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ORIGINAL ARTICLE

Effects of Boron and Zinc on yield and Quality of Okra Seed

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ABSTRACT
The study was conducted at the Horticulture Research Centre of the Bangladesh Agricultural Research Institute, Joydebpur, Gazipur during 2009-2013 in order to investigate the seed quality of different sources and locations of Bangladesh and to evaluate the effects of B and Zn on the yield and quality of okra seed with a view to improve the micronutrient management practices for quality seed production. The okra variety BARI Dharosh-1 was used for the study. Individual and combined application of B and Zn resulted improved yield and quality of okra seed while higher doses of B and Zn resulted negative effect on yield and quality of okra seed. The highest seed yield, germination, seedling vigour index and protein content were noted down with 2 kg B/ha and 4 kg Zn/ha. The foliar application of 0.2 % B and 0.2 % Zn individually and combined produced maximum yield and quality of okra seed.
Key words: *Okra, Boron, Zinc, yield, seed quality*

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INTRODUCTION

Okra [*Abelmoschus esculentus* (L.) Moench] is one of the most important vegetable crops of many subtropical and tropical countries including Bangladesh. It is also called ladies' fingers in several English speaking countries. Okra is native to West Africa and South Asia [1]. It is an annual warm loving crop that belongs to the Malvaceae family and grows warm temperature regions of the world. Although okra is a rainfed crop, it also comes up well under irrigated conditions during kharif and summer seasons. It is also an important vegetable crop in Bangladesh that plays an important role to meet the national demand of vegetable of the country more specifically during summer when vegetables are scanty in the market [2,3]. The young green fruits (seed pods) are generally used as vegetable but sometimes can be dehydrated and canned and marketed. Each 100 g green tender okra fruits contain 1.76 g protein, 8.73 g carbohydrate, 1.1 g fiber, 88 IU Vitamin A, 9.8 mg Vitamin C and 116 mg Ca [4]. Besides, its seed is the good source of protein [5]. Sometimes, dry okra seeds are roasted and used as a substitute for coffee. The fruits also have some medicinal value and a mucilaginous preparation from the fruit can be used as a plasma replacement or blood volume expander [6], against gastric and inflammatory diseases [7]. In Bangladesh, during 2009-2010, the total okra production was about 43.32 thousand tons from 1.06 thousand hectare of land with 4.10 t/ha average yield [8] .

Quality seed is the basis of any successful crop production. Crop production can be increased up to 25-50% using quality seed [9]. In Bangladesh, the estimated annual requirement of okra seed is about 300 tonnes [10, 11] where Bangladesh Agricultural Development Corporation (BADC) and private seed companies produce about 25%, imported 25% and rest 50% seed from farmer's seed every year. The farmer's seeds are in most cases of inferior quality and use of poor quality seeds is responsible for low yield in Bangladesh [12]. Hence, to increase the okra production by reducing seed import, more attention should be given to improve quality okra seed in Bangladesh. There are several factors affect quality seed production including genetic purity, agro-ecological conditions, fertilizer management especially micro nutrients, pest and disease infestation, adequate cultural management and storage of seed. Though the effects of different chemical fertilizers on the yield and quality of okra seed were studied earlier, the effects of micronutrients on yield and quality of okra seed were not studied detail so far in Bangladesh. Among all micronutrients, the deficiency of zinc and boron in Bangladesh soils was most prevalent which are important in seed formation and seed quality [13]. Furthermore, boron is required for proper development and differentiation of plant tissues. In its absence, 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, and its inadequacy is often associated with sterility and malformation of reproductive organs [14]. Boron facilitates the transport of carbohydrates through cell membranes. If boron deficiency occurs, the assimilated product accumulates in the leaves and the young growing point lacks sugar. Maximum production of starch and sugar is restricted if crops are inadequately supply with boron [15].

Zinc mainly functions as the metal component of a series of enzymes. The most important enzymes activat by this element are carbonic anhydrase and a number of dehydrogenases. Zinc deficiency is thought to restrict RNA synthesis, which in turn inhibits protein synthysis [14]. Zinc is also involved in auxin production and flower and fruit setting. Shoots and buds of zinc deficient plants contain very low auxin, which causes dwarfism and growth reproduction. The net results are stunted plants and prolonged duration of growth. Like boron, zinc deficiency is found to occur in high pH soils [16]. It is also plays an important role in chlorophyll formation, cell division, meristematic activity of tissue expansion of cell and formation of cell wall. It increases photosynthesis and translocation of food materials. 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 in this function, it prevents excessive p uptake by roots and transport of P from roots to leaves [17] .

Therefore, it apparent that Boron and zinc play an important role directly and indirectly in improving the yield and quality of okra seed production. Management practices, particularly boron and zinc, would help increasing yield, quality of okra seed. Till now, little is known about effect of boron and zinc on yield and quality of okra seed. Therefore, the present research was undertaken to figure out the effect of boron and zinc on the yield and quality of okra seeds.

MATERIALS AND METHODS

The experiment was carried out at the Vegetable Research Field, Horticulture Research Centre, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur during April-September 2010. The experiment was laid out in the Randomized Complete Block Design (RCBD) with two factorial concept having 3 replications. Factor-'A' includes four different levels of boron applied as boric acid such as B_0 = 0 kg B/ha, $B_{1.5}$ = 1.5 kg B/ha, $B_{2.0}$ = 2.0 kg B/ha and $B_{2.5}$ = 2.5 kg B/ha whereas factor-'B' also comprises four different zinc levels applied as zinc sulphate (Zn_0 = 0 kg Zn/ha, Zn2.0 = 2.0 kg Zn/ha, $Zn_{4.0}$ = 4.0 kg Zn/ha and $Zn_{6.0}$ = 6.0 kg Zn/ha. Therefore, altogether there were 16 treatment combinations which were randomly allotted in each block. The unit plot size was 4 m × 2.4 m with 60 cm × 40 cm spacing. In addition to the different levels of boron and zinc, 10 t cow dung, 200 kg urea, 250 kg TSP, 150 kg MP and 100 kg gypsum per hectare were applied as per Fertilizer Recommendation Guide of BARC [18]. The okra variety was BARI Dherosh-1. The data were recorded from ten randomly selected plants from each plot for all the traits including plant height, days to first flowering, fruit length and breath, number of seeds per fruit, 1000-seed weight, seed yield, per cent germination, seedling shoot and root length, seedling vigour, seed protein content, seed oil content, seed zinc content and seed boron content. The recorded data were analyzed using MSTATC program and means were separated by DMRT.

RESULTS AND DISCUSSION

It has found that only five days required to 80 % emergence of the seedlings (Table 1, 2 and 3). Boron application to the soil showed significant effect on days to 50 % flowering in plants. The period for 50% flowering in plants decreased with increasing levels of boron application (Table 1). The minimum period (31.75 days) for 50% flowering was recorded in plants when 2 Kg B/ha while maximum (33.58 days) was found when boron was not applied. Zinc application to the soil did not exert any influence on plants for attaining flowering stage. Marked variation in 50% flowering was found due to combined effect of boron and zinc. The lowest period (31.00 days) for 50% flowering was recorded in plants where 2 kg B and 4 kg Zn/ha were applied together while the maximum period (34.00 days) for 50 % flowering was found when boron and zinc was not applied. Marked variation in 50% flowering was found due to combined effect of boron and zinc. This might be due to a positive role of regulating the boron and zinc in balance absorption of nutrients leading to the favorable C: N ratio. This result is in agreement with the findings of Mallick *et al.* [19]. Boron application to the soil did not influence the plant height though it ranged from 168.58 cm to 174.84 cm. On the other hand, plant height was significantly differed due to effect of zinc. The lowest plant height (168.83 cm) was in control and highest (175.29 cm) in case of application of 4 kg Zn/ha. Combination of boron and zinc significantly influenced plant height. The results of the study reflected that plant height was increased with increasing combined levels of boron and zinc. Maximum plant height (179.47 cm) was recorded with combination of 2 kg B and 4 kg Zn/ha, while it was the lowest (162.01 cm) in control (Table 3). Days to 1st harvest of matured fruit. The height of a plant depends on nutrient availability in the soil. With increasing level of Zn and B fertilizer increased the plant height. Application of boron and zinc might have resulted balanced absorption of nutrients, increased rate of photosynthesis and reduced transpiration. Davis *et al*. [20] reported that uptake of N, K, Mg and Ca was increased with boron application. The number of days required for first harvest of matured okra from the date of seed sowing was significantly influenced by the levels of boron. Earliness was found with the increasing level of boron (Table 1). Application of 2 kg B/ha reduced the first harvesting period (69.08 days) compared to control (71.25 days). The combined application of boron and zinc significantly affected the number of days to first harvest. The harvesting was earliest when the plants were applied with 2 kg B and 4 kg Zn/ha (68 days), followed by 1.5 Kg B and 4 kg Zn/ha (68.33 days). Harvesting was relatively late (72.00 days) when the crop was raised with no boron and zinc application (Table 3). Salam [21] reported that minimum days were required to first harvest (77.00 days) with the application of 2.5 kg B + 6 kg Zn and 20 t/ha cowdung, while the maximum days was taken to first harvest (89.00 days) under control (without boron, zinc and cowdung). The number of fruit per plant was significantly increased with the increasing level of boron (Table 1). The highest fruit per plant (20.49) was observed with the level of boron (2kg B/ha), while it was the lowest (17.95) in control (B0). On the other hand, the highest fruit per plant (20.08) was recorded with 4 kg Zn/ha, whereas it was the lowest (18.39) with control (Zn0) (Table 2). Fruit per plant was significantly influenced by the combined effect of boron and zinc application. In general, fruit per plant increased with the increasing level of boron and zinc application (2 kg/ha. and 4 kg/ha Zn). The highest fruit per plant (21.02) was obtained from 2 kg B and 4 kg Zn/ha, while the lowest (17.80) was recorded with no boron and zinc application (Table 3). It might probably be due to better pollen germination and pollen tube growth.

Table 1. Main effect of boron on days to 80% seedling emergence, days to 50% flowering, plant height , days to 1st harvest and fruits per plant of okra

Treatment	Days to 80% seedling emergence	Days to 50% flowering	Plant height (cm)	Days to 1st harvest	No. of fruits/plant
B_0	5.00	33.58 a	168.59	71.25 a	17.95 c
$B_{1.5}$	5.00	32.17 b	170.08	69.25 b	19.46 b
$B_{2.0}$	5.00	31.75 b	174.84	69.08 b	20.49 a
$B_{2.5}$	5.00	32.17 b	174.67	69.17 b	20.01 a
LSD	Ns	*	Ns	*	**
CV (%)	0.00	4.39	4.14	2.42	2.25

B_0 = 0 kg boron/ha, $B_{1.5}$ = 1.5 kg boron/ha, $B_{2.0}$ = 2 kg boron/ha, $B_{2.5}$ = 2.5 kg boron/ha. In a column, the figures having similar letter(s) do not differ significantly at 0.05 level by DMRT. *= significant at 0.05 level, **= Significant at 0.01 level and NS= Non significant.

Table 2. Main effect of zinc on on days to 80% seedling emergence, days to 50% flowering, plant height , days to 1st harvest and fruits per plant of okra

Treatment	Days to 80% seedling emergence	Days to 50% flowering	Plant height (cm)	Days to 1st harvest	No. of fruits/plant
Zn_0	5.00	33.00	168.83 b	70.42	18.39 c
$Zn_{2.0}$	5.00	32.50	170.76 ab	69.83	19.56 b
$Zn_{4.0}$	5.00	31.92	175.29 a	68.92	20.08 a
$Zn_{6.0}$	5.00	32.25	173.28 ab	69.58	19.88 ab
LSD	Ns	Ns	*	Ns	**
CV (%)	0.00	4.39	4.14	2.42	2.25

Zn_0 = 0 kg zinc/ha, $Zn_{2.0}$ = 2 kg zinc/ha, $Zn_{4.0}$ = 4 kg zinc/ha, $Zn_{6.0}$ =6 kg zinc/ha. In a column, the figures having similar letter(s) do not differ significantly at 0.05 level by DMRT. *= significant at 0.05 level, **= Significant at 0.01 level and NS= Non significant.

Table 3. Combined effect of boron and zinc on days to 80% seedling emergence, days to 50% flowering, plant height , days to 1st harvest and fruits per plant of okra

Treatment	Days to 80% seedling emergence	Days to 50% flowering	Plant height (cm)	Days to 1st harvest	No. of fruits/plant
$B_0 Zn_0$	5.00	34.00 a	162.01 ab	72.00 a	17.80 e
$B_0 Zn_2$	5.00	34.00 a	165.11 b	71.67 ab	17.91 e
$B_0 Zn_{4.0}$	5.00	33.33 ab	172.46 ab	71.00 abc	18.15 de
$B_0 Zn_{6.0}$	5.00	33.00 ab	170.54 ab	70.33 abc	17.92 e
$B_{1.5} Zn_0$	5.00	33.00 ab	165.85 ab	70.67 abc	17.90 e
$B_{1.5} Zn_{2.0}$	5.00	32.00 ab	170.65 ab	69.00 abc	19.04 cd
$B_{1.5} Zn_{4.0}$	5.00	31.67 ab	172.95 ab	68.33 c	20.46 ab
$B_{1.5} Zn_{6.0}$	5.00	32.00 ab	170.85 ab	69.00 abc	20.46 ab
$B_{2.0} Zn_0$	5.00	32.00 ab	170.48 ab	69.67 abc	19.43 bc
$B_{2.0} Zn_{2.0}$	5.00	32.00 ab	173.50 ab	69.67 abc	20.64 a
$B_{2.0} Zn_{4.0}$	5.00	31.00 b	179.47 a	68.00 c	21.02 a
$B_{2.0} Zn_{6.0}$	5.00	32.00 ab	175.89 ab	69.00 abc	20.88 a
$B_{2.5} Zn_0$	5.00	33.00 ab	172.76 ab	69.33 abc	18.44 cde
$B_{2.5} Zn_{2.0}$	5.00	32.00 ab	173.80 ab	69.00 abc	20.66 a
$B_{2.5} Zn_{4.0}$	5.00	31.67 ab	176.28 ab	68.33 bc	20.68 a
$B_{2.5} Zn_{6.0}$	5.00	32.00 ab	175.85 ab	70.00 abc	20.26 ab
LSD	Ns	*	*	*	**
CV (%)	0.00	4.39	4.14	2.42	2.25

Table 4. Main effect of boron on fruit length, fruit girth, seeds per fruit, unfilled seeds per fruit, 1000-seed weight and seed yield per plant of okra

Treatment	Fruit length (cm)	Fruit girth (cm)	No. of seeds/fruit	Unfilled seed/fruit (%)	1000 -seed wt. (g.)	Seed yield/plant
B_0	17.23 b	1.78 c	56.37 b	5.69 a	55.33 d	55.97 c
$B_{1.5}$	18.60 a	1.94 b	58.56 a	3.63 b	55.82 c	64.33 b
$B_{2.0}$	19.38 a	2.05 a	59.51 a	3.08 d	59.89 a	73.38 a
$B_{2.5}$	19.09 a	2.03 a	58.88 a	3.15 c	58.92 b	69.58 a
LSD	**	*	*	*	*	**
CV (%)	3.62	2.28	2.23	1.47	0.65	6.67

B_0 = 0 kg boron/ha, B 1.5 = 1.5 kg boron/ha, B 2.0 = 2 kg boron/ha, B 2.5 = 2.5 kg boron/ha, Zn 0 = 0 kg zinc/ha, Zn 2.0 = 2 kg zinc/ha, $Zn_{4.0}$ = 4 kg zinc/ha, $Zn_{6.0}$ =6 kg zinc/ha. In a column, the figures having similar letter(s) do not differ significantly at 0.05 level by DMRT. *= Significant at 0.05 level, **= Significant at 0.01 level and NS= Non significant.

Table 5. Main effect of zinc on on fruit length, fruit girth, seeds per fruit, unfilled seeds per fruit, 1000-seed weight and seed yield per plant of okra

Treatment	Fruit length (cm)	Fruit girth (cm)	No. of seeds/fruit	Unfilled seed/fruit (%)	1000-seed wt. (g.)	Seed yield/plant
Zn_0	17.36 b	1.84 c	56.96 b	5.65 a	55.73 c	58.45 b
$Zn_{2.0}$	18.59 a	1.92 b	58.36 a	4.61 b	57.70 b	66.13 a
$Zn_{4.0}$	19.22 a	2.02 a	59.12 a	2.59 d	58.72 a	69.84 a
$Zn_{6.0}$	19.12 a	2.01 a	58.86 a	2.70 c	57.80 b	68.83 a
LSD	**	**	*	*	*	**
CV (%)	3.62	2.28	2.23	1.47	0.65	6.67

B_0 = 0 kg boron/ha, B 1.5 = 1.5 kg boron/ha, B 2.0 = 2 kg boron/ha, B 2.5 = 2.5 kg boron/ha, Zn 0 = 0 kg zinc/ha, Zn 2.0 = 2 kg zinc/ha, $Zn_{4.0}$ = 4 kg zinc/ha, $Zn_{6.0}$ =6 kg zinc/ha. In a column, the figures having similar letter(s) do not differ significantly at 0.05 level by DMRT. **= Significant at 0.01 level, *= Significant at 0.05 level and NS= Non significant.

There was a marked difference in length of fruit due to boron application ranged from 17.23 cm to 19.38 cm. The highest fruit length (19.38 cm) was recorded with 2 kg B/ha followed by 19.09 cm from 2.5 kg B/ha., while it was the lowest (17.23 cm) where no boron was applied (Table 4). Similarly, soil application of zinc significantly influenced the length of fruit. The length of fruit was the lowest (17.36 cm) in control, while it was the highest (19.22 cm) when 4 kg Zn/ha was applied and followed by 19.12 cm from 6 kg Zn/ha. Distinct variation was observed among the combinations of boron and zinc application as to the length of fruit. The maximum fruit length (20.01 cm) was recorded with the application of 2 kg B and 4 kg Zn/ha, whereas the minimum (16.66 cm) was found with no boron and zinc application (Table 6).

Table 6. Combined effect of boron and zinc on on fruit length, fruit girth, seeds per fruit, unfilled seeds per fruit, 1000-seed weight and seed yield per plant of okra

Treatment	Fruit length (cm)	Fruit girth (cm)	No. of seeds/fruit	Unfilled seed/fruit (%)	1000-seed wt. (g.)	Seed yield/plant
$B_0 Zn_0$	16.66 d	1.71 f	55.95 d	6.45 a	54.95 g	54.72 e
$B_0 Zn_2$	17.10 d	1.73 f	56.12 d	6.15 b	55.15 fg	55.43 e
$B_0 Zn_{4.0}$	17.75 cd	1.84 de	57.15 bcd	5.08 cd	55.67 f	57.74 e
$B_0 Zn_{6.0}$	17.40 d	1.84 de	56.25 cd	5.10 c	55.54 fg	55.98 e
$B_{1.5} Zn_0$	17.40 d	1.77 ef	56.26 cd	6.10 b	55.20 fg	55.58 e
$B_{1.5} Zn_{2.0}$	18.25 bcd	1.98 c	58.75 abc	4.50 e	56.35 e	63.03 cde
$B_{1.5} Zn_{4.0}$	19.15 abc	2.00 bc	59.23 ab	1.76 i	57.46 d	69.63 abcd
$B_{1.5} Zn_{6.0}$	19.60 ab	2.00 bc	60.00 a	2.17 h	54.26 h	69.10 abcd
$B_{2.0} Zn_0$	18.00 bcd	1.96 c	58.46 abcd	5.00 d	56.40 e	64.06 bcde
$B_{2.0} Zn_{2.0}$	19.50 ab	1.99 bc	59.35 ab	3.80 g	60.00 b	73.49 abc
$B_{2.0} Zn_{4.0}$	20.01 a	2.15 a	60.11 a	1.75 i	61.75 a	78.30 a
$B_{2.0} Zn_{6.0}$	20.00 a	2.10 ab	60.10 a	1.77 i	61.40 a	77.56 a
$B_{2.5} Zn_0$	17.38 d	1.94 cd	57.20 bcd	5.05 cd	56.37 e	59.45 de
$B_{2.5} Zn_{2.0}$	19.52 ab	1.98 c	59.25 ab	4.00 f	59.30 c	72.58 abc
$B_{2.5} Zn_{4.0}$	19.98 a	2.10 ab	60.00 a	1.76 i	60.00 b	74.44 ab
$B_{2.5} Zn_{6.0}$	19.50 ab	2.10 ab	59.10 ab	1.77 i	60.00 b	71.84 abc
LSD	**	**	*	*	*	**
CV (%)	3.62	2.28	2.23	1.47	0.65	6.67

The increase in fruit length was associated with increase in size of fruit, and was probably due to boron and zinc help photosynthesis and translocation of food materials. Similar observation was reported by Yadav *et al.* [22]. Maximum fruit girth (2.05 cm) was recorded with 2 kg B/ha followed by (2.03 cm) with 2.5 kg B/ha, while the minimum (1.78 cm) was found from no boron application (Table 4). Fruit girth also increased with the increasing levels of zinc application up to 4 kg Zn/ha and then decreased (Table 5). Fruit girth was the highest (2.15 cm) in combined application of 2 kg B and 4 kg Zn/ha, and the lowest (1.71 cm) in control (Table 6). There was a significant difference among the levels of soil applied boron and zinc in the number of filled seeds per fruit. It ranged from 56.37 in without boron to 59.51 in 2 kg B/ha (Table 4). The number of filled seeds per fruit increased with the increasing levels of zinc up to 4 kg Zn/ha and then decreased (Table 5). The highest number of filled seeds per fruit (59.12) was recorded from 4 kg Zn/ha, whereas the lowest (56.96) was recorded from no zinc application. The highest number of filled seeds per fruit (60.11) was noted from 2 kg B and 4 kg Zn/ha, while it was the lowest (55.95) in no boron and zinc application (Table 6). Boron application to soil had significant effect on per unfilled seeds per fruit. Per cent unfilled seeds were decreased with the increasing boron level (Table 4). The lowest unfilled seed (3.08) was observed with the level of boron 2 kg B/ha, while it was highest (5.69) with no boron application. The effect of zinc on per cent unfilled seed was also significant. The lowest unfilled seed (2.59) was recorded with 4 kg Zn/ha, whereas it was highest (5.65) with no zinc application (Table 5). Percent unfilled seed was significantly influenced by the combined effect of boron and zinc as soil application. In general, the percent unfilled seed decreased with the increasing levels of boron and zinc (2 kg B/ha and 4 kg Zn/ha). 1000-seed weight was significantly influenced by the application of boron to soil levels. The highest 1000-seed weight (59.89 g) was recorded from 2 kg B/ha followed by 2.5 kg B/ha (58.92 g) and the lowest (55.33 g) was recorded from control. The effect of zinc application was also significant on 1000-seed weight. The maximum 1000-seed weight (58.72 g) was recorded from 4 kg Zn/ha followed by 6 kg Zn/ha, (57.80 g) while the lowest (55.73 g) was recorded from the control (Table 5). The variation among the treatment combinations in the 1000-seed weight was significant and it increased with the increasing levels of boron and zinc application up to 2 kg B and 4 kg Zn/ha and then decreased (Table 6). It is possible due to boron that cause an cell division, carbohydrate metabolism, sugar and starch formation, and zinc improves mobilization of photosynthates and the amount of photosynthate available for reproductive sinks and increased seed weight [23]. Similar observation was reported by Shruti and Chauhan [24]. The yield of seed per plant varied significantly due to boron application to soil. The highest seed yield per plant (73.38 gm) was obtained from 2 kg B/ha, whereas the lowest level of seed yield per plant (55.97 gm) was obtained from 0 kg B/ha. Likewise, the yield of seed per plant increased with increase in zinc level as soil application (Table 4). The yield ranged from 58.45 gm to 69.84 gm among the level of zinc application. The combinations of boron and zinc application showed significant difference in seed yield per plant. The combination of 2 kg B and 4 kg Zn/ha produced the highest yield per plant (77.56 gm) (Table 30), whereas it was the lowest (54.72 gm) in control (Table 6). Increase in seed yield and its components may be attributed due to increase in seed weight per fruit as a result of improvement in seed number due to adequate mother plant nutrition. Further, it can be ascribed due to influence of other yield attributes such as number, of fruits per plant, fruit length, fruit girth. This result is well agreed with Patil *et al.* [25], Bhat and Dhar [26] and Dixit [27].

The seed yield per hectare varied significantly among the levels of boron application to soil. The highest yield of seed per hectare (2.70 t/ha.) was obtained from 2 kg B/ha, which was followed by 2.5 kg B/ha (2.57 t/ha) (Table 7). Zinc application to the soil also significantly influenced the seed yield per hectare. The highest seed yield per hectare (2.58 t/ha.) was recorded from 4 kg Zn/ha, whereas it was the lowest (2.15 t/ha) when no zinc was applied (Table 8). The seed yield per hectare significantly increased with the increasing levels of boron and zinc up to 2 kg B and 4 kg Zn/ha and then decreased (Table 9). Seed germination was significantly increased with increasing boron levels up to 2 kg B/ha and then decreased (Table 7). The effect of zinc application on seed germination was also significant. The highest germination percentage (95.49) was recorded with 4 kg Zn/ha, whereas it was the lowest (86.98) with no zinc application (Table 8). In general, the seed germination percentage was significantly increased with the increasing levels of boron and zinc up to 2 kg B and 4 kg Zn/ha and then decreased (Table 9). The increase in seed quality parameters may be due to application of micronutrients (Zn, B) in catalytic activity and breakdown of complex substances into simple form (glucose, amino acids and fatty acids etc.), which in turn reflected on enhancing the germination. Similar result was found by Dordas [28] and Manivasagaperumal [29]. Seedling shoot length varied significantly due to boron application to soil which ranged from 17.51 cm to 19.44 cm. The highest seedling shoot length (19.44 cm) was recorded from 2 kg B/ha followed by 2.5 kg B/ha, while it was the lowest (17.51 cm) when no boron was applied (Table 7). Application of soil zinc also significantly influenced the seedling shoot length. The highest shoot length of seedling (19.56 cm) was from 4 kg Zn/ha followed by 6 kg Zn/ha, (19.41 cm) and the lowest (17.73 cm) from 0 kg Zn/ha. The maximum seedling shoot length (20.11 cm) was recorded with the highest level of boron and zinc up to 2kg B and 4 kg Zn/ha and then decreased. Whereas the minimum (17.00 cm) was found from no boron and zinc application (Table 9). Similarly, root length of seedling was significantly increased with the increasing boron level up to 2 kg B/ha (Table 7). The highest root length of seedling (10.79 cm) was from 4 kg Zn/ha followed by 6 kg Zn/ha, (10.70) and the lowest (9.98 cm) from 0 kg Zn/ha. The maximum root length of seedling (11.00 cm) was recorded with the highest level of boron and zinc up to 2kg B and 4 kg Zn/ha and then decreased. Whereas the minimum (9.40 cm) was found with no boron and zinc application (Table 9). Seedling vigour index increased with increase in soil applied boron level up to 2 kg B and 4 kg Zn/ha and then decreased (Table 7 and Table 8). A significant difference in seedling vigour index among the different combination of boron and zinc was observed. The highest vigour index (3066.51) was recorded from the combination of 2 kg B and 4 kg Zn/ha which was followed by 2.0 kg B/ha and 6 kg Zn/ha (3048.57) whereas the lowest (2177.00) exerted with no boron and zinc application (Table 9). Variation was also observed regarding application of combinations of boron and zinc on shoot, root length and vigour index. These may be due to boron is association with the development of cell wall and cell differentiation and zinc plays an important role in cell division, meristematic activity of tissue expansion of cell and formations of cell wall hence helps in root elongation and shoot growth of plant. This result is in agreement with the findings of Kiran [30].

Table 7. Main effect of boron on seed yield, germination percentage, shoot length, root length and seed vigour of okra

Treatment	Seed yield (t/ha.)	Germination (%)	Shoot length (cm)	Root length (cm)	Seedling vigour
B_{0}	2.06 d	86.09 b	17.51 b	9.88 b	2351.84 c
$B_{1.5}$	2.40 c	92.45 a	19.09 a	10.58 a	2748.11 b
$B_{2.0}$	2.70 a	94.58 a	19.44 a	10.76 a	2859.84 a
$B_{2.5}$	2.57 b	94.26 a	19.30 a	10.74 a	2836.48 ab
LSD	**	**	**	**	**
CV (%)	4.38	2.65	4.37	5.04	3.44

B_{0} = 0 kg boron/ha, B 1.5 = 1.5 kg boron/ha, B 2.0 = 2 kg boron/ha, B 2.5 = 2.5 kg boron/ha, Zn 0 = 0 kg zinc/ha, Zn 2.0 = 2 kg zinc/ha, $Zn_{4.0}$ = 4 kg zinc/ha, $Zn_{6.0}$ =6 kg zinc/ha. In a column, the figures having similar letter(s) do not differ significantly at 0.05 level by DMRT. **= Significant at 0.01 level, *= Significant at 0.05 level and NS= Non significant.

Table 8. Main effect of zinc on seed yield, germination percentage, shoot length, root length and seed vigour of okra

Treatment	Seed yield (t/ha.)	Germination (%)	Shoot length (cm)	Root length (cm)	Seedling vigour
Zn_0	2.15 c	86.98 c	17.73 b	9.98 b	2407.66 c
$Zn_{2.0}$	2.44 b	90.11 b	18.64 ab	10.48 ab	2624.79 b
$Zn_{4.0}$	2.58 a	95.49 a	19.56 a	10.79 a	2882.89 a
$Zn_{6.0}$	2.55 ab	94.81 a	19.41 a	10.70 a	2880.92 a
LSD	**	**	**	**	**
CV (%)	4.38	2.65	4.37	5.04	3.44

Table 9. Combined effect of boron and zinc on seed yield, germination percentage, shoot length, root length and seed vigour of okra

Treatment	Seed yield (t/ha.)	Germination (%)	Shoot length (cm)	Root length (cm)	Seedling vigour
$B_0 Zn_0$	2.00 e	83.22 c	17.00 c	9.40 b	2177.00 g
$B_0 Zn_2$	2.04 e	86.40 c	17.30 bc	9.78 ab	2329.71 fg
$B_0 Zn_{4.0}$	2.13 de	87.10 bc	18.03 abc	10.20 ab	2474.92 ef
$B_0 Zn_{6.0}$	2.07 e	87.67 bc	17.70 bc	10.15 ab	2425.73 ef
$B_{1.5} Zn_0$	2.05 e	87.50 bc	17.50 bc	9.85 ab	2393.12 efg
$B_{1.5} Zn_{2.0}$	2.33 d	88.70 bc	18.77 abc	10.56 ab	2601.57 de
$B_{1.5} Zn_{4.0}$	2.58 bc	98.50 a	20.08 a	11.00 a	2955.08 abc
$B_{1.5} Zn_{6.0}$	2.66 ab	95.08 a	20.00 a	10.89 a	3042.66 a
$B_{2.0} Zn_0$	2.36 cd	88.60 bc	18.32 abc	10.35 ab	2540.16 ef
$B_{2.0} Zn_{2.0}$	2.72 ab	92.65 ab	19.25 ab	10.81 a	2784.13 cd
$B_{2.0} Zn_{4.0}$	2.87 a	98.57 a	20.11 a	11.00 a	3066.51 a
$B_{2.0} Zn_{6.0}$	2.84 ab	98.50 a	20.07 a	10.88 a	3048.57 a
$B_{2.5} Zn_0$	2.19 de	88.59 bc	18.10 abc	10.35 ab	2520.38 ef
$B_{2.5} Zn_{2.0}$	2.68 ab	92.70 ab	19.25 ab	10.78 a	2783.78 bcd
$B_{2.5} Zn_{4.0}$	2.75 ab	97.78 a	20.00 a	10.97 a	3035.06 a
$B_{2.5} Zn_{6.0}$	2.66 ab	98.00 a	19.87 a	10.88 a	3006.73 ab
LSD	**	**	**	**	**
CV (%)	4.38	2.65	4.37	5.04	3.44

B_0 = 0 kg boron/ha, B 1.5 = 1.5 kg boron/ha, B 2.0 = 2 kg boron/ha, B 2.5 = 2.5 kg boron/ha, Zn 0 = 0 kg zinc/ha, Zn 2.0 = 2 kg zinc/ha, $Zn_{4.0}$ = 4 kg zinc/ha, $Zn_{6.0}$ =6 kg zinc/ha. In a column, the figures having similar letter(s) do not differ significantly at 0.05 level by DMRT. ** = Significant at 0.01 level,
*= Significant at 0.05 level and NS= Non significant.

Protein content of okra seeds was significantly increased with the increasing level of boron and zinc (Table 10 and Table 11). The protein content was lowest (17.33 %) in control and the highest (19.24 %) in 2.00 B/ha. On the other hand, the highest protein content of seed (19.08 %) was found in 4 kg Zn/ha and the lowest (17.85 %) in control. However, the seed produced with 2.00 kg B/ha and 4 kg Zn/ha had the maximum protein content (19.95 %) followed by 2.00 kg B/ha and 6 kg Zn/ha (19.87 %), and it was the minimum (16.90 %) in seeds produced without boron and zinc application (Table 12). Boron had no influence on oil content of seed (Table 10). Zinc application in soil significantly increases the oil content of okra seed (Table 11). The oil content of okra seed was significantly increased when 2.00 kg B/ha and 4 kg Zn/ha were applied to the soil (Table 12). It might be due to boron which plays an important role in protein synthesis in plant and zinc is directly involved in both gene expression and protein synthesis, Cakmak [31] has speculated that Zn deficiency stress may inhibit the activities of a number of antioxidant enzymes, resulting in extensive oxidative damage to proteins, chlorophyll and nucleic acids. These results agreed with those reported by Babhulkar *et al.* [32] and Kaisher *et al.* [33]. Marked variation in boron content of seed was exhibited in response to boron application in soil. The maximum boron content (42.05 ppm) was recorded with the highest level of boron application (2.5 kg B/ha), whereas it was the minimum (30.87 ppm) with no boron application (Table 10). Significant variation among the treatment combinations was also observed in boron content of seed. The highest boron content (42.80 ppm) was observed in the seeds produced with the combination of 2.5 kg B and 6 kg Zn/ha, and the lowest (30.90 ppm) was recorded from no boron application (Table 12). The zinc content of seed was influenced by the soil application of boron. It ranged from 43.95 ppm to 44.96 ppm among the levels of boron. However, the zinc content of seed ranged between 35.77 ppm to 53.12 ppm due to the application of different levels of zinc application in soil, the highest (53.12 ppm) zinc content found with 6 kg Zn/ha, followed by the application of 4 kg Zn/ha (47.55 ppm). Zinc content of seed was lowest (35.76 ppm) when no zinc was applied (Table 11). Significant variation among the combinations of boron and zinc was detected in respect of zinc content in seed. The highest zinc content (53.78 ppm) was recorded in seed produced with 1.5 kg B/ha and 6 kg Zn/ha and the lowest (34.95 ppm) was found with no boron and zinc application (Table 12). Yadav *et al.* [34] obtained the highest concentration and uptake of boron and zinc with 4 kg boron and 20 kg ZnSO4, respectively.

Table 10. Main effect of boron on protein content, oil content, boron content and Zn content of okra seed

Treatment	Protein content (%)	Oil content (%)	Boron content (%)	Zn content (%)
B_0	17.33 c	15.98	30.87 d	43.95 b
$B_{1.5}$	18.85 b	16.49	36.97 c	44.45 ab
$B_{2.0}$	19.24 a	16.90	39.05 b	44.96 a
$B_{2.5}$	18.86 b	16.58	42.05 a	44.94 a
LSD	**	ns	**	**
CV %	1.74	6.35	2.01	1.59

B_0 = 0 kg boron/ha, B 1.5 = 1.5 kg boron/ha, B 2.0 = 2 kg boron/ha, B 2.5 = 2.5 kg boron/ha, Zn 0 = 0 kg zinc/ha, Zn 2.0 = 2 kg zinc/ha, $Zn_{4.0}$ = 4 kg zinc/ha, $Zn_{6.0}$ =6 kg zinc/ha. In a column, the figures having similar letter(s) do not differ significantly at 0.05 level by DMRT. **= Significant at 0.01 level, *= Significant at 0.05 level and NS= Non signifiant.

Table 11. Main effect of zinc on protein content, oil content, boron content and Zn content of okra seed

Treatment	Protein content (%)	Oil content (%)	Boron content (%)	Zn content (%)
Zn_0	17.85 c	16.00 b	36.82 b	35.77 d
$Zn_{2.0}$	18.30 b	16.42 ab	37.17 ab	41.87 c
$Zn_{4.0}$	19.08 a	17.00 a	37.37 ab	47.55 b
$Zn_{6.0}$	19.05 a	16.53 ab	37.57 a	53.12 a
LSD	**	*	*	**
CV (%)	1.74	6.35	2.01	1.59

B_0 = 0 kg boron/ha, B 1.5 = 1.5 kg boron/ha, B 2.0 = 2 kg boron/ha, B 2.5 = 2.5 kg boron/ha, Zn 0 = 0 kg zinc/ha, Zn 2.0 = 2 kg zinc/ha, $Zn_{4.0}$ = 4 kg zinc/ha, $Zn_{6.0}$ =6 kg zinc/ha. In a column, the figures having similar letter(s) do not differ significantly at 0.05 level by DMRT. **= Significant at 0.01 level, *= Significant at 0.05 level and Ns= Non significant.

Table 12. Combined effect of boron and zinc on protein content, oil content, boron content and Zn content of okra seed

Treatment	Protein content (%)	Oil content (%)	Boron content (%)	Zn content (%)
$B_0 Zn_0$	16.90 g	15.65 b	30.90 g	34.95 d
$B_0 Zn_2$	17.25 fg	15.90 ab	30.91 g	41.80 c
$B_0 Zn_{4.0}$	17.88 ef	16.38 ab	30.88 g	46.79 b
$B_0 Zn_{6.0}$	17.30 fg	16.00 ab	30.80 g	52.27 a
$B_{1.5} Zn_0$	17.83 ef	16.12 ab	36.80 f	36.11 d
$B_{1.5} Zn_{2.0}$	18.50 cde	16.38 ab	37.17 ef	41.02 c
$B_{1.5} Zn_{4.0}$	19.19 abc	16.87 ab	37.00 ef	46.89 b
$B_{1.5} Zn_{6.0}$	19.86 a	16.60 ab	36.90 f	53.78 a
$B_{2.0} Zn_0$	18.40 cde	16.13 ab	38.80 de	35.98 d
$B_{2.0} Zn_{2.0}$	18.73 bcd	16.91 ab	38.80 de	42.00 c
$B_{2.0} Zn_{4.0}$	19.95 a	17.77 a	38.80 de	48.09 b
$B_{2.0} Zn_{6.0}$	19.87 a	16.77 ab	39.80 cd	53.77 a
$B_{2.5} Zn_0$	18.27 de	16.10 ab	40.80 bc	36.03 d
$B_{2.5} Zn_{2.0}$	18.71 bcd	16.50 ab	41.80 ab	42.67 c
$B_{2.5} Zn_{4.0}$	19.30 ab	16.98 ab	42.80 a	48.41 b
$B_{2.5} Zn_{6.0}$	19.18 abc	16.77 ab	42.80 a	52.67 a
LSD	**	*	**	**
CV (%)	1.74	6.35	2.01	1.59

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