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Response of Different Levels of Boron Fertilizer on Growth and Yield of Okra (*Abelmoschus esculentus* L.)

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Abstract
The study was carried out at the Agricultural Research Field of IUBAT to investigate the impact of varying levels of boron (B) fertilizer on the growth and production of okra (Hybrid Okra-Shomy). The experiment followed a Randomized Complete Block Design (RCBD) with four replications. The experiment included four treatments: T0 (Control), T1 (1kg B ha-1), T2 (2kg B ha-1), and T3 (3kg B ha-1). These treatments were implemented in order to assess the optimal outcomes of the study. The findings of the study showed that T2 (2kgB/hac) treatment performed better in all aspects of growing parameter especially yield contributing traits like number of fruit/plant (89.75), number of fruit/treatment (387.98), individual fruit weight (17.34gm), number of seed/fruit (57.50),100 seed weight (8.15gm), yield/plant (387.98gm), yield/hac (1549.7kg), yield (17.09) ton/hac, Plant fresh weight/plant (524.81gm) and root length (20.40cm), respectively.

1. Introduction

Okra, scientifically known as *Abelmoschus esculentus* L. is a widely consumed vegetable that falls under the family Malvaceae. In Bangladesh, it is commonly referred to as "Dherosh" or "Bhindi." Notably, okra possesses the greatest chromosomal number among vegetables, with a count of 2n=130. In various English-speaking nations, this vegetable is commonly referred to as "ladies' fingers." In the United States of America, it is known as "gumbo," while in Spanish it is called "guino-gumbo," and in Portuguese, it is referred to as "guibeiro" (Benchasr, 2012).The plant known as okra is indigenous to the regions of West Africa and South Asia. The cultivation of this particular vegetable crop holds significant importance in Bangladesh as it serves as a crucial means to fulfill the national need for vegetables, particularly during the summer season when there is a scarcity of vegetables in the market.According to Kumar (2019), the use of fertilizer has a significant impact on the growth and production of this particular crop, indicating that the appropriate use of fertilizer is crucial for achieving

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increased productivity. The immature, green fruits are commonly used as a culinary vegetable, although they may sometimes undergo drying and canning processes for commercial sale. According to Varmudy (2011), a 100 g serving of green tender okra fruits contains 1.76 g of protein, 8.73 g of carbohydrates, 1.1 g of fiber, 88 IU of Vitamin A, 9.8 mg of Vitamin C, 0.70 mg of iron, 59 mg of ascorbic acid, 385.00 μg of β-carotene, 0.25 mg of thiamin, 2.80 mg of riboflavin, and niacin 0.20mg.Dry okra seeds can be roasted and used in place of coffee. Fruits possess therapeutic properties, as they can serve as a plasma replacement or blood volume expander for the treatment of gastrointestinal and inflammatory illnesses, as well as depression. According to Singla *et al*. (2018), okra is known for its high iodine content, which has been found to be effective in preventing goitre disease.

Additionally, nutritionists typically encourage the consumption of okra due to its potential to regulate cholesterol levels and support weight reduction programs.Boron (B) is found to be highly abundant in the soils of Bangladesh, which holds significant importance in the processes of seed production and seed quality. In addition, the presence of boron is essential for the adequate growth and development of plant tissues.

The absence of a particular factor leads to the occurrence of abnormal fruit formation and development. Due to its limited mobility within plants, boron shortage mostly affects the reproductive process of plants, leading to sterility and deformation of reproductive organs. Hence, the incorporation of boron in okra cultivation has the potential to significantly enhance both the quantity and quality of yield. Consequently, this study was conducted to assess the over all impact of boron on the growth and productivity of okra.

2. Material and Methods

Site and Soil Characteristics

The research was conducted at IUBAT Agricultural Research field, IUBAT University from May to September 2019. The objective of the study was to investigate the impact of various levels of boron fertilizer on the growth and yield of Okra. The experiment followed a Randomized Complete Block Design (RCBD) with four replications. The soil in this area is classified as grey terrace according to the USDA soil taxonomy (USDA, 1975).

It belongs to the chhiata soil series within the agroecological zone known as Madhupur Tract (AEZ-28). The chemical properties of the initial soils showed the results like pH 6.6, organic matter 1.2%, N 0.064%, K 0.13 meq/100gm, P 13.4μg g-1, S 13.3 μg g-1,Zn 0.73 μg g-1 and B 0.17 μg g-1 as reported by Habibur *et al.* (2020).

Treatments

The experiment used the Okra hybrid variety called Shomy. The study involved the application of different levels of boron fertilizer as treatments. There were four treatments in total: No application of B (T0), 1kg B/hac (T1), 2 kgB/hac (T2), and 3 kgB/hac (T3). In this study, the application of boric acid fertilizer as a source of boron was done through foliar application. The application was carried out at 15-day intervals, with a total of two applications. The application of fertilizer and manure followed the recommendation of BARI (Bangladesh Agricultural Research Institution).Different amounts of boric acid fertilizer were applied to the plots(1mX1m) at different time intervals. In T0, no boric acid was used. In T1, 0.6gm/plot of boric acid was applied. In T2, the amount of boric acid applied increased to 1.2 gm/plot. Finally, in T3, the highest amount of boric acid, 1.8gm/plot, was used.

The Okra hybrid (Shomy) seeds were sown in a single line. Prior to sowing, the seeds were soaked for 24 hours. Ten days after germination, thinning was carried out to ensure that the plants were spaced 40×30 cm apart. Intermittent intercultural operations, such as weeding and irrigation, were provided as needed. Data have been gathered based on factors thatcontribute to growth and yield.

Data Collection

Data were collected and organized for various parameters related to the plants, including height (cm), stem diameter (cm), number of leaves, leaf area (cm2), leaf length (cm), number of fruits, single fruit weight (gm), fruit length (cm), fruit diameter (cm), number of seeds/fruit, root length (cm), fruit yield/plant, and yield/hectare.

Statistical Analysis

The data collected from various parameters were subjected to statistical analysis using the STATISTIX-10 computer software package in order to determine the significance of the variations seen in the growth and production of okra resulting from varied doses of boron fertilizer. The mean values were determined for each treatment. The assessment of the difference between treatments was conducted using the Least Significant Difference (LSD) test at a significance level of 0.05%.

2. Result and Discussion

The study's findings have been presented, analyzed, and compared using various tables and graphs. Potential interpretations have been provided under the designated headings.

Growth Parameter

Plant Height (cm) and Stem Diameter (cm)

The highest plant height (27.5cm) was found at 30 DAT from T0, which was statistically equivalent to other treatments. The pattern was similarly observed in various treatments on different days. Habibur *et al.* (2020) also reported a comparable outcome, noting that the impact of boron on okra plant height was found to be statistically negligible.No significant variation in stem diameter was seen across the treatments on different days, except at 30 days after treatment (DAT). The present investigation observed that the treatment T0 exhibited the highest stem diameter (7.62 cm) at 90 days, while the treatment labeled as T2 displayed the lowest stem diameter (7.27 cm) (Table 1). The observed disparity in stem diameter suggests a possibility that boron may have a significant effect only on okra yield attributes.

Table 1: Plant height (cm), stem diameter (cm), plant fresh wt (gm), plant dry wt (gm) and root length (cm) of okra as influenced by different level of boron fertilizer.

	Plant height(cm)					**Stem diameter(cm)**							
Treatment	**30DAT**	**45DAT**	**60DAT**	**75DAT**	**90DAT**	**30DAT**	**45DAT**	**60DAT**	**75DAT**	**90DAT**	**Plant fresh weight/plant (gm)**	**Plant dry weight/plant(gm)**	**(cm)**
T_0	27.5a	62.45a	107.31a	132.70a	137.18a	1.43ab	4.18a	6.72a	7.48a	7.62a	468.22a	125a	16.12a
T_1	24.68a	63.63a	106.68a	131.68a	135.31a	1.96a	3.94a	5.99a	7.21a	7.48a	455.25a	125.44a	16.64a
T_2	21.34a	59.68a	98.87a	134.31a	141.06a	1.23b	3.87a	5.97a	7.07a	7.27a	524.81a	121.63a	20.40a
T_3	23.46a	62.23a	105.12a	130.25a	136.43a	1.7ab	4.31a	6.24a	7.28a	7.44a	415.13a	125a	20.40a
CV	**27.04**	**12.27**	**10.25**	**7.65**	**8.51**	**19.35**	**15.76**	**8.90**	**6.80**	**6.59**	19.68	13.36	17.53
LSD	**10.48**	**12.16**	**17.11**	**16.14**	**18.72**	**1.43ab**	**4.18a**	**6.72a**	**7.48a**	**7.62a**	146	25.92	5.16

Plant Wet Weight (g) and Plant Dry Weight (g)

The fresh weight of plants varied significantly as a result of the levels of Boric acid fertilizer applied (Table 1). The findings of the study revealed that the treatment marked as T2 (2kg B ha-1) exhibited the maximum fresh weight (524.81 g)/ plant. In contrast, the treatment designated as T3 (3kg B ha-1) displayed the lowest fresh weight (415.13 g)/plant.

There was a large difference in plant dry weight as a result of B dose (Table 1). The results showed that T1 (1kg B ha-1) had the highest plant dry weight plant-1 (125.44g), whereas T3 (3kg B ha-1) had the lowest (104.88g). Inadequate drying of plant samples could be responsible for some of the observed variations in moisture content within samples.

Root Length (cm)

Maximum root length (20.40cm) was found from both T3 and T2 treatment which implies boron might be the reason for development of root length (Table 1).Similar results were reported by Klikno and Kutschera (2017).

Table 2: The leaf number and leaf area (cm2) of okra as affected by various boron fertilizer levels at different DAT.

	Leaf number					Leaf area (cm2)				
Treatment	**30DAT**	**45DAT**	**60DAT**	**75DAT**	**90DAT**	**30DAT**	**45DAT**	**60DAT**	**75DAT**	**90DAT**
T_0	7.28ab	10.83a	14.71a	15.68a	18.31a	92.38a	390.71a	633.54a	645.34a	92.38a
T_1	8.32a	10.25a	14.81a	15.93a	16.88a	106.24a	413.05a	605.19a	612.40a	106.24a
T_2	6.5b	10.43a	12.87a	17a	18.37a	81.47a	366.38a	612.47a	618.15a	81.47a
T_3	7.08ab	10.17a	13.37a	16.75a	17.75a	90.21a	410.93a	626.57a	622.81a	90.21a
CV	**12.98**	**14.19**	**12.30**	**12.30**	**10.38**	**31.12**	**17.13**	**11.96**	**11.91**	**31.12**
LSD	**1.51**	**2.36**	**2.74**	**2.74**	**2.95**	**40.57**	**40.33**	**21.42**	**22**	**40.57**

Number of Leaves and Leaf Area (cm2)

At final harvesting time highest number of leaves (18.37) were found in T2, whereas lowest (16.88) in T1 treatment. The maximum leaf area was found in T0 (645.3cm2) and minimum of 612.4cm2 with T1 (Table 2), though all are statistically similar and other study reported significant influence of boron on number of a leaf (Siddiq *et al.,* 2019).

Yield and Yield Contributing Character

Number of Fruit/Treatment and Number of Fruit/Plant

The number of fruits/plant is a crucial yield attribute that has a strong correlation in achieving higher yield.Table 3 showed thatthe highest number of fruit/plant was recorded in T2 (89.75), followed by T1 (80.25). On the other hand, the lowest number of fruit/plant was observed in T3 (75.75) (Table 3). Based on the available data, it appears that the application of boron@ 2 kg/hac significantly increased the quantity of fruit produced. Similar results were also reported by Nusrat *et al.,* (2020). The number of fruit/treatment ranged from 75.75 to 89.75(Table 3). The maximum number of fruit (387.9) was observed in treatment T2, while the minimum (319.32) was found in treatment T1.

This difference in fruit yield among the treatments was statistically significant. (Table 3) and boron @2 kg/hac was linked to enhanced performance, which may have resulted from a synergistic interaction with other fertilizers used.The findings of Al-dulaimi *et al*. (2017) and Habibur *et al*. (2020) align with the results mentioned in the present study.

Table 3: Okra yield contributing characteristics as affected by different levels of Boron fertilizer

Treatment	Total number of fruit/Plant	Number of fruits/treatment($4m^2$)	Fruit length(cm)	Fruit diameter (cm)	Individual fruit wt.(gm)	Number of seed/fruit	100-seed weight(gm)	Yield(gm)/plant	Yield gm/plot ($4m^2$)	Yield(kg/hac)	Yield(ton/hac)
T_0	79.56a	329c	11.35a	6.12a	15.91c	54.39ab	7.99a	329.8c	5334.7b	13410.1c	14.59c
T_1	80.25a	319.32d	9.86a	5.22bc	15.30d	47.00bc	7.62a	319.32d	5117.8c	12778.7d	14.12d
T_2	89.75a	387.98a	11.24a	5.94ab	17.34a	57.50a	8.15a	387.98a	6174.2a	1549.7a	17.09a
T_3	75.75a	3352.45b	9.79a	5.18c	16.79b	41.75c	7.40a	352.5b	5314.1b	1409.3b	15.50b
CV	12.53	0.73	9.08	8.25	1.71	11.54	6.15	0.73	0.04	0.00	0.96
LSD	16.03	4.07	1.53	0.74	0.4	9.26	0.76	4.07	60.92	1.04	0.234

Fruit Length (cm) and Fruit Diameter (cm)

As a result of varying levels of boron fertilizer, little variation in okra fruit length was seen. The findings of the study showed that the treatment marked as T0 revealed the highest fruit length (11.35cm) at the marketable stage.Conversely, the treatment labeled as T3, which involved the application of 3kgB/hac, resulted in the lowest fruit length (9.79cm) (Table 3) which implies insignificant influence of boron on fruit length of okra.It is worth noting that Habibur *et al*. (2020) and Mahrin *et al*. (2022) have found a significant influence of boron on okra fruit length as highlighted by Muhammad *et al.* (2019).

Excitingly, the application of various doses of Boron fertilizer led to a significant variation in fruit diameter (Table 3). Results showed that the highest fruit diameter (6.12 cm) was observed in the T0 (Control) treatment where no boron fertilizer was added, which is statistically similar to the T2 treatment. The lowest fruit diameter (5.18cm) was found in the T3 treatment with 3 kgB/hac followed by T1 treatment (Table 3).

Individual Fruit Weight (g)

The effect of various levels of Boron fertilizer on the weight of a single fruit exhibited significant variation (Table 3). The highest individual fruit weight (17.36g) was observed in T2 (2kg B ha-1) and the lowest individual fruit weight (15.94cm) was observed in T1 (1kg B ha-1). This variation suggests that there are differences in the vegetative growth, which can be influenced by 2kgBoric acid/hac and potentially lead to variations in photosynthesis and ultimately fruit weight. Previous research has also documented comparable results in the context of okra (Habibur *et al*., 2020).

Number of Seed/ Fruit

The number of seeds/fruits was notably affected by the varying levels of boron fertilizer, as indicated in Table 3. T2 treatment produced the maximum number of seeds/fruits, with a value of 57.50 and T3, application of 3kgB/hac, exhibited the lowest number of seeds/fruits, with a value of 41.75 as also reported by Habibur *et al*. (2020).

100 Seed Weight (g)

The results showed that the T2 treatment had the most seeds (8.15gm) and that the T3 treatment (3kg B ha-1) had the least (7.40gm) (Table 3). A similar finding was also reported by Habibur *et al.* (2020), who noted that boron's ability to transfer carbohydrates through cell membranes had an impact on the weight of okra seeds.

Yield of Okra

The quantity of fruits, the weight of each fruit, and the fruit yield interact in a complex way to produce the yield. The T2 crop had the highest yield (387.98gm/plant, 6174.2gm/pot, 1549.7kg/hac, and 17.09 ton/hac), while the T1 crop had the lowest yield (319.32 gm/plant, 5117.8gm/plot, 1277.7kg/hac, and 14.12 ton/hac, respectively) with respect to the amount of boron fertilizer applied (Table 3). This indicates that inadequate or unbalanced micronutrient utilization is one of the main causes of the low yield of okra, as also noted by Ali (2012). The treatment T2 showed the highest result in regard to seed yield and most of the yield features of okra, which further suggests that boron @2kg/hac is an effective dose for enhancing okra yield.The present findings support previous research conducted by Bhupenchandra *et al*. (2022), Narayani and Kumar (2023) and Sarker *et al*. (2018), which proposed that boron could have facilitated the absorption of nutrients by increasing photosynthesis. This, in turn, bumped the number of fruits and plant growth, ultimately leading to an increase in okra yield.

4. Conclusion

The present study generated information that could potentially help in the production of okra in an efficient manner. Based on the aforementioned findings, it can be inferred that treatment T2 (2 kg B ha-1) exhibited superior efficacy in promoting the growth, development, and production of okra. Notably, this treatment demonstrated the highest yield (17.08t ha-1), hence establishing its superiority over the other treatments examined in the current study.

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Conflict of interest

The authors declare no potential conflict of interest regarding the publication of this work.

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