiment, the highest number of branches/plant (4.56) was observed at a boron concentration of 75 ppm. Conversely, the lowest number of branches/plant (3.44) resulted with control group (0 ppm), which was identical to the results for 25 ppm and 50 ppm boron concentrations (Table 1). Regarding the frequencies of boron application, the highest number of branches/plant (3.91) was achieved when boron was applied thrice at 30, 50, and 70 DAS. Conversely, the lowest plant height (3.66 cm) was observed when boron was applied only once at 30 DAS, which was comparable to the results of twice applications at 30 and 50 DAS (Table 1). However, numerically, the highest number of branches/plant was recorded at 75 ppm with three boron applications at 30, 50, and 70 DAS ($B_3 \times T_3$) (Table 2). Conversely, the lowest number of branches /plant was found in the control group (0 ppm) with a single boron application at 30 DAS ($B_0 \times T_1$) (Table 2).

Shoot Dry Weight

The dry weight of the shoot of the plant was positively affected by varying the doses, frequencies, and combination of boron treatments. The highest shoot dry weight (43.47 g/plant) was observed at a dose of 75 ppm, comparable to 50 ppm and 25 ppm. In contrast, the lowest shoot dry weight (24.26 g/plant) was recorded in the control group with 0 ppm of boron (Table 1). When boron was applied thrice at 30, 50, and 70 DAS, the highest shoot dry weight (33.86 g/plant) was achieved while the lowest shoot dry weight (31.86 g/plant) was recorded when boron applied once at 30 DAS, which was at par with twice applications at 30 DAS and 50 DAS (Table 1). Furthermore, the highest shoot dry weight (45.20 g/plant) was recorded with 75 ppm boron applied thrice at 30, 50, and 70 DAS ($B_3 \times T_3$). Contrarily, the minimum shoot dry weight (23.66 g/plant) was found without boron application ($B_0 \times T_2$) (Table 2).

Root Dry Weight

Different concentrations, frequencies and their interactions of boron had a considerable effect on the plant's root dry weight. The highest root dry weight (5.66 g/plant) was observed at 75 ppm boron concentration and the lowest weight (4.86 g/plant) in without boron application (Table 1). Furthermore, when boron was applied at 30 DAS, the root dry weight varied depending on the frequencies of application. The lowest root dry weight (5.163 g/plant) was recorded when boron was applied once at 30 DAS, whereas the maximum root dry weight (5.321 g/plant) was observed when boron was applied twice at 30 and 50 DAS (Table 1).

Table 1. Effect of concentration and frequencies of boron on plant height, number of branches/ plant shoot and root dry weight of sesame plant at 60 DAS

Treatments	Plant height (cm)	Branches/plant (no.)	Shoot dry weight/plant (g)	Root dry weight/plant (g)
Concentration of Boron				
B_0	101.10b	3.44b	24.26d	4.86c
B_1	103.00ab	3.44b	28.46c	5.17b
B_2	103.90a	3.56b	34.30b	5.17b
B_3	104.70a	4.56 a	43.47a	5.66a
Sig. level	*	**	**	**
CV (%)	2.35	15.40	2.50	1.80
Frequencies of Boron				
T_1	101.9	3.66	32.15b	5.163b
T_2	103.3	3.66	31.86b	5.321a
T_3	104.3	3.91	33.86a	5.173b
Sig. level	NS	NS	**	**
CV (%)	2.35	15.40	2.50	1.80

According to the DMRT, figures in a column for each factor of treatment with the same letter or without a letter do not significantly differ from each other, however figures with dissimilar letter(s) do. ** = 1 % level of significant, * = 5 % level of significant, NS = Not significant; B_0 = 0 ppm, B_1 = 25 ppm, B_2 = 50 ppm, B_3 = 75 ppm, T_1 = Once at 30 DAS, T_2 = Twice at 30 and 50 DAS, T_3 = Thrice at 30, 50 and 70 DAS

Table 2. Interaction effects of concentrations and frequencies of boron application on plant height, number of branches/plant, shoot, root and total dry weight of plant at 60 DAS

Interaction (Concentration × Frequencies)	Plant height (cm)	Branches/plant (no.)	Shoot Dry weight/plant (g)	Root dry weight/ plant (g)
$B_0 \times T_1$	101.7	3.33	25.15g	4.70h
$B_1 \times T_1$	101.3	3.33	27.88f	4.95g
$B_2 \times T_1$	101.7	3.66	32.82d	5.20e
$B_3 \times T_1$	103.0	4.33	42.77b	5.80a
$B_0 \times T_2$	100.7	3.33	23.66h	4.90g
$B_1 \times T_2$	104.7	3.66	28.02f	5.40cd
$B_2 \times T_2$	104.0	3.33	33.32d	5.31de
$B_3 \times T_2$	103.7	4.33	42.43b	5.66ab
$B_0 \times T_3$	101.0	3.66	23.97gh	5.00fg
$B_1 \times T_3$	103.0	3.33	29.50e	5.16ef
$B_2 \times T_3$	106.0	3.66	36.76c	5.01fg
$B_3 \times T_3$	107.3	5.00	45.20a	5.51bc
Sig. level	NS	NS	**	**
CV (%)	2.35	15.40	2.50	1.80

According to the DMRT, figures in a column for each factor of treatment with the same letter or without a letter do not significantly differ from each other, however figures with dissimilar letter(s) do. ** = 1 % level of significant, NS = Not significant; B_0 = 0 ppm, B_1 = 25 ppm, B_2 = 50 ppm, B_3 = 75 ppm, T_1 = Once at 30 DAS, T_2 = Twice at 30 and 50 DAS, T_3 = Thrice at 30, 50 and 70 DAS

Table 3. Effect of concentrations and frequencies of boron on yield and yield contributing characters of sesame (BARI Til-4)

Treatments	Plant height (cm)	Branches/ plant (no.)	Pods/ plant (no.)	Seeds / pod (no.)	Biological yield (kg/ha)	Harvest index (%)
Concentration of Boron						
B_0	105.2c	3.75c	38.56c	43.10d	2174.0a	18.38d
B_1	106.9b	4.15b	36.62d	45.7c	2047.0b	21.19c
B_2	108.5a	4.26b	40.87b	46.50b	2078.0b	23.42b
B_3	109.3a	4.84a	43.09a	52.44a	2061.0b	27.82a
Sig. level	**	**	**	**	**	**
CV(%)	1.52	4.83	2.57	1.03	2.85	3.64
Frequencies of Boron						
T_1	106.2b	4.45a	40.02a	46.45b	2138.0a	21.64c
T_2	107.7a	3.88 b	40.23a	46.82b	2093.0a	22.78b
T_3	108.5a	4.43a	39.10 b	47.55a	2039.0b	23.69a
Sig. level	**	**	*	**	**	**
CV (%)	1.52	4.83	2.57	1.03	2.85	3.64

According to the DMRT, figures in a column for each factor of treatment with the same letter or without a letter do not significantly differ from each other, however figures with dissimilar letter(s) do. ** = 1 % level of significant, * = 5 % level of significant, B_0 = 0 ppm, B_1 = 25 ppm, B_2 = 50 ppm, B_3 = 75 ppm, T_1 = Once at 30 DAS, T_2 = Twice at 30 and 50 DAS, T_3 = Thrice at 30, 50 and 70 DAS

In Table 2, the most significant root dry weight was recorded (5.80 g/plant) at 75 ppm boron concentration with a single application at 30 DAS ($B_3 \times T_1$). This result was statistically similar to the root dry weight obtained from 75 ppm boron concentration with two applications at 30 and 50 DAS ($B_3 \times T_2$). Conversely, minimum root dry weight (4.70 g/plant) was recorded in without boron application ($B_0 \times T_1$).

Crop Characteristics, Yield Components and Oil Content at Harvest

Plant Height

Different concentrations, frequencies, and interactions of boron doses significantly affected the height of the BARI Til-4 plant. The tallest plant height (109.3 cm) was found with 75 ppm boron, which was comparable to the plant height at 50 ppm. Conversely, the shortest plant (105.2 cm) has resulted in 0 ppm boron (Table 3). Another observation was that applying boron three times at 30, 50, and 70 DAS resulted in the highest plant (108.5 cm), which was on par with applying boron twice at 30 and 50 DAS. However, the shortest plant height (106.2 cm) was found when boron was applied only once at 30 DAS (Table 3). Table 4 presents additional findings, showing that the tallest plant (112.1 cm) occurred with thrice application of 75 ppm boron at 30, 50, and 70 DAS ($B_3 \times T_3$). Conversely, the shortest plant (104.6 cm) was found in without boron application (B0 × T3).

Number of Branches/Plant

The number of branches/plant in BARI Til-4 was significantly influenced by various concentrations, frequencies and their interactions. The maximum branches/plant (4.84) was observed at 75 ppm boron, followed by 50 ppm and 25 ppm. The lowest number of branches /plant (3.75) was recorded without boron (0 ppm) (Table 3). When examining the timing of boron application, the highest quantity of branches/plant (4.45) resulted from a single application of boron at 30 DAS, which was similar to three applications of boron at 30, 50, and 70 DAS. The lowest number of branches/plant (3.88) observed with boron application at 30 and 50 DAS (Table 3). Regarding the interaction of boron concentration and application timing, the highest quantity of branches/plant (5.13) was resulted in the combination of 75 ppm boron with three applications at 30, 50, and 70 DAS ($B_3 \times T_3$). Conversely, the lowest number of branches/plant (3.40) occurred in the interaction of 0 ppm boron with two applications at 30 and 50 DAS ($B_0 \times T_2$) (Table 4).

Number of Pods/Plant

Different doses of boron at different concentration, frequencies and their interactions all had a substantial impact on the quantity of pods/plant. The highest quantity of pods/plant (43.09) was observed when using 75 ppm boron. Conversely, the lowest number of pods/plant (36.62) was recorded with 25 ppm boron (Table 3). When analyzing the frequencies of boron application, having the most pods/plant (40.23) resulted from applying boron twice at 30 and 50 DAS, which was similar to a single application of boron at 30 DAS. The lowest number of pods/plant (39.10) occurred with three applications of boron at 30, 50, and 70 DAS (Table 3). Furthermore, in the interactions between boron concentrations and application frequencies, the most significant number of pods/plant (44.13) was found with 75 ppm boron and three applications of boron at 30, 50, and 70 DAS ($B_3 \times T_3$). Conversely, with the fewest pods/plant (36.67) resulted in without boron application ($B_0 \times T_1$) (Table 4).

Number of Seeds/Pod

The quantity of seeds/pod of BARI Til-4 was significantly affected by variations in boron concentration, frequencies, and their combinations. The highest seeds/pod (52.44) were observed when applying 75 ppm of boron and the lowest seeds/pod (43.10) were found in 0 ppm boron (Table 3). When examining the effect of boron application frequencies, the highest seeds/pod (47.55) occurred with thrice applications of boron at 30, 50, and 75 DAS. The lowest seeds/pod (46.45) was recorded when boron was applied only once at 30 DAS, which showed similar results to the twice application of boron at 30 and 50 DAS (Table 3). Regarding the interaction of boron concentrations and application frequencies, the highest quantity of seeds/pod (54.33) was found when using 75 ppm at 30, 50, and 70 DAS ($B_3 \times T_3$). Conversely, the lowest seeds per pod (42.13) were observed in the interaction of 0 ppm boron with a single application at 30 DAS ($B_0 \times T_1$) (Table 4).

Seed Yield

Variable boron concentrations, application frequencies, and their interactions had a significant impact on the seed production of sesame. The highest yield of seed (571.9 kg/ha) was observed with 75 ppm boron, while the lowest seed yield (399.6 kg/ha) was recorded in the control group with 0 ppm boron (Figure 1). When examining the effect of boron application frequencies, the highest yield of seed (481.9 kg/ha) was achieved with thrice applications of boron at 30, 50, and 70 DAS. This result was comparable to the yield (460.5 kg/ha) obtained from the twice application of boron at 30 and 50 DAS. The lowest seed yield was found in boron was applied only once at 30 DAS (Figure 1). In relation to how the frequencies and concentration of boron interact, the highest yield of seed (609.0 kg/ha) was observed when using 75 ppm boron in combination with three applications at 30, 50, and 70 DAS ($B_3 \times T_3$). Conversely, the lowest seed yield (368.7 kg/ha) was found in the interaction of 0 ppm boron with three applications at 30, 50, and 70 DAS ($B_0 \times T_3$) (Figure 1).

Stover Yield

The stover yield of BARI Til-4 was significantly affected by variations in boron concentration, frequencies, and their interaction. The highest stover yield (1774.0 kg/ha) was measured in the control group with 0 ppm boron, while the lowest stover yield (1489.0 kg/ha) was observed when using 75 ppm boron (Figure 2). Examining the effect of boron application frequencies alone, the highest stover yield (1678.0 kg/ha) occurred when boron was applied once at 30 DAS. Conversely, the lowest stover yield (1557.0 kg/ha) was found when boron was applied three times at 30, 50, and 70 DAS (Figure 2).

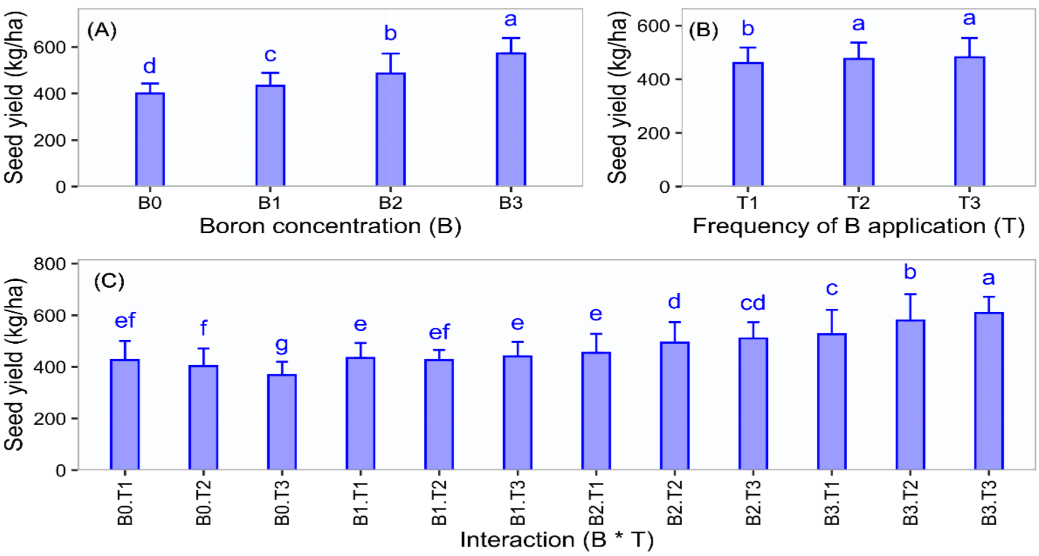

Figure 1. Effect of boron concentrations and application frequencies on sesame seed yield.
B_0 = 0 ppm, B_1 = 25 ppm, B_2 = 50 ppm, B_3 = 75 ppm, T_1 = Once at 30 DAS, T_2 = Twice at 30 and 50 DAS, T_3 = Thrice at 30, 50 and 70 DAS

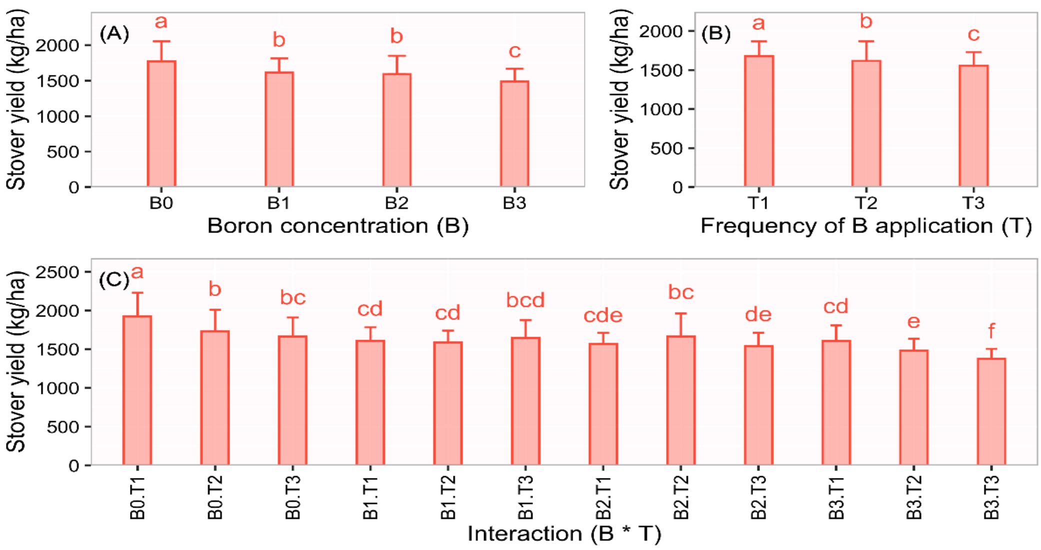

Figure 2. Effect of boron concentrations and application frequencies on sesame stover yield.
B_0 = 0 ppm, B_1 = 25 ppm, B_2 = 50 ppm, B_3 = 75 ppm, T_1 = Once at 30 DAS, T_2 = Twice at 30 and 50 DAS, T_3 = Thrice at 30, 50 and 70 DAS

Table 4. Interaction effects of concentrations and frequencies of boron application on yield contributing characters of sesame

Interaction (Conc. × Frequencies)	Plant height (cm)	Branches /plant (no.)	Pods/plant (no.)	Seeds/ pod (no.)	Biological yield (kg ha^{-1})	Harvest index (%)
$B_0 \times T_1$	104.9ef	3.86cd	36.67f	42.13 f	2354.0a	18.12f
$B_1 \times T_1$	105.1def	4.46b	41.27c	45.65 d	2044.0cd	21.28e
$B_2 \times T_1$	106.8c-f	4.66b	38.73de	46.88 c	2022.0cd	22.46de
$B_3 \times T_1$	107.9b-e	4.80ab	43.40ab	51.13 b	2133.0bc	24.70c
$B_0 \times T_2$	106.1c-f	3.40e	37.20ef	42.79 f	2133.0bc	18.90f
$B_1 \times T_2$	108.5bc	3.93cd	40.33cd	45.59 d	2014.0d	21.17e
$B_2 \times T_2$	108.2bcd	3.60de	41.67bc	47.04 c	2161.0b	22.90d
$B_3 \times T_2$	107.9b-e	4.60b	41.73bc	51.87 b	2063.0bcd	28.13b
$B_0 \times T_3$	104.6f	4.00c	41.80bc	44.37 e	2035.0cd	18.11f
$B_1 \times T_3$	106.9c-f	4.06c	28.27g	45.89 d	2084.0bcd	21.13e
$B_2 \times T_3$	110.5ab	4.53b	42.20bc	45.59 d	2050.0bcd	24.89c
$B_3 \times T_3$	112.1a	5.13a	44.13a	54.33 a	1987.0d	30.65a
Sig. level	*	**	**	**	**	**
CV (%)	1.52	4.83	2.57	1.03	2.85	3.64

According to the DMRT, figures in a column for each factor of treatment with the same letter or without a letter do not significantly differ from each other, however figures with dissimilar letter(s) do. ** = 1 % level of significant, * = 5 % level of significant, B_0 = 0 ppm, B_1 = 25 ppm, B_2 = 50 ppm, B_3 = 75 ppm, T_1 = Once at 30 DAS, T_2 = Twice at 30 and 50 DAS, T_3 = Thrice at 30, 50 and 70 DAS

Regarding the interaction of boron concentration and application frequencies, the highest stover yield (1927.0 kg/ha) was found in the interaction of 0 ppm boron with a single application at 30 DAS ($B_0 \times T_1$). Conversely, the lowest stover yield (1378.0 kg/ha) was observed in the interaction of 75 ppm boron with thrice applications at 30, 50, and 70 DAS ($B_3 \times T_3$) (Figure 2).

Biological Yield

The biological yield of BARI Til-4 was significantly affected by the variations in boron concentration, application frequencies, and their interactions. The highest biological yield (2174 kg/ha) was observed in the control group with 0 ppm boron. The lightest biological yield (2047 kg/ha) was found with 25 ppm boron, which was statistically similar to the yields obtained with 50 ppm and 75 ppm boron (Table 3). A single application of boron at 30 DAS resulted in the highest biological yield (2138.0 kg/ha), which did not differ considerably from the yields achieved with twice boron applications at 30 and 50 DAS. The lowest biological yield (2039.0 kg/ha) was recorded with three times applications of boron at 30, 50, and 70 DAS (Table 3). In the interaction of 0 ppm boron with a single application at 30 DAS ($B_0 \times T_1$), the highest biological yield (2354.0 kg/ha) was found, while the lightest biological yield (1987.0 kg/ha) was recorded in the interaction of 75 ppm boron with thrice applications at 30, 50, and 70 DAS ($B_3 \times T_3$) (Table 4).

Harvest Index

The harvest index of BARI Til-4 had a considerable impact on boron concentration, application frequencies, and their interaction. The greater harvest index (27.82%) was found with 75 ppm boron, the least harvest index (18.38%) was observed in the control group with 0 ppm boron (Table 3). With thrice applications of boron at 30, 50, and 70 DAS, the greater harvest index (23.69%) was achieved, and the lowest harvest index (21.64%) was found with a single application at 30 DAS (Table 3).

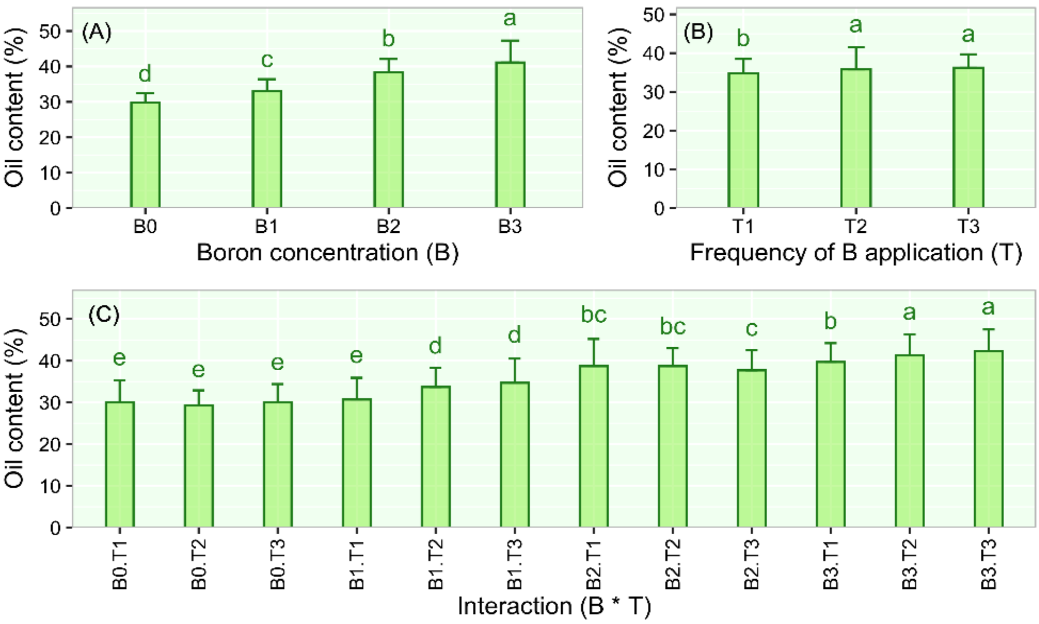

Figure 3. Effect of boron concentrations and application frequencies on sesame oil content.
B_0 = 0 ppm, B_1 = 25 ppm, B_2 = 50 ppm, B_3 = 75 ppm, T_1 = Once at 30 DAS, T_2 = Twice at 30 and 50 DAS, T_3 = Thrice at 30, 50 and 70 DAS

In the interaction of 75 ppm boron with thrice applications at 30, 50, and 70 DAS ($B_3 \times T_3$), the greater harvest index (30.65%) was observed, while the least harvest index (18.12%) was recorded in the interaction of 0 ppm boron with a single application at 30 DAS ($B_0 \times T_1$) (Table 4).

Oil Content

The oil content of BARI Til-4 was significantly affected by boron concentration, application frequencies, and their interaction. The highest oil content (41.11%) was obtained with 75 ppm boron, while the lowest oil content (29.78%) was recorded in the control group with 0 ppm boron (Figure 3). With three frequencies of boron application at 30, 50, and 70 DAS, the highest oil content (36.17%) was observed, followed by twice applications at 30 and 50 DAS. The lowest oil content (35.75%) was found with a single application of boron at 30 DAS (Figure 3). In the interaction of 75 ppm boron with three times applications at 30, 50, and 70 DAS ($B_3 \times T_3$), the highest oil content (42.33%) was observed, which was statistically similar to the interaction of 75 ppm boron with twice application at 30 and 50 DAS ($B_3 \times T_2$). The lowest oil content was found without boron application ($B_0 \times T_1$, $B_0 \times T_2$, and $B_0 \times T_3$) which was at par with the interaction of 25 ppm applied once at 30 DAS ($B_1 \times T_1$) (Figure 3).

Discussion

The growth characteristics of BARI Til-4 plants had a profound impact on the administration of various boron doses. The control group with 0 ppm boron had the lowest height, whereas the treatment with 75 ppm boron had the highest plant height and the most branches/plant (Table 1). The highest shoot and root dry weight was produced by the 75 ppm boron treatment as well (Table 1). When exposed to varying frequencies of boron treatment, how tall the plant is and the number of branches/plant did not show any appreciable differences. From the three times application frequencies, the tallest plants were found with three time applications at 30, 50 and 75 DAS whereas one application of boron at 30 DAS produced the shortest plants (Table 1). Three boron treatments at 30, 50, and 70 DAS resulted in the highest number of branches/plant in terms of numbers (Table 1). Furthermore, boron was treated three times at 30, 50, and 70 DAS to achieve the highest shoot dry weight, while two treatments at 30 and 50 DAS to get the highest root dry weight were recorded (Table 1). Several physiological processes, including cell division and elongation, which eventually lead to increased plant height, depend on the mineral boron. Similar observations showed that boron fertilization increases production potential through more branching (Schon and Blevins, 1990). According to Miller and Donahue (1997) boron is a crucial ingredient for the synthesis of new cells, which results in a considerable rise in leaf dry weight when boron supplies are adequate. Ramirez and Linares (1995) also reported that boron is applied optimally, sesame leaves produce more dry matter but this production is drastically reduced when boron levels in the leaf tissue are lower. The results of this study demonstrated that the highest growth criteria, including plant height, the number of branches/plant, and shoot dry weight, were recorded at concentrations of 75 ppm with three applications at 30, 50, and 70 DAS, while the highest root dry weight was recorded at concentrations of 75 ppm with a single application of boron at 30 DAS, which was statistically comparable to 75 ppm at twice applications at 30 and 50 DAS (Table 2). The height of the plant was greater at the optimal boron fertilization rate than at higher doses, according to Hemantaranjan et al. (2000). This might be because boron is crucial for physiological processes like cell division and elongation, which eventually helped the plant grow taller. Sarkar (2008) demonstrated that boron fertilizer promoted branching. The amount and frequencies of boron had a considerable influence on the BARI Til-4 crop's characteristics at harvest time. The application of 75 ppm boron had the biggest effect on plant height, whereas 0 ppm boron had the lowest effect (Table 3). When boron levels were 75 ppm, the highest branches/plant was observed (Table 3). The highest values for the number of pods/plant and number of seeds/pod were achieved with either 50 ppm or 75 ppm boron, and these two dosages were statistically comparable. The lowest values were discovered in the 0 ppm boron treatment (Table 3). Except biological yield and stover yield on a dry weight basis, the 0 ppm boron treatment showed the least favorable outcomes in terms of seed yield, harvest index, and oil content (Table 3, Figures 1 & 3). Concerning the frequencies of boron treatment, the yield and oil content of BARI Til-4 fluctuated dramatically. When boron was treated three times, at 30, 50, and 70 days after sowing (DAS), the tallest plants were seen, whereas when boron was applied just once, at 30 DAS, the shortest plants were seen. Boron sprays at 30, 50, and 70 DAS, the highest number of branches/plant was observed (Table 3). Aside from that, three treatments of boron at 30, 50, and 70 DAS were found to produce the most pods/plant and seeds/pod, whereas only one application at 30 DAS produced the lowest values (Table 3). The three boron treatments at 30, 50, and 70 DAS resulted in the highest seed production, harvest index, and oil content values (Table 3, Figures 1 & 3).

The features of the BARI Til-4 crop were profoundly impacted by the connection between boron content and dose frequencies. The crop characteristics examined in this study plant height, number of branches/plant, number of pods/plant, number of seeds/pod, seed yield, harvest index, and oil content were shown to be best when 75 ppm of boron was administered three times at 30, 50, and 70 DAS (Table 4, Figure 1 & 3). The findings of the 75 ppm boron administered with a single treatment at 30 DAS are statistically equal to the results of the number of branches/plant and number of pods/plant (Table 4). The interaction between 0 ppm of boron and a single application of boron at 30 DAS produced the highest stover production and biological yield, while the interaction between 75 ppm of boron and three applications of boron at 30, 50, and 70 DAS produced the least favorable results (Table 4 and Figure 2).

Boron is one of the most important micronutrients for the proper growth and development of sesame. Boron deficiency results in fewer and shorter-lasting flowers, slower growth of the pollen tube, and fewer fruits as a result. A sufficient intake of boron increases the dry weight of the petiole and leaves. Capsule dry weight and yield are both greatly improved (Sindoni et al., 1994) and found that boron supplementation reduction only significantly reduced root and shoot dry weight at the 30 day mark, as opposed to boron removal at all ages. The reduction in boron concentration affected the development of seeds as well as the amounts of boron in leaves, sterns, and pods. The amount of boron in the pods and seed weight showed a substantial and linear association.

When the amount of boron in the leaf tissue fell below the necessary level, a significant reduction in the amount of dry matter generated in the shape of the leaves, stems, and roots occurred. However, when the amount of boron in the leaf tissue rose, seed oil content and dry weight declined (Sarkar, 2008; Huq, 2012) and found that the interaction between boron content and frequencies dramatically boosted the number of pods/plant. Pod production/plant could vary depending on how much boron is applied. According to a previous article (Sarkar, 2008), which claimed that boron deficiency resulted in the growth of less fruits, the control plot's lowest seeds/pod yield may be the cause of this. The mineral composition, capsule development, seed production, and stover output of sesame were all affected by the use of boron fertilizer (Bennetti, 1993). Mathew and George (2011) observed that stover yield affected for boron deficiency. Oil content significantly differs in seeds due to boron application (Haque, 2008; Liu et al., 2003).

Conclusion

It might be inferred from the investigation that among the boron treatments 75 ppm boron was found to be the most effective. Thrice (30, 50 and 70 DAS) application of 75 ppm boron had significant impact for improving yield components and increasing the yield of sesame**.** However further research at different Agro-ecological zones and in the *kharif* season is necessary to draw a definite conclusion and for recommendation with respect to application boron fertilizers for sesame cultivation.

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Conflicts of Interest

The writers attest to having no financial or other competing interests to disclose with relation to the current work.

Data Availability Statement

The study's data may be requested from the corresponding author. Since the statistics are being disclosed for the first time, they are not yet available to the general public. The writers are more than happy to provide them upon request.

References

Ahmed AS, Hossain MB. 1999. The problem of boron deficiency in crop production in Bangladesh. Boron in Soils and Plant. Khewer Academy Publication, pp 1-5. https://doi.org/10.1007/978-94-011-5564-9_1

BBS (Bangladesh Bureau of Statistics) 2022. Statistical Yearbook of Bangladesh Statistic Division Ministry of Planning Government of Peoples Republic of Bangladesh.

Bennetti M. 1993. Sesame Research Report 1991-92 Wet Season Katherine Department Industrial Fisheries Technology building Department Prime lndustry And Fisheries Australia, 215, 34.

FAOSTAT. Food and Agriculture Organization statistical databases, 2013. Available online: http://faostat.fao.org

Gardner FP, Pearce RB, Mistechell RL 1985: Physiology of Crop Plants State University p 66

Gomez KA, Gomez AA. 1984. Statistical procedure for agricultural research Second Edition International Rice Researce Institute John Wiley and Sons NewYork, pp 1-340.

Haque MR. 2008. Growth, yield and oil content of sesame as influenced by sulphur and boron fertilization Master's Thesis Department of Agronomy Sher-e-Bangla Agricultural University Dhaka.
Hemantaranjan A, Trivedi AK, Mariram S. 2000. Effect of foliar applied boron and soil applied iron and sulphur on growth and yield of soyabean (*Glycine max*). Indian Journal Plant Physiology, 5 (2), 142-144.
Huq MO. 2012: Effect of sulphur and boron on seed yield of sesame (Sesarnum indicum L.). Master's Thesis Department of Agronomy Bangladesh Agricultural University Mymenensingh
Islam M, Risat M, Jahiruddin. 1997. Direct & residual effect of Zn and Bo yield nutrient uptake in a rice-mustard cropping system Journal Indian Society Soil Science, 45(1), 126-129.
Jamjod S, Niruntrayagul S, Rerkasem B. 2004. Genetic control of boron efficiency in wheat (Triticum aestivum L.). Euphytica 135, 21–27. https://doi.org/10.1023/B:EUPH.0000009541.42762.08
Khanam M, Rahman MM, Islam MK. 2001. Effect of manured and fertilizers on the growth and yield of BRRI dhan 30. Pakistan Journal Science, 4(2), 172-174. https://doi.org/10.3923/pjbs.2001.172.174
Liu P, Yang Y, Yang YA. 2003. Effect of molybdenum and boron on quality of soyabean. Seience Agriculture Science, 36(2), 184-189.
Mathew J, George S. 2011. Sulphur and boron improves yields of oilseed sesame in sandy loam soil of Onattukara Regional Agricultural Research Station Kayamkulam Kerala Better Crops-South Asian, pp 14-15.
Miah MAM, Afroz Rasid, Shiblee SAM. 2015. Factors affecting adaptation of improved sesame technologies in some selected areas in Bangladesh. Scientific Journal Krisi Foundation, 13(1), 140-151. https://doi.org/10.3329/agric.v13i1.26558
Miller WR, Donahue LR. 1997. Soils in our environment. Prentice Hall of India Private Limited New Delhi India 7 Edition, Pp 302-315.
Mohsana. 2009. Effect of different levels of sulfer and boron on the yield and oil content of sesame. Master's Thesis. Department of agronomy, Bangladesh Agricultural University, Mymensingh, p 43 48.
Nayar NM, Mehra KL. 1970. Sesame: Its uses, botany, cytogenetics and origin. Econ. Bot, 24, 20–31.
Paul SK, Khatun MM, Sarkar MAR. 2019. Effect of sulphur on the seed yield and oil content of sesame (*Sesamum indicum* L.). Journal of Bangladesh Agricultural University, 17(1), 33–38. https://doi.org/10.3329/jbau.v17i1.40660
Raja A, Hattab KO, Gurusamy L, Vembu G, Suganya S. 2007. Sulphur application on growth and yield and quality of sesame varieties. International Journal of Agriculture Researce, 2, 599-606. https://doi.org/10.3923/ijar.2007.599.606
Ramirez R, Linares JC. 1995. Boron deficiency symptoms and dry matter production of sesame under greenhouse conditions. Communications in Soil Science and Plant Analysis Venezuela, 26(17/18), 3043-3049. https://doi.org/10.1080/00103629509369507
Russel DF. 1986. MSTAT-C Package Programme Department of Crop and Soil Science Michigan State University, United state of America.
Sanga DL. 2013. Evaluation of soil fertility status and optimization of its management in sesame (*Sesamum indicum* L.) growing areas of Dodoma district. Master's Thesis. Department of Soil science and land management, Sokoine University of Agriculture Morogoro Tanzania.
Sarkar S. 2008. Effect of nitrogen and boron on the growth and yield of sesame Master's Thesis Department of Agronomy Sher-e-Bangla Agricultural University, Dhaka.
Schon MK, Blevins DG. 1990. Foliar boron applications increase the final number of branches and pods on branches of field grown soybeans. Plant Physiology, 92, 602-607.
Sindoni M, Zamora J, Ramirez R. 1994. Symptoms of boron deficiency and dry matter production in sesame Agronomy journal, 44(1), 135-150.
Singh MLG, Anant NK. 1960. Effect of N, P and S on the yield and oil content of sesame. Indian Journal of Agronomy, 4,176-181.
Ssekabembe CK, Osini DSO, Nantongo S. 2002. Overview of the preliminary findings of the sesame project at Makerere University 1998-2002 In: Filth Regional meeting of Forum on Agricultural Resource Husbandry 9 Sept 2002 Kampala Uganda, pp 154-157.