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Impact of Foliar Application of Boron and Zinc on Growth, Quality and Seed Yield of Okra

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Abstract: The experiment was carried out in the field of Horticulture Research Centre (HRC), Bangladesh Agricultural Research Institute (BARI), Gazipur to evaluate the effect of foliar application of boron (B) and zinc (Zn) on growth, yield attributes, quality and seed yield of okra. The experiment was planned with 16 treatment combinations comprising four levels each of B (0, 0.1, 0.2 and 0.3% borax, respectively) and Zn (0, 0.1, 0.2 and 0.3% zinc sulphate, respectively) along with the blanket dose of fertilizers of N, P, K, S and cow dung at 120, 40, 80, 20 and 10000 kg ha^{-1}, respectively were used in all treatments. The two factor experiment was laid out in the randomized complete block design with three replications. Results revealed that the foliar application of boron and zinc either single or in combination had significant effect on yield, yield attributes and quality of okra seed. Most of the yield attributes of okra were significantly increased by the combined foliar application of borax and zinc sulphate up to 0.2% borax and 0.2% zinc sulphate. The highest seed yield (2.52 t ha^{-1}) was obtained from the treatment combination of 0.2% borax and 0.2% zinc sulphate followed by the treatment combination of 0.2% borax and 0.3% zinc sulphate. The highest oil content (16%) in seed was also produced from the same treatment (0.2% borax and 0.2% zinc sulphate). The improved protein content (17.75%) was found in combination of 0.1% borax and 0.3% zinc sulphate. The combined foliar applications of zinc and boron fertilizers were detected superior to their single application. The results suggest that the combination of 0.2% borax and 0.2% zinc sulphate could be used as foliar for seed yield maximization of okra. Hence, the foliar fertilization rates of zinc sulphate should be increased for okra production.

Keywords: Boron and Zinc, Quality, Yield Attribute, Okra Seed Yield

1. Introduction

Okra (*Abelmoschus esculentus L.)* is a nutritious summer vegetable in Bangladesh. One of the main constraints of okra production is lack of quality seed. Quality seed is the key requirement of successful crop production. By using quality seed, production can be increased up to 15-50% [1, 2]. In Bangladesh, the estimated annual requirement of okra seed is about 300-400 tones [3, 4]. Observation denoted that Bangladesh Agricultural Development Corporation (BADC) and private seed companies produced about 25% of the total okra seed; another 25% seeds are imported. The rest 50% seeds are farmer's own produced seeds. The farmer's preserved seeds are, in most cases, of inferior quality and used of these poor quality seeds are responsible for low yield in Bangladesh [5]. Several factors like genetically purity; balanced fertilization including micro nutrient, preventive measure the pest and disease infestation and appropriate cultural management contributed to achieve higher yield of good quality seed. Micronutrients such as boron and zinc both are played significant role for producing good quality vegetable seed. Foliar application of micronutrient to the crops is a good option which immediate fulfills the specific nutrient deficiency. A number of studies have highlighted the benefits of foliar fertilization in improving plant growth, crop yield, nutrient uptake and product quality [6, 7, 8]. Foliar application is the best way to nourish plants that grow in soil with poor quality due to adverse pH [9]. The zinc and boron deficiency in soils of Bangladesh is most prevalent [10]. Boron and zinc influences directly or indirectly for improving the yield and quality seed production of okra [11]. Boron is required for proper development and differentiation of plant tissues [12]. The absence of boron abnormal formation and development of fruit occur. Since boron is relatively immobile in plants, the early casualties of boron deficiency occur in the reproductive process of plants, in addition to male sterility, pistil sterility is happened due to boron deficiency [13, 14]. Boron facilitates the transport of carbohydrates through cell membranes. It is involved in flowering and fruiting of the plant. Boron deficiency affects the growing points of roots and youngest leaves [15, 16]. Maximum production of starch and sugar is restricted if crops are suffered inadequate supply of boron [17]. Zinc mainly functions as the metal component of a series of enzymes, chlorophyll synthesis and cell membrane integrity. The most important enzymes activated by this element are carbonic anhydrase and a number of dehydrogenases [18]. Zinc deficiency is thought to restrict RNA synthesis, which in turn inhibits protein synthysis [19]. Zinc is also involved in auxin production and flower and fruit setting [20]. Zinc application also helps in increasing the uptake of nitrogen and potash. Zinc provides a protective mechanism against the excessive uptake of boron. Zinc is necessary for root cell membrane integrity, and its function, it prevents excessive P uptake by roots and transport of P from roots to leaves [21]. Information about the effects of boron and zinc in soil applications are available but the foliar application of boron and zinc on growth, quality and seed yield of okra is inadequate in Bangladesh. Hence, the study was undertaken to find out the effective foliar spray dose of boron and zinc on growth, quality and seed yield maximization of okra.

2. Materials and Methods

2.1. Experimental Site and Soil

The experiment was conducted during April 2013 to September 2013 at the field of Horticulture Research Centre (HRC), Bangladesh Agricultural Research Institute (BARI), located in the moist monsoon subtropical region of Gazipur (24° 0′ 13″ N latitude; 90° 25′ 0″ E longitude) at an elevation of 8.4 m above sea level. The soils in this area are classified as grey terrace according to the USDA Soil Taxonomy [22] and belong to the chhiata soil series under the agroecological zone - Madhupur Tract (AEZ-28). The experimental site has a typical tropical and sub-tropical continental monsoon climatic condition. It is characterized by comparatively high monsoon rainfall, high humidity, and high temperature [23]. The mean annual air temperature is 31.9^0 C. The mean annual precipitation is 451.8 mm, with approximately 72.9% occurring from June to October.

Before starting the experiment, initial soil sample (0-15 cm) of the experiment was analyzed and the chemical properties are presented in the Table 1.

Table 1. *Initial nutrient status of the experimental soil.*

Location	pH	OM%	Ca	Mg	K	Total N%	P	S	Zn	B
			meq 100 g^{-1}				µg g^{-1}			
Gazipur	6.6	1.20	6.0	2.3	0.13	0.064	13.4	13.1	0.73	0.17
Critical level	-	-	2.0	0.50	0.12	0.12	7.0	10	0.6	0.2
Interpretation*	Slightly acidic	Low	Optimum	Very high	Low	Very low	Medium	Medium	Low	Low

*Fertilizer Recommendation Guide, [18]

2.2. Land Preparation, Treatments, Design and Layout

A tractor operated disc plough was used for open the land. After that the land was prepared thoroughly by tractor operated rotavetor followed by laddering and leveling. The experiment was planned with 16 treatment combinations comprising four levels each of B (0, 0.1, 0.2 and 0.3% borax, respectively) and Zn (0, 0.1, 0.2 and 0.3% zinc sulphate, respectively) along with the blanket dose of fertilizer of N, P, K, S and cow dung at 120, 40, 80, 20 and 10000 kg ha^{-1}, respectively was used in all treatments. The treatments were arranged viz. $T_1=B_0Zn_0$; $T_2=B_0Zn_{0.1}$; $T_3=B_0Zn_{0.2}$; $T_4=B_0Zn_{0.3}$; $T_5=B_{0.1}Zn_0$; $T_6=B_{0.1}Zn_{0.1}$; $T_7=B_{0.1}Zn_{0.2}$; $T_8=B_{0.1}Zn_{0.3}$; $T_9=B_{0.2}Zn_0$; $T_{10}=B_{0.2}Zn_{0.1}$; $T_{11}=B_{0.2}Zn_{0.2}$; $T_{12}=B_{0.2}Zn_{0.3}$; $T_{13}=B_{0.3}Zn_0$; $T_{14}=B_{0.3}Zn_{0.1}$; $T_{15}=B_{0.3}Zn_{0.2}$ and $T_{16}=B_{0.3}Zn_{0.3}$. The spray treatments were clarified as B_0 = 0% borax (as 0% boron), $B_{0.1}$= 0.1% borax (as 0.01% boron), $B_{0.2}$= 0.2% borax (as 0.02% boron), $B_{0.3}$= 0.3% borax (as 0.03% boron) and Zn_0 = 0% zinc sulphate (as 0% zinc), $Zn_{0.1}$ = 0.1% zinc sulphate (as 0.04% zinc), $Zn_{0.2}$ = 0.2% zinc sulphate (as 0.07% zinc), $Zn_{0.3}$= 0.3% zinc sulphate (as 0.11% zinc). The two factor experiment was laid out in the randomized complete block design with three replications. The sources of N, P, K, S, B and Zn were urea, TSP, MoP, gypsum, boric acid and zinc sulphate, respectively. The unit plot size was 4 m × 2.4 m, where 40 plants were accommodated in each plot at a spacing of 60 cm × 40 cm. Two adjacent unit plots were separated by 70 cm space, and there was 100 cm space between the blocks.

2.3. Preparation of B and Zn Spray Solution and Application Method

As per the treatment details one gram of borax was dissolved in one litre water in a container to make 0.1 per cent borax solution and one gram of zinc sulphate was dissolved in one litre of water in another container to make the concentration of 0.1 per cent zinc sulphate solution. Similarly two grams and three grams of borax and zinc sulphate were dissolved in one litre of water to make 0.2% and 0.3% borox and zinc sulphate solution, respectively. Then all the micronutrient solutions were used to spray. The foliar spray was given for three times first before flowering at 32 DAS, second after third picking, at 85 DAS and third one at 15 days after second spray. On the other hand, full dose of cowdung, TSP, gypsum, ½ of MoP and ¼ of urea were applied during final land preparation. Remaining MoP was applied at 40 days after sowing. Rest of urea was applied with 3 equal splits at 20, 40 and 60 days after sowing.

2.4. Seed Sowing and Agronomic Practice

The test crop variety was BARI Dharosh-1. Healthy seeds were sown in a line maintaining plant to plant distance of 40 cm and three seeds were sown per pit. After 12 days of sowing (5-6 leaves stage), comparatively weak seedlings were removed from each pit and finally only one healthy and vigorous seedling was kept in a pit. Two hand weedings were done for all plots at 25 and 60 days after sowing. The disease influx was managed by spraying the fungicide Secure 600 wg @ 0.2% two times at an interval of 10 days start at flowering stage. The insect (pod borer and aphid) infestations were controlled by spraying Karate @ 0.2% two times at 10 day intervals start at fruit bearing stage. Irrigation was applied as and when required. Seeds were collected after picking the mature fruits.

2.5. Data Collection Procedure

2.5.1. Seed Collection

Seeds were collected manually from the fruits and cleaned, graded and sun dried for 4 days to attain the acceptable moisture level as close to 8% measured by Seed Buro moisture meter (12 Series Moisture Tester, Model-1200).

2.5.2. Plant Height

The height of the plant was measured with a meter scale taking 10 plants randomly selected from a treatment plot when harvesting of fruits was completed. Average height was determined adding the total length of all the 10 plants and dividing by ten.

2.5.3. Number of Fruits Per Plant

The number of fruit per plant was recorded by counting all fruits harvested from ten plants randomly selected in each treatment plot and was divided by ten.

2.5.4. Length of Fruit

The length of fruit was determined by measuring the vertical length of the fruit by using a 30 cm (12 inch) ruler. Average length of fruit was determined by adding the total length of the fruit divided by the total number of fruits harvested separately from ten plants which selected randomly in each treatment.

2.5.5. Girth of Fruit

The girth of fruit was determined by measuring the width of the same fruit by using a digital slide calipers. Average girth of fruit was determined by sum of the total diameter of fruits divided by the total number of fruits harvested separately from ten plants which selected randomly in each treatment.

2.5.6. Thousand Seed Weight

Thousand seed weight (g) was determined by the counting of 500 seeds randomly from each plot and was weighing through electronic balance and converting it into 1000-seed weight.

2.5.7. Seed Yield per Hectare

The seed yield per plot was recorded, and then per plot yield was converted into t ha^{-1}.

2.5.8. Protein Content in Seed

Protein content of seeds was estimated following the method described by Lowery et al. [24]. One gram of each seed sample was soaked in distilled water for 4 hours and then crushed. After crushing, distilled water was added up to a volume of 100 ml. Then filtrate was defatted by adding diethyl ether. Then 0.4ml of the supernatant was pipetted in a test tube containing freshly prepared Folin-Ciocalteau Phenol reagent. The mixture of these three solutions was then shaken and allowed to stand for 30 minute. The optical density was measured in a spectrophotometer at 750 nm. Bovin Serum albumin was used to plot a standard curve for estimation of protein content in the solution. Each sample was replicated three times. Samples have been preserved for next analysis. Protein content was determined quarterly.

2.5.9. Oil Content in Seed

The oil percentage was estimated following Gadgil et al. [25] method from moisture-free seed meal by solvent extraction using other petroleum ether (boiling point 60°C to 80°C) in a Soxhlet appratus for eight hours. The meal was pre-dried (60°C; 24 hours). Two grams of meal were used for the estimation of oil. No further oil was recovered from the residue after eight hour of refluxing.

2.6. Soil Sample Collection and Analysis

Initial soil sample (0-15 cm depth) of three locations were collected and brought to the laboratory and spread on a brown paper for air drying. The air-dried soil samples were ground and passed through a 2-mm sieve. The sieving soil samples were kept into plastic container with proper label for chemical analysis. Soil pH was measured by glass electrode pH meter using soil: water ratio of 1: 2.5 [26]. Organic carbon was determined following the wet oxidation method as described by Page et al. [26] and the organic matter content was calculated by multiplying the% organic carbon with the Van Bemmelen factor 1.73. Total N by Microkjeldahl method [27]; available P was determined following Bray and Kurtz [28] method; exchangeable K by 1N NH_4OAc method [29]; exchangeable Ca by 1N NH_4OAc method [30]; available S by turbidity method using $BaCl_2$ [31]; available Zn by DTPA method [32]; available B by azomethine-H method [26].

2.7. Statistical Analysis

Collected data were analyzed statistically using MSTAT-C computer package program. The significance of the difference among the treatments was estimated by Duncan's Multiple Range Test (DMRT) at 5% level of probability [33].

3. Results

3.1. Main Effect of Boron

Insignificant variation was observed in the plant height due to foliar application of boron (Table 2). It was observed that the plant height was gradually increased with the increasing levels of borax application. Results reveal that the highest plant height (159.37cm) was recorded with 0.3% borax application where as it was the lowest (155.91 cm) from control. Number of fruits per plant is very important yield attribute which significantly correlated to achieve higher seed yield of okra. However, the number of fruits per plant was affected significantly by different rates of boron containing fertilizer. This study result showed that the highest number of fruit per plant (18.51) was observed with the level of B (0.2% borax), which was statistically identical with 0.3% borax and it was the lowest (17.27) with no borax application. The fruit length of okra showed significantly difference due to foliar application of boron. The highest fruit length (16.83 cm) was recorded from plants treated with 0.2% borax which was statistically similar with 16.72 cm from 0.3% borax, while it was the lowest (15.65 cm) when no borax was applied (Table 2). There was no significant variation among the treatments in fruit girth of okra due to foliar application of borax (Table 2). From the study, fruit girth was ranged from 1.72 cm to 1.79 cm among the borax rates. Maximum fruit girth (1.79 cm) was recorded with 0.2% borax followed by (1.77 cm) with 0.3% borax, while minimum (1.72 cm) was found from control treatment. The number of filled seeds per fruit was significantly influenced by different levels of borax application. From the study number of seeds per fruit was varied from 55.96 to 58.83 among the levels of borax, and the highest number of filled seeds per fruit (58.83) was obtained from 0.2% borax, which was statistically comparable with 0.3% borax (58.79) while minimum (55.96) was recorded with no application of borax (Table 2).

Table 2. *Main effect of boron as foliar application on growth and yield attributes of okra.*

Treatments	Plant height (cm)	No. of fruits plant^{-1}	Fruit length (cm)	Fruit girth (cm)	No. of seeds fruit^{-1}
B_0	155.91	17.27 c	15.65 c	1.72	55.96 b
$B_{0.1}$	157.68	17.85b	15.98 b	1.75	57.17ab
$B_{0.2}$	159.34	18.51a	16.83 a	1.79	58.83a
$B_{0.3}$	159.37	18.40a	16.72 a	1.77	58.79a
Level of significance	NS	*	**	NS	**
CV (%)	-	2.25	3.62	-	2.23

Note: B_0 = 0% borax (as 0% boron), $B_{0.1}$ = 0.1% borax (as 0.01% boron), $B_{0.2}$ = 0.2% borax (as 0.02% boron), $B_{0.3}$ = 0.3% borax (as 0.03% boron)

The seed weight was also significantly correlated to reflect the higher yield of okra. Marked variation in 1000-seed weight was found due to foliar application of B containing fertilizer. The highest 1000-seed weight (59.27g) was observed from 0.3% borax and the lowest (56.04 g) was recorded from no application of borax (Table 3). Protein content of seeds was differed significantly due to B application. It was increased with increasing level of borax up to 0.2% and then decreased (Table 3). The highest (17.66%) content of protein was found in 0.2% borax application, which was statistically identical with 0.3% borax (17.64%) and the lowest (16.78%) was in control. Slight variation was observed among the treatments in respect of oil content of seeds due to borax application, but it was showed insignificant. It is increased with increasing the level of borax. The highest oil content (15.91%) was observed with 0.3% borax followed by 0.2% borax (15.90%), whereas the lowest (15.14%) was noted with no borax application (Table 3). The seed yield of okra responded significantly to the application of different levels of borax. The experiment results reveal that the highest yield of seed (2.39 t ha^{-1}) was obtained from 0.2% borax which was statistically similar with 0.3% borax (2.37 t ha^{-1}) and the lowest (2.00 t ha^{-1}) was from no borax application (Table 3).

Table 3. *Main effect of boron as foliar application on seed yield and quality attributes of okra.*

Treatment	1000 -seed wt. (g.)	Protein content in seed (%)	Oil content in seed (%)	Seed yield (t ha^{-1})
B_0	56.04c	16.78b	15.14	2.00c
$B_{0.1}$	57.45b	17.43a	15.59	2.17b
$B_{0.2}$	59.21a	17.66a	15.90	2.39a
$B_{0.3}$	59.27a	17.64a	15.91	2.37a
Level of significance	*	**	NS	**

Treatment	1000 -seed wt. (g.)	Protein content in seed (%)	Oil content in seed (%)	Seed yield (t ha^{-1})
CV (%)	0.65	1.74	-	2.28

Note: B_0 = 0% borax (as 0% boron), $B_{0.1}$ = 0.1% borax (as 0.01% boron), $B_{0.2}$ = 0.2% borax (as 0.02% boron), $B_{0.3}$ = 0.3% borax (as 0.03% boron)

3.2. Main Effect of Zinc

Plant height was increased due to use of Zn containing fertilizer; however it was non-significant (Table 4). It was recorded highest (158.68 cm) in 0.3% zinc sulphate application and lowest (157.07 cm) in control. Significant variation was observed in respect of number of fruit per plant due to the foliar application of zinc sulphate. Number of fruit per plant was the maximum (18.39) in 0.3% zinc sulphate, while the lowest in (17.33) in control (Table 4). Regarding length of okra fruit, it was showed similar trend of number of fruit per plant. This study showed that it was ranged from 16.04 to 16.45 cm across the treatments; fruit per plant was the highest (16.45 cm) with 0.3% zinc sulphate and 0.2% zinc sulphate (16.44 cm) application both was statistically similar and the control having the lowest (16.04 cm). Fruit girth was increased with increasing level of zinc sulphate application (Table 4) up to 0.2% and then decreased. The okra plant got with 0.2% zinc sulphate by foliar application was produced the highest fruit girth (1.79 cm), while the lowest (1.73 cm) was found from no application of zinc sulphate. The number of filled seeds per fruit was increased with the increasing levels of zinc sulphate application up to 0.3% (Table 4). The highest number of filled seeds per fruit (58.69) was recorded from 0.3% zinc sulphate, which was statistically similar with 0.2% zinc sulphate (58.55), whereas the lowest (56.17) was recorded with no zinc sulphate application (Table 4).

Table 4. *Main effect of foliar application of zinc on growth and yield attributes of okra.*

Treatments	Plant height (cm)	No. of fruits $plant^{-1}$	Fruit length (cm)	Fruit Girth (cm)	No. of seeds $fruit^{-1}$
Zn_{0}	157.07	17.33 b	16.04 c	1.73	56.17 b
$Zn_{0.1}$	157.91	18.00 a	16.26 b	1.76	57.33 ab
$Zn_{0.2}$	158.62	18.32 a	16.44 a	1.79	58.55 a
$Zn_{0.3}$	158.68	18.39 a	16.45 a	1.75	58.69 a
Level of significance	NS	*	**	NS	*
CV (%)	-	2.25	3.62	-	2.23

Note: Zn_0 = 0% zinc sulphate (as 0% zinc), $Zn_{0.1}$ = 0.1% zinc sulphate (as 0.04% zinc), $Zn_{0.2}$ = 0.2% zinc sulphate (as 0.07% zinc), $Zn_{0.3}$= 0.3% zinc sulphate (as 0.11% zinc)

Thousand seed weight was ranged from 57.17 g to 58.47 g across to different zinc sulphate rates of foliar application, while the highest 1000 seed weight (58.38 g) was recorded from 0.2% zinc sulphate which was statistically similar with 0.3% zinc sulphate (58.47 g) and the lowest (57.17 g) was recorded from the control plot (Table 5). The effect of zinc sulphate application had also significant effect on protein content of seed (Table 5). The foliar application of 0.3% zinc sulphate showed significantly superiority to increase protein content (17.50%) in seeds and control treatment showed the lowest protein content (17.14%) in seed. Foliar application of zinc sulphate had no significant effect on oil content in seed of okra. It was the highest (15.75%) in 0.2% zinc sulphate application and the lowest (15.45%) was in control. In case of seed yield, significantly maximum seed yield 2.33 t ha^{-1} was recorded under foliar application of 0.3% zinc sulphate which was statistically at par the treatment receiving of 0.2% and 0.1% zinc sulphate, respectively. The lowest seed yield 2.05 t ha^{-1} was recorded from the control treatment (Table 5).

Table 5. *Main effect of foliar application of zinc on yield contributing and quality characters of okra seed.*

Treatments	1000-seed wt. (g.)	Protein content in seed (%)	Oil content in seed (%)	Seed yield (t ha^{-1})
Zn_0	57.17 b	17.14 b	15.45	2.05 b
$Zn_{0.1}$	57.94 a	17.38 ab	15.62	2.21 a
$Zn_{0.2}$	58.38 a	17.49 a	15.75	2.32 a
$Zn_{0.3}$	58.47 a	17.50 a	15.74	2.33 a
Level of significance	*	**	NS	**
CV (%)	0.65	1.74	-	2.28

Note: Zn_0 = 0% zinc sulphate (as 0% zinc), $Zn_{0.1}$ = 0.1% zinc sulphate (as 0.04% zinc), $Zn_{0.2}$ = 0.2% zinc sulphate (as 0.07% zinc), $Zn_{0.3}$= 0.3% zinc sulphate (as 0.11% zinc)

A polynomial relationship was observed between seed yield and application rates of borax. The seed yield trend of okra was increased significantly positive between the applications of 0.2% to 0.3% borax to the okra plant, but the trend of seed yield was showed statistically similar between the borax rates of 0.2% to 0.3% (Figure 1). A polynomial relationship was also detected in between seed yield of okra and foliar application rates of zinc sulphate. The trend of okra seed yield was exhibited highly positive but statistically similar between applications of 0.2% to 0.3% zinc sulphate (Figure 2). Therefore, the optimum dose of zinc containing fertilizer will be estimated after the rearrange the rates of zinc sulphate in future study.

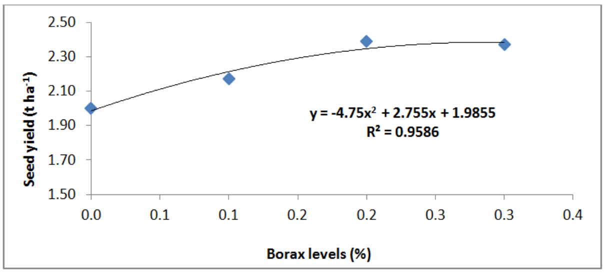

Figure 1. *Relationship between borax application and seed yield of okra.*

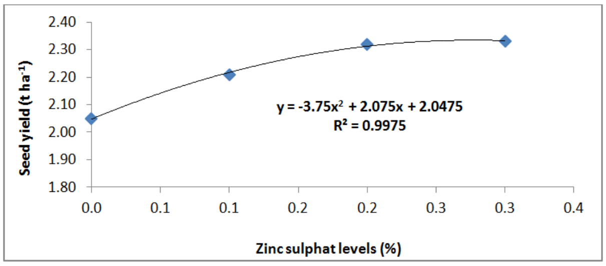

Figure 2. *Relationship between zinc sulphat application and seed yield of okra.*

3.3. Interaction Effect of Boron and Zinc

The interactions between boron with zinc were not noticed significant in increasing in plant height of okra. The tallest plant (160.00 cm) was recorded from the treatments of T_{11} and T_{12}, while the dwarf plant (155.31 cm) was found in control (T_1) treatment (Table 6). The interaction effect of boron and zinc was significant on number of fruits per plant. Significantly the highest number of fruits per plant (19.00) was recorded from T_{11}=$B_{0.2}Zn_{0.2}$ treatment which was statistically identical to T_{12}, T_{14}, T_{15}, T_{16}, T_{10}, T_8 and T_7 treatments and the lowest number of fruit per plant (17.05) was found in control (T_1) treatment (Table 6). Length of fruit was also influenced by combined application of boron and zinc. Results reveal that maximum fruit length (17.00 cm) was found in the treatments of T_{11}, T_{12} and T_{15} those were significantly different with the other treatment but statistically identical to T_{14} and T_{10} treatments and the minimum fruit length (15.55 cm) was found in control (T_1) treatment. The interactions between boron and zinc did not influenced significantly on the fruit girth of okra. From the study, the fruit girth ranged from 1.71 cm to 1.82 cm across the treatments. The highest fruit girth was (1.82 cm) found in T_{11} treatment, while the lowest (1.71 cm) in control (Table 6). Results obtained on filled seed per fruit varied significantly due to application of both boron and zinc. Significantly the highest number of filled seeds per fruit (59.86) was noted from T_{11} (combination of 0.2% borax and 0.2% zinc sulphate) which was statistically similar to most of the cases and the lowest (55.00) from no borax and zinc sulphate application (Table 6).

Table 6. *Interaction effect of foliar application of boron and zinc on growth and yield attributes of okra.*

Treatments	Plant height (cm)	No. of fruits plant^{-1}	Fruit length (cm)	Fruit girth (cm)	No. of seeds fruit^{-1}
T_1=B_0Zn_0	155.31	17.05d	15.55d	1.71	55.00c
T_2=$B_0Zn_{0.1}$	155.38	17.31d	15.60d	1.71	55.30bc
T_3=$B_0Zn_{0.2}$	156.50	17.43cd	15.75d	1.75	56.78abc
T_4=$B_0Zn_{0.3}$	156.45	17.31d	15.70d	1.70	56.75abc
T_5=$B_{0.1}Zn_0$	156.40	17.30d	15.70d	1.67	55.70bc
T_6=$B_{0.1}Zn_{0.1}$	157.66	17.60bcd	15.70d	1.75	56.50abc
T_7=$B_{0.1}Zn_{0.2}$	158.00	18.00a-d	16.00c	1.78	57.80abc
T_8=$B_{0.1}Zn_{0.3}$	158.65	18.50abc	16.50b	1.78	58.70abc
T_9=$B_{0.2}Zn_0$	158.60	17.50bcd	16.45b	1.78	57.00abc
T_{10}=$B_{0.2}Zn_{0.1}$	158.75	18.58ab	16.87a	1.78	58.88ab
T_{11}=$B_{0.2}Zn_{0.2}$	160.00	19.00a	17.00a	1.82	59.86a
T_{12}=$B_{0.2}Zn_{0.3}$	160.00	18.95a	17.00a	1.79	59.57a
T_{13}=$B_{0.3}Zn_0$	158.00	17.45cd	16.45b	1.74	57.00abc
T_{14}=$B_{0.3}Zn_{0.1}$	159.85	18.50abc	16.85a	1.79	58.65abc
T_{15}=$B_{0.3}Zn_{0.2}$	159.97	18.84a	17.00a	1.80	59.76a
T_{16}=$B_{0.3}Zn_{0.3}$	159.65	18.81a	16.60b	1.75	59.74a
Level of significance	NS	*	**	NS	*
CV (%)	-	2.25	3.62	-	2.23

Note: B_0 = 0% borax (as 0% boron), $B_{0.1}$ = 0.1% borax (as 0.01% boron), $B_{0.2}$ = 0.2% borax (as 0.02% boron), $B_{0.3}$ = 0.3% borax (as 0.03% boron)
Zn_0 = 0% zinc sulphate (as 0% zinc), $Zn_{0.1}$ = 0.1% zinc sulphate (as 0.04% zinc), $Zn_{0.2}$ = 0.2% zinc sulphate (as 0.07% zinc), $Zn_{0.3}$= 0.3% zinc sulphate (as 0.11% zinc)

The thousand seed weight and protein content in seed was responded significantly to foliar applications of different doses of borax and zinc sulphate (Table 7). The results indicated that the highest 1000-seed weight (59.98g) was noted from the plants produced in T_{11} treatment which was statistically as same as T_{10}, T_{12}, T_{14}, T_{15} and T_{16} treatments and the lowest (55.55 g) was recorded from control (no borax and zinc sulphate application) treatment. The highest protein content (17.75%) produced in seed with T_8 (combination of 0.1% borax and 0.3% zinc sulphate) treatment, which was statistically alike to T_{11}, T_{12}, T_{13}, T_{14}, T_{15}, T_{16}, T_{10}, T_9, T_7 and T_6 treatments and the lowest (16.52%) was produced in seeds with no borax and zinc sulphate application (Table 7). No significant difference was found in oil content of seeds among the treatment combination of borax and zinc sulphate (Table 7). The highest oil content (16.00%) in seed was produced in T_{11} (combination between 0.2% borax and 0.2% zinc sulphate) and the lowest oil content (15.00%) was noted in the seeds in control (T_1) treatment. The interaction between boron and zinc also had the positive effect on the yield of seed per hectare. The yield per hectare was increased with the increasing levels of borax and zinc sulphate up to 0.2% borax and 0.2% zinc sulphate and then decreased. This was found to be maximum (2.52 t ha^{-1}) in T_{11} treatment (combination of 0.2% borax and 0.2% zinc sulphate) and the lowest seed yield (1.93 tha^{-1}) was recorded from no application of borax and zinc sulphate (Table 7).

Table 7. *Interaction effect of foliar application of boron and zinc on yield contributing characters and quality of okra seed.*

Treatments	1000- Seed wt. (g.)	Protein content in Seed (%)	Oil content in Seed (%)	Seed yield (tha-1.)
T_1=B_0Zn_0	55.55e	16.52d	15.00	1.93f
T_2=$B_0Zn_{0.1}$	55.90e	16.70d	15.10	1.97ef
T_3=$B_0Zn_{0.2}$	56.40de	16.97bcd	15.25	2.06def
T_4=$B_0Zn_{0.3}$	56.31de	16.95bcd	15.23	2.04def
T_5=$B_{0.1}Zn_0$	56.25de	16.90cd	15.20	2.00ef
T_6=$B_{0.1}Zn_{0.1}$	57.51cd	17.48abc	15.58	2.11def
T_7=$B_{0.1}Zn_{0.2}$	57.55cd	17.60abc	15.77	2.21bcd
T_8=$B_{0.1}Zn_{0.3}$	58.50bc	17.75a	15.83	2.34abc
T_9=$B_{0.2}Zn_0$	58.50bc	17.60abc	15.80	2.16cde
T_{10}=$B_{0.2}Zn_{0.1}$	58.85abc	17.64abc	15.85	2.38ab
T_{11}=$B_{0.2}Zn_{0.2}$	59.98a	17.70ab	16.00	2.52a
T_{12}=$B_{0.2}Zn_{0.3}$	59.50ab	17.68ab	15.97	2.48a
T_{13}=$B_{0.3}Zn_0$	58.38bc	17.56abc	15.78	2.14de
T_{14}=$B_{0.3}Zn_{0.1}$	59.50ab	17.69ab	15.96	2.38ab
T_{15}=$B_{0.3}Zn_{0.2}$	59.60ab	17.70ab	15.98	2.48a
T_{16}=$B_{0.3}Zn_{0.3}$	59.59ab	17.63abc	15.94	2.48a
Level of significance	*	**	NS	*
CV (%)	0.65	1.74	-	2.28

Note: B_0 = 0% borax (as 0% boron), $B_{0.1}$ = 0.1% borax (as 0.01% boron), $B_{0.2}$ = 0.2% borax (as 0.02% boron), $B_{0.3}$ = 0.3% borax (as 0.03% boron)
Zn_0 = 0% zinc sulphate (as 0% zinc), $Zn_{0.1}$ = 0.1% zinc sulphate (as 0.04% zinc), $Zn_{0.2}$ = 0.2% zinc sulphate (as 0.07% zinc), $Zn_{0.3}$= 0.3% zinc sulphate (as 0.11% zinc)

4. Discussion

Plant height of the okra did not significantly influenced by boron. On the other hand, foliar application of zinc has significant effect on plant height. Similar result was observed by Abbasi et al. [34], who reported that foliar application of zinc produced good results for plant height and branching of okra. Sharangi et al. [35] reported that spraying of 0.2% Zn on fennel lead to increase of plant height. The present study demonstrated that the interaction effect of boron and zinc significantly influenced to fruit set of okra. The maximum number of fruit $plant^{-1}$ was recorded from the plants receiving as foliar of 0.2% borax and 0.2% zinc sulphate. Combined of Boron and zinc application might be helped balanced absorption of nutrients, increasing the rate of photosynthesis, as a result fruit per plant was highest. These results are supported to the findings of Mahesh et al. [36] who were investigated the interaction effect of boron and zinc on okra that might be helped to better pollen germination and growth of pollen tube and more number of fruit set. Boron facilitates the reduction of male sterility and increase normal fruit. Zinc involved in the biochemical synthesis of phytohormone, IAA through the pathway of conversion of tryptophan to IAA, which also improved yield and its attributes. The results are also supported to the report of Al-Dulaimi et al. [37] and Al-Ubaydi et al. [38], where they obtained a significant increase in the pod number, pod weight and total yield when applying zinc as foliar application in bean plants. Zinc influences the flower fertilization, pollen production and number of flower which ultimately affected on the production of fruit. The foliar application of boron, zinc and their interaction was significantly effect on fruit length of okra. Muhammad et al. [39] reported that higher level of boron and zinc application was increased the fruit length. Different rates of boron, zinc and their combinations were contributed significantly to improve the number of seeds in fruit of okra. The experimental results showed that the highest number of filled seeds $fruit^{-1}$ was obtained due to combined application of 0.2% borax and 0.2% zinc sulphate followed by 0.2% borax and 0.3% zinc sulphate to the okra plant. Shruti and Chauhan, [40] reported that the application of zinc, boron and manganese lead to increase the number of seed of okra fruit. Wen et al. [41] noted that the application of boron increased the number of seeds pod^{-1} by 41-52% in alfalfa crop. Significant variation was observed in 1000-seed weight due to foliar application of boron and zinc. It was found that 1000-seed weight was linearly increased with application of both the micronutrients individually or their combination over control treatments. Sharangi et al. [35] conducted an experiment on fennel and showed that foliar application of 0.1% B resulted in the highest seeds $umbel^{-1}$ and 1000 seed weight. Boron is important for development and growth of new cells in the plant meristem and it plays a pivotal role in pollination, fruit set and seeds formation, movement of nitrogen, phosphorus, starches, etc in different crops [42]. The increase in seed weight might be due to better mineral utilization of plants accompanied with enhancement of photosynthesis, other metabolic activity and greater diversion of food material to seed [43]. In the present experiment born, zinc and their interaction was created influenced significantly to the protein content in seed. These two micronutrients might be due to facilitate in more protein synthesis. However the improved protein content was found in combined application of 0.1% borax and 0.3% zinc sulphate followed by 0.2% borax and 0.3% zinc sulphate. Similar phenomenon noted by Zaver and Vaghani Manji, [44] who observed that spraying of zinc significantly contributed to get improved protein in seeds of okra. These results are agreed by Alrawi and Aljumail [45], who reported that spraying of zinc significantly affects the protein of okra seeds. In this experiment, the highest seed yield per hectare was obtained from the single application of 0.2% borax, while the maximum seed yield was found in the alone foliar spraying of 0.3% zinc sulphate. The interaction between the 0.2% borax and 0.2% zinc sulphate was contributed to achieve the highest seed yield of okra. Wen et al. [41] conducted an experiment on alfalfa who observed that the application of boron increased seed yield by 22-35%. Zeidan et al. [46] also reported that application of Zn, Fe and Mn significantly increased grain yield of wheat. Increase in seed yield might be correlated to increase in number of fruit per plant and seed weight. This result is supported by Kumar and Sen [47] who reported that the interaction effect of zinc and boron significantly influenced on the seed yield of okra. The above results and discussion indicated that both the boron and zinc were involved in many physiological activities, photosynthesis, and respiration and nitrogen metabolism and synergistic affects to uptake the other nutrients by plant.

5. Conclusion

It could be concluded that foliar application of boron and zinc either single or in combinations, resulted improved seed yield, good performance of yield contributing characters and quality of okra seeds. The treatment T_{11} (combination of 0.2% borax and 0.2% zinc sulphate) demonstrated the highest results in respect to seed yield and most of the yield attributes of okra. The combined foliar applications of boron and zinc fertilizers were detected superior to their single application. The results suggest that the combination of 0.2% borax and 0.2% zinc sulphate could be used as foliar for seed yield maximization of okra. Hence, the foliar fertilization rates of zinc sulphate should be increased for okra production.

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