INFLUENCE OF MORPHO-PHYSIOLOGICAL CHARACTERS AND YIELD OF OKRA THROUGH APPLICATION OF ZINC AND BORON

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CERTIFICATE

*This is to certify that the thesis entitled “**INFLUENCE OF MORPHO-PHYSIOLOGICAL CHARACTERS AND YIELD OF OKRA THROUGH APPLICATION OF ZINC AND BORON**” submitted to the **Department of Agricultural Botany**, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTERS OF SCIENCE (M.S.)** in **AGRICULTURAL***

***BOTANY**, embodies the result of a piece of bonafide research work carried out by **NUSRAT JAHAN**, Registration No. 1708263 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that any help or source of information, received during the course of this investigation has been duly acknowledged.

DECEMBER, 2018

Dhaka, Bangladesh

(Prof. Dr. Md. Ashabul Hoque)
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Dedicated to

My

Beloved Daughter

FATIMA

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ABSTRACT

The study was carried out at the Central Farm of Sher-e-Bangla Agricultural University, Dhaka during the period from April to August 2018 to study the influence of morpho-physiological characters and yield of okra (BARI Dherosh- 1). The treatments of the experiment was T_0 (control), T_1 (20 kg Zn ha^{-1}), T_2 (30 kg Zn ha^{-1}), T_3 (10 kg B ha^{-1}), T_4 (20 kg B ha^{-1}), T_5 (20 kg Zn ha^{-1} + 10 kg B ha^{-1}), T_6 (20 kg Zn ha^{-1} + 20 kg B ha^{-1}), T_7 (30 kg Zn ha^{-1} + 10 kg B ha^{-1}) and T_8 (30 kg Zn ha^{-1} + 20 kg B ha^{-1}). The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Results revealed that the highest plant height (118.30 cm) was recorded from T_8 (30 kg Zn ha^{-1} + 20 kg B ha^{-1}) but the highest number of leaves plant^{-1} (30.06) was recorded from T_7 (30 kg Zn ha^{-1} + 10 kg B ha^{-1}). Results also revealed that the highest leaf area index, (298.60) and SPAD value (65.73), single fruit weight (14.14 g), fruit length (15.12 cm), fruit diameter (1.96 cm), % fruit dry matter (9.26 g), number of fruits plant^{-1} (36.12), fresh fruit weight plant^{-1} (510.70 g), fruit yield plot^{-1} (7.75 kg) and fruit yield ha^{-1} (17.22 t ha^{-1}) were found from T_7 (30 kg Zn ha^{-1} + 10 kg B ha^{-1}) treatment, whereas the control treatment (T_0) showed lowest performance for the respected parameters. From the above results it can be said that 30 kg Zn ha^{-1} with 10 kg B ha^{-1} combination may be helpful for okra cultivation in the field level to increase okra production.

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ABBREVIATIONS AND ACRONYMS

AEZ = Agro-Ecological Zone
BBS = Bangladesh Bureau of Statistics
BCSRI = Bangladesh Council of Scientific Research Institute
cm = Centimeter
CV % = Percent Coefficient of Variation
DAS = Days After Sowing
DMRT = Duncan‟s Multiple Range Test
et al., = And others
e.g. = exempli gratia (L), for example
etc. = Etcetera
FAO = Food and Agricultural Organization
g = Gram (s)
i.e. = id est (L), that is
Kg = Kilogram (s)
LSD = Least Significant Difference
m^2 = Meter squares
ml = MiliLitre
M.S. = Master of Science
No. = Number
SAU = Sher-e-Bangla Agricultural University
var. = Variety
^{o}C = Degree Celceous
% = Percentage
NaOH = Sodium hydroxide
GM = Geometric mean
mg = Miligram
P = Phosphorus
K = Potassium
Ca = Calcium
L = Litre
µg = Microgram
USA = United States of America
WHO = World Health Organization
LAI = Leaf Area Index
TSP = Triple Super Phosphet
UNDP = United National Development Programme
BARI = Bangladesh Agricultural Research Institute
SRDI = Soil Resources Development Institute

CHAPTER I

INTRODUCTION

Okra [*Abelmoschus esculentus* (L.) Moench] is a popular vegetable belongs to the family Malvaceae and locally known as “Dherosh” or “Bhinde”. It is also called ladies' fingers in several English speaking countries. Okra is native to West Africa and South Asia (Prakash *et al*., 2014). It is 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 (Ahmad, 1995 and Rashid, 1995). The young green fruits (green pods), which are consumed as vegetables can be used in salads, soups. 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 (Ishaque, 1976). Besides, okra seed is the great source of protein (Adelakun, *et al*., 2009). Dry roastd okra seeds are used as a substitute for coffee. Okra fruits have some medicinal importanc also fruit can be used as a plasma replacement or blood volume expander (Savello *et al*., 1980), Okra works against gastric and inflammatory diseases (Lengsfeld *et al*., 2004). In Bangladesh, during 2017-2018, the total okra production was about 56,145 thousand tons from 28303 (acres) of land with 1.98 t acre^{-1} average yield (Year book of Agricultural Statistics-2018).

Zinc, manganese, iron, boron, copper, chlorine the deficiency of zinc and boron in Bangladesh soils was most prevalent which are important in seed formation and seed quality (Begum, *et al*., 2015). Boron is necessary for proper development and differentiation of plant tissues. Abnormal Fruits formation and development occurs due to boron deficiency. Boron is relatively immobile in plants, early casualties of boron deficiency occur in the reproductive system of plants. Inadequacy of boron is often responsible for sterility and malformation of reproductive organs (Katyal and Randhawa, 1993).

Boron inhance the carbohydrates transportation through cell membranes. During boron deficiency the product accumulates in the leaves and the young growing point lacks sugar. If adequate supply of boron ensured maximum starch and sugar production is increassed in crops (Kalloo, 1985). The main functions of zinc is as the metal component of a series of enzymes. Zinc deficiency is responsible to restrict RNA synthesis, that inhibits protein synthesis (Katyal and Randhawa, 1983). Zinc inhance auxin production and auxin initiates flower and fruit setting. Zinc deficiency causes dwarfism of plant and growth become stunted in vegitative stage. Like boron, zinc deficiency is found to occur in high pH soils (Keren and Bingham, 1985). Zinc acts as a major role for proper chlorophyll formation, cell division, meristematic activity of tissue expansion of cell and formation of cell wall. Photosynthesis and translocation of food materials is increases by zinc. Uptaking of nitrogen and potassium from soil to plant mainly depend upon zinc. For root cell membrane integrity, zinc plays an important role and in this function, it prevents excessive p uptake by roots and transport of P from roots to leaves (Welch *et al*., 1982).

Therefore, directly and indirectly boron and zinc play an important role in improving the yield and quality of okra production. Proper management practices, particularly boron and zinc, would help increasing yield, quality of okra.

Till now, a few is known about effect of boron and zinc on yield of okra. Therefore, the present research was undertaken to figure out the effect of boron and zinc with the following objectives:

1. To know the integrated performance of zinc and boron for growth and yield of okra
2. To determine the optimum doses of zinc and boron association on growth and yield of okra

CHAPTER II

REVIEW OF LITERATURE

Okra is one of the most nutritious rich for its taste and status of vegetable and plays an important role to meet the demands in the country during the crisis period in early summer. A very few studies on boron and zinc related to yield and development of okra have been carried out in our country as well as many other countries of the world. In this chapter, an attempt has been made to review the available information in home and abroad regarding the effect of boron and zinc on the yield of okra and other crops.

2.1 Effect of boron (B)

For cell wall formation, development of seeds and fruits. Firoz *et al*. (2009) observed boron is very essential that the application of boron @ 1 kg ha^{-1} produced the highest yield (512.3 g plant^{-1}) and the lowest (445.4 g plant^{-1}) was observed in control.

According to Dursun *et al*. (2010) boron application decreased the concentration of nitrogen (N), calcium (Ca), and magnesium (Mg) but increased phosphorus (P), potassium (K), iron (Fe), manganese (Mn), zinc (Zn), and copper (Cu) concentrations. Thus it concluded that addition of boron @ 2.5 kg ha^{-1} is sufficient to elevate boron level in soil.

Malek and Rahim (2011) indicated that application of boron level @ 3 kg ha^{-1} gave the highest seed yield (1769.11 kg ha^{-1}) which was followed by 0 kg B ha^{-1} (control) gave the lowest seed yield (1371.93 kg ha^{-1}) in carrot. Saha *et al*. (2010) revealed that, spraying of borax @ 0.3per cent at 30 and 45 DAT gave maximum total head yield of 13.37 t ha^{-1} in broccoli.

Naz *et al*. (2012) reported that the application of boron @ 2 kg ha^{-1}, enhanced number of flower clusters per plant, fruit set percentage, total yield, fruit weight loss and total soluble solids of tomato.

Manna *et al*. (2014) revealed that the application of 0.5% boron significantly increased the growth (plant height and number of leaf plant^{-1}), yield and quality (TSS and Pyruvic acid) of onion.

Islam *et al*. (2015) reported positive effect of boron @ 2.0 kg B ha^{-1} on the yield and quality of broccoli. Mekdad (2015) investigated that foliar spraying of boron at 120 and 150 ppm in sugar beet, significantly improved root yield, its attributes and percentage of white sugar content.

Panda and Sahoo (2019) started a long term field experiment during 2012-13 at E block of central research station, under AICRP on Micronutrient, O.U.A.T, Bhubaneswar to standardize the dose and frequency of boron application for rice-knol khol cropping system where boron is applied to first crop and Knol khol gets residual boron. In the present investigation residual effect of different graded doses of boron and its frequency of application on quality and post harvest parameters of Knol khol for the year 2017-18 was studied. The experiment was laid out in a Factorial Randomized Block Design with three replications and four different doses of boron (0.5 kg/ha, 1.0 kg/ha, 1.5 kg/ha and 2.0 kg/ha) at three different frequencies (application of boron once, alternate year and every year) were applied. The results revealed that the maximum values of quality and post harvest parameters (viz., Total soluble solid content of knob (6.7oBrix), Ascorbic acid content of knob (78.2 mg/100g), Firmness of knob (7.9kgf), Dry matter content (9.21%), Duration of maximum retention of shelf life of knob (5.03 days), Percentage of marketable knobs (96.1%) with no knob cracking were recorded with residual effect of boron @ 1.5kg/ha in every year application. The knob cracking increased as the Boron availability decreased.

Khattab *et al*. (2019) found that Jojoba plants [*Simmondsia chinensis* (Link) Schneider] are appropriate to the semiarid regions; it has the ability to survive in a harsh desert environment and it is very drought-resistant and can be grown on marginal lands without replacing any existing crops. After that, Jojoba is a new oil-producing industrial crop, oil-producing cash crop, and has much of the interest in worldwide in recent years. So, processes are made to increase the seed yield of jojoba as requirements of essential fertilizer and evaluation of new clones. Two field experiments were conducted on five clones (S-BS-, S-700, 610, S-L, and S-G) aged 3 and 13 years from planting at North Sinai, Egypt on sandy soil to study the effect of foliar spray with nitrogen, phosphorus, and boron with three rates of NPB (00, NPB1 (N 1%, P 0.75%, and B 0.4%) and NPB2 (N 1.5%, P1.25% and B 0.8%)) on oil and other contents of jojoba plants. Results showed that all treatments improved the vegetative growth, yield, and seed quality. Concerning oil, weight of 100 seeds and oil percent in seeds with treatment NPB2 under clone S-700 gave the highest value for all study parameters. Therefore, for improving yield and seed quality, it could be recommended with foliar spray NPB2 (N1.5%, P 1.25%, and B0.8%) under the condition of this study on jojoba plants.

Franczuk *et al*. (2019) carried out a study on the effects of boron topdressing and Effective Microorganism (EM) treatments on the growth, yield and quality of broccoli harvested in summer. EM is a microbial inoculant promoted to stimulate plant growth and soil fertility in agriculture. Boron (B) is one of eight micronutrients needed for proper plant growth. Different combinations of Effective Microorganism were applied: added to the nursery substrate before planting seeds (EM1); added to the nursery substrate before planting seeds and as topdressing in a form of spray after seedlings were planted out (EM2); as pre-planting treatment in the field, just before the seedlings were transplanted (EM3); as pre-planting treatment in the field, followed by topdressing as a spray (EM4); control (without EM). Boron was applied as mineral fertilizer three weeks after broccoli seedlings had been planted out in the field. The experiment was carried out between 2014 and 2015, at the Experimental Station of Siedlce University of Natural Sciences and Humanities, located in central-eastern Poland. Compared to the control, each method of Effective Microorganisms application to broccoli significantly increased its marketable curd yield, average curd weight and leaf greenness index (SPAD). Plants had the longest arc of curd and the largest L-Ascorbic acid content when EM were added to the substrate and then applied in the field in the form of spray. Effective Microorganisms applied as EM1, EM2, and EM3 combinations increased the potassium and calcium content in broccoli. However, there was no significant effect of EM application on dry matter, sugar and protein content in broccoli curds. Boron application to broccoli resulted in an increase in the marketable curd yield, the weight of marketable curds, the length of arc of curd, and dry matter, phosphorus and potassium content.

Venkata-narayana *et al*. (2019) carried out an investigation during kharif, 2018 in tomato crop by application of Nova Ami-B in combination with recommended dose of fertilizers to evaluate the efficiency of Nova amino chelated boron. The experiment was laid out in Randomized Block Design(RBD) with five treatments and control i.e T1: Control (No application of any fertilizer), T2: Recommended Dose of Fertilizers (RDF), T3: T2+ 2.5g/l Boron at 20 and 45 DAT, T4: T2 + 2.5ml/l of Nova Ami-B at 20 and 45 DAT, T5: 2.5g/l Boron at 20 and 45 DAT, T6: 2.5ml/l of Nova Ami-B at 20 and 45 DAT. Experiment revealed that application of (T4) Recommended Dose of Fertilizers + Nova Ami-B resulted in improved plant height, number of flowers per plant, number of fruits per plant, fruit weight per plant, total soluble solids and lycopene content over other treatments but T3 showed more number of leaves per plant.

Badini (2019) carried out the present study during the Kharif season March 2017, at the Department of Horticulture Sindh Agriculture University Tandojam, Pakistan. The experiment was laid out in three replication and six treatments combination. Hence, consider to each levels of Zinc (Zn 10 kg ha^{-1} and B 4 kg ha^{-1}) and results of the design to indicated the application of Significantly, increase plant height cm, number of branches plant^{-1}, number of pods plant^{-1}, Weight of pods plant^{-1} g, pod length cm, Single pod weight g, pod yield ha^{-1}, pod yield plot kg. Among the different levels of different Zinc and Boron, the number of branches plant^{-1} and the increased application plant height cm immature, the Zn and Boron to improve the different recommended dose of fertilizer and yield of okra.

Bhadra (2019) conducted an experiment at the Horticulture Farm of Bangladesh Agricultural University, Mymensingh, during the period from October 2014 to February 2015 to study the effects of cow dung and boron on growth and yield of broccoli. The experiment consisted of two factors; Factor A: cow dung - 4 levels such as C0: no cow dung (control), C1: cow dung 10 ton/ha, C2: cow dung 15 ton/ha and C3: cow dung 20 ton/ha. Factor B: boron - 4 levels, such as B0- no boron (control), B1: boron 1 kg/ha, B2: boron 2 kg/ha and B3: boron 3 kg/ha. The experiment was laid out following a randomized complete block design (RCBD) with three replications. In case of cow dung the maximum plant height at 60 DAT (61.47 cm), spread of plant at 60 DAT (50.00 cm), number of leaves per plant at 60 DAT (11.39), length of the largest leaf at 60 DAT (57.69 cm), primary curd weight (374.58 g), yield per hectare (15.74 t/ha) were recorded from C3 (cow dung 20 ton/ha) treatment and the lowest was recorded from the control (C0) treatment. In case of boron the maximum plant height at 60 DAT (57.69 cm), spread of plant at 60 DAT (48.44 cm), number of leaves per plant at 60 DAT (11.21), length of the largest leaf at 60 DAT (54.45 cm), primary curd weight (286.78 g), yield per hectare (12.03 t/ha) and the minimum days required for curd initiation (51.17 DAT) were recorded from B2 (boron 2kg/ha) treatment and the lowest was recorded from control (B0) treatment. Regarding combination of cow dung and boron the maximum plant height at 60 DAT (63.11 cm), spread of plant at 60 DAT (52.33 cm), number of leaves per plant at 60 DAT (12.97), length of the largest leaf at 60 DAT (60.25 cm), primary curd weight (399.33 g), yield per hectare (16.71 t/ha) and the minimum days required for curd initiation (50.10 DAT), were recorded from C3B2 (cow dung 20 t/ha and boron 2 kg/ha) treatment and the lowest was recorded from C0B0 (no cow dung and no boron) treatment.

The highest production of broccoli is obtained from 20 ton/ha cow dung and 2 kg/ha boron at Horticulture farm condition of Bangladesh Agricultural University, Mymensingh.

Exogenous application of boron significantly increased the number of leaves plant^{-1} and plant height compared to control in tomato (Verma *et al.*, 1973). Sharma (1995) reported that borax at 20 kg ha^{-1} and calcium carbonate at 10 kg ha^{-1} applied alone or in combination showed best results on plant growth and development.

Sharma (1999) stated that application of borax 20 kg ha^{-1} gave the maximum plant height (70.6 cm) and number of branches per plant (6.9), while the control registered the least plant height (59 cm) and number of branches plant^{-1} (5.8).

Yoganand (2001) recorded the lowest plant height (53.43 cm) and number of branches plant^{-1} (5.18) with borax 0.2% sprayed at pre-flowering stage as against control (54.90 cm and 5.47, respectively)

Verma *et al.* (2004) concluded that foliar application of borax showed positive effect on seed yield, seed germination % and test weight in *capsicum* which were significantly better than the other treatments. Foliar spray of borax (0.1%) at flowering stage in chilli (*Capsicum annuum* L.) cv. Byadagi Kaddi recorded the higher seed yield (170 kg ha^{-1}) and number of seeds fruit^{-1} (83.4) as compared to control (Natesh *et al.*, 2005).

Foliar spray of borax (0.5%) recorded that the higher number of seeds (221.20) and seed yield fruit^{-1} seed germination (83.82%), seedling vigour index (1000.4) and seedling dry weight (51.10 mg) with lower electrical conductivity (0.36 dSm^{-1}) in bell pepper (Kumar and Malabasari, 2011).

Kumari (2012) suggested that exogenous application of boron, iron and manganese each at 100 ppm at 30 days after transplanting at an interval of 10 days resulted in maximum seed yield and seed germination% in tomato.

Sharma (1995) concluded that the boron 20 kg ha^{-1} showed pronounced beneficial effect on test weight (3.94 g) and per cent seed germination (96.5) as compared to boron 10 kg ha^{-1} (3.41 g and 94.33%, respectively) in tomato.

Sharma (1999) recorded that the highest per cent seed germination (91.2) and test weight (6 g) with combined application of borax 20 kg and calcium carbonate 20 kg ha^{-1} as against control (83.6%) in bell pepper (*Capsicum annuum* L.). The average number of seeds per fruit (55.66) and weight of 500 seeds (2.549

g) were significantly recorded with spray of H_3BO_3 0.50%, while the maximum seed yield was obtained with spray of $ZnSO_4$ 0.50% (Dongre *et al.*, 2000).

Sharma (1995) reported that applying borax 20 kg ha^{-1} in soil exhibited pronounced beneficial effect on number of fruits plant^{-1} (23.1), fruit yield (762.7 q ha^{-1}) and seed yield (246.2 kg ha^{-1}) as compared to borax 10kg ha^{-1} (18.9, 635.7 q ha^{-1} and 176.5 kg, respectively). Verma *et al.* (1995) noticed that the marketable fruit yield (285.04 q ha^{-1}) increased markedly with the application of boron 2 kg ha^{-1} as compared to control (266.92 q ha^{-1}) in tomato.

Sharma (1999) recorded the highest plant height (70.6 cm) and number of branches per plant (6.9) in bell pepper with boron 20 kg ha^{-1} and least with control (59 cm and 5.8, respectively). A combined application of borax 20 kg and calcium carbonate 20 kg ha^{-1} proved best in recording the highest fruit and seed yield per plant.

In chilli, Dongre *et al.* (2000) recorded the maximum fruit yield plant^{-1} when boron was sprayed in the form of H_3BO_3 at 0.25% as against control. Furthermore, highest average fruit length (11.12 cm) and fruit diameter (1.175 cm) was recorded when H_3BO_3 was sprayed at 0.1%.

Exogenous application spray of boron at flowering period was found in increasing fruit weight (55.78g), number of fruits plant^{-1} (44.99) and fruit yield (31.82 t ha^{-1}) in tomato (Hamsaveni *et al.*, 2003). In *Capsicum*, Verma *et al.*

(2004) found that foliar application of borax (0.5%) enhanced the seed yield as well as the number of fruits plant^{-1}.

Karuppaiah (2005) found the foliar application of borax at 35, 50 and 65 days after transplanting to be the best in terms of number of flowers plant^{-1}, number of productive flowers plant^{-1}, number of fruits plant^{-1},individual fruit weight and yield (32.15 t ha^{-1}), followed by copper sulphate (0.5%) and zinc sulphate (0.5%) sprayed at 35, 50 and 65 days after transplanting in brinjal.

The highest fruit yield (33 t ha^{-1}) was recorded through the soil application of boron (20 kg ha^{-1}) in tomato (Sathya *et al*., 2010). Foliar spray of borax 0.5% resulted in significantly highest number of fruits (8.3) and fruit yield plant^{-1} (377.8g) in bell pepper (Kumar and Malabasari, 2011). Application of boron kg ha^{-1} resulted in maximum number of flower clusters plant^{-1}, and yield of tomato (Naz *et al*., 2012).

In tomato, Rab and Haq (2012) noticed that foliar application of borax alone significantly increased the number of flowers cluster^{-1}, fruits cluster^{-1} and fruits plant^{-1}, fruit weight, fruit firmness and total soluble solids content in the fruits. The foliar application of boron (H_3BO_3) at 150 ppm increased the number of flower buds plant^{-1} number of flowers cluster^{-1} number of flower clusters plant^{-1}, total number of flowers plant^{-1} , fruit set% , number of fruits plant^{-1} (216%) and fresh weight of fruits plant^{-1} (88%) than that of control in brinjal (Suganiya *et al*., 2015).

In tomato, Ali *et al*. (2013) recorded the height fruit set%, number of fruits plant^{-1}, fruit weight, fruit length, fruit diameter, number of large sized fruits with least number of small fruits, yield plant^{-1} and yield. Foliar application of zinc resulted in maximum number of flowers cluster^{-1} (18.14), fruits cluster^{-1} (8), fruits plant^{-1} (90.14), fruit weight (95.14g) and yield (25.14 t ha^{-1}) in tomato (Kazemi, 2013). The height number of flowers per plant, number of fruits per plant, yield plant^{-1} and fruit yield hectare^{-1} was registered with the application of boric acid + zinc sulphate + copper sulphate at 250 ppm each as a foliar spray in tomato (Singh and Tiwari, 2013).

Boron is necessary for cell wall formation, development seed and fruit. Firoz *et al*. (2009) observed that the application of boron @ 1 kg ha^{-1} produced the highest yield than the control treatment. According to Dursun *et al.* (2010) boron application decreased the concentration of nitrogen (N), calcium (Ca), and magnesium (Mg) but increased phosphorus (P), potassium (K), iron (Fe), manganese (Mn), zinc (Zn), and copper (Cu) concentrations. Thus it concluded that addition of boron @ 2.5 kg ha^{-1} is sufficient to elevate boron level in soil. Malek and Rahim (2011) indicated that application of boron level @ 3 kg ha^{-1} gave the highest seed yield (1769.11 kg ha^{-1}) which was followed by 0 kg B ha^{-1} (control) gave the lowest seed yield (1371.93 kg ha^{-1}) in carrot. Saha *et al.* (2010) revealed that, spraying of borax @ 0.3per cent at 30 and 45 DAT gave maximum total head yield of 13.37 t ha^{-1} in broccoli. Naz *et al.* (2012) studied the effect of Boron (B) on the flowering and fruiting of tomato and reported that application of boron @ 2 kg ha^{-1}, enhanced number of flower clusters per plant, fruit set percentage, total yield, fruit weight loss and total soluble solids. Manna *et al*. (2014) revealed that the application of 0.5% boron significantly increased the growth (plant height and number of leaf per plant), yield and quality (TSS and Pyruvic acid) of onion.

2.2 Effect of Zn

Kalroo *et al*. (2013) concluded that with increasing zinc level, the growth and yield contributing traits improved gradually. The highest concentration of zinc at 5 ml/l water resulted in 85.66 cm plant height, 77 cm plant spread, 13 branches per plant and took 56.33 days to flower emergence. Sivaiah *et al.* (2013) recorded the maximum growth rate (85.7%) with the application of zinc followed by the application of micronutrients mixture (78.2%) in tomato.

The soil application of zinc sulphate 20 kg ha^{-1} + $ZnSO_4$ 0.5% foliar spray before flowering showed significant increase in seed yield and its components in chilli (Singh *et al*., 1989).

Yoganand (2001) noticed that the lower germination (64.81%), root length (4.86 cm) and shoot length (5.95 cm) with the application of $ZnSO_4$ (0.2%) at pre-flowering stage of bell pepper as compared to control (64.91%, 4.25 cm and 5.22 cm, respectively).

Chandra and Verma (2003) found that the application of boron 2 kg and calcium 2 kg ha^{-1} to soil prior to transplanting was most effective for obtaining the highest fruit and seed yield in tomato. Foliar spray of boron 0.5% at 50 per cent flowering period significantly increased the number of seeds per fruit (142.83) and seed yield (241 kg ha^{-1}). Further, it has resulted in better seed quality parameters, viz., test weight (2.92 g), germination (93.88%) index (1281) in tomato. (Hamsaveni *et al*., 2003).

Hussain *et al*. (1989) obtained higher weight of Thousand seeds (0.56 g) with zinc spray at 0.1% as against soil application in chilli. Yoganand (2001) recorded germination% (64.81%), root length (4.86 cm) and shoot length (5.95 cm) when the plants were sprayed with $ZnSO_4$ (0.2%) at pre-flowering stage of bell pepper.

Basavarajeshwari *et al*. (2010) reported that the foliar application of zinc sulphate, increased the number of seeds fruit^{-1} (128.43). In chilli (*Capsicum annuum* L.) cv. ByadagiKaddi, Natesh *et al*.(2005) recorded higher seed yield (248.26 kg ha^{-1}) with increased quality parameters by foliar spray of $ZnSO_4$ (0.1%) at flowering stage as compared to control.

Zinc deficient soils, Khomchack *et al*. (1971) found that addition of zinc 0.02% to irrigation water increased the yield by 16.3% in tomato production. Gupta and Hansraj (1980) observed the more yield of tomato by controlling near about 20 ppm zinc concentration in the plant. Mallick and Muthukrishnan (1980) observed that the foliar application of zinc at 5 and 10ppm increased the fruits number plant^{-1} to the tune of 97 and 99% and fruit weight by 25 and 28%, respectively in tomato. The foliar application of $ZnSO_4$ 0.02 or 0.05% at 30, 50 and 70 days after planting had positive effect both on fruit weight and yield of tomato (Elabdeen and Metwally, 1982).

Hussain *et al*. (1989) recorded the higher yield and yield components of chilli with foliar application of zinc or boron or in combination of zinc, boron and iron each at 0.1% as compared to control. While studying the effect of zinc sulphate on yield of aubergine in calcareous soils, Bid *et al*. (1992) noted that zinc sulphate and copper sulphate at 10 and 20 kg ha^{-1}, respectively decreased zinc and copper deficiency symptoms and significantly increased the yield.

Ravichandran *et al*. (1995) obtained the heaviest fruits (52.2 g) with soil application of $ZnSO_4$ (25 kg ha^{-1}) and the highest yield (27.1 t ha^{-1}) and number of fruits plant^{-1} (20) with soil application of $ZnSO_4$ (25 kg ha^{-1}) in combination with zinc (0.5%) foliar spray 30 days after transplanting in brinjal. Verma *et al*. (1995) obtained the highest marketable tomato yield (285.88 q ha^{-1}) when zinc sulphate was applied @ 10 kg ha^{-1}. Foliar application of zinc had positive impact on chilli (Radulovic, 1996).

Raj *et al*. (2001) found significant increase in yield, zinc and iron content of brinjal fruits with the application of zinc and iron either through soil or foliar spray. Among the treatments, soil application of $ZnSO_4$ 12.5 kg ha^{-1} along with three sprays of $ZnSO_4$ 0.2% and $FeSO_4$ 0.5% at weekly interval at later stages recorded significantly highest fruit yield of 37.7 t ha^{-1} with 23.6% increased over control in brinjal cv. Bhagyamathi.

Foliar application of zinc, copper and boron produced the highest number of fruits plant^{-1} but the increasing Polyfeed spray frequency 3-4 times did not increase the number of fruits plant^{-1} in chilli (Jiskani, 2005).

In chilli, spraying ferrous sulphate 100 ppm significantly increased the number of fruits per plant (49.40) and fruit length (9.10 cm) as compared to control

(Basavarajeshwari *et al.,* 2010).The significantly higher number of fruits and fruit yield were registered with the application of NPK 100:100:50 kg ha^{-1} + Azospirillum + PSB each @ 125 g ha^{-1} (root dipping) along with $ZnSO_4$ (0.2%) spray (Kiran *et al*., 2010).

Kalroo *et al*. (2013) revealed that zinc at 5 mlL^{-1} water resulted in maximum number of fruits plant^{-1} (481.33), fruit length (5.50 cm), fresh fruit yield (705 g plant^{-1}) and fruit yield (16.35 t ha^{-1}). However, the fruit yield (16.350 t ha^{-1}) did not increase significantly under concentration of zinc 5 mlL^{-1} water when compared with 4 mlL^{-1} water, that indicates zinc at 4 mlL^{-1} water was an optimum level for obtaining economical fruit yield (16.093 t ha^{-1}) in chilli. Near about similar results have also been reported by Jiudith *et al*. (2005) from England and Maheswari *et al*. (2003), Yadav *et al*. (2003), Bhatt and Srivastava (2006) and Hatwar *et al*. (2003) from India.

Sivaiah *et al*. (2013) found that foliar spray of zinc, molybdenum, boron, copper, manganese and iron in combination each at 100 ppm except manganese (at 50 ppm) increased the maximum fruit yield per plant followed by application of boron and zinc individually. The highest yield (1138 kg ha^{-1}) was recorded with combined application of zinc and boron (3 and 1 kg ha^{-1}, respectively), which was closely followed by zinc 3 + boron 2 kg ha^{-1} and zinc 4.5 + boron 2 kg ha^{-1}, and the lowest (703 kg ha^{-1}) in control. However, from regression analysis, the optimum-economic dose of zinc was found to be 3.91 kg ha^{-1}, whereas, it was 1.70 kg ha^{-1} for boron (Shil *et al*., 2013). Foliar application of boron 0.25% + APSA-80 resulted in earliest flowering and fruiting (72 and 94 days, respectively) and highest number of fruits per plant (8.63) and total yield (356.55 q ha^{-1}) in brinjal (Gogoi *et al*., 2014).

Aboyeji (2019) conducted a field experiments during 2016 and 2017 cropping seasons in the derived agro-ecological zone of Nigeria to study the combined and sole effect of zinc and boron fertilizers on the growth, seed yield, and quality of groundnut (*Arachis hypogaea* L). Experiment was laid out in randomized complete block design (RCBD), replicated four times. Tree levels of zinc (0, 4, and 8 kg ha^{-1}) and four levels of boron (0, 300, 600, and 900 ml ha^{-1}) were combined and evaluated. Groundnut seeds were analyzed at the end of the experiments to determine nutrient elements and some heavy metal contents. Data collected were subjected to Statistical Analysis of Variance using SAS 2000. Treatment means were compared using the Duncan multiple range test at 0.05 level of probability.)e effect of zinc was not significant on the vegetative parameters, while application 8 kg Zn ha^{-1} significantly increased number of seeds, weight of seeds, seed yield per hectare, and seed quality though the values were similar to the application of 4 kg Zn ha^{-1} only on the seed yield and its parameters. Application of 600 and 900 ml B ha^{-1} gave higher and statistically similar values for vegetative parameters, yield, and yield parameters, while 600 ml B ha^{-1} significantly improved the seed quality. It can therefore be recommended that for optimum yield and seed quality, application of 8 kg Zn ha^{-1} combined 600 ml B·ha^{-1} is sufficient in the study area without increasing the heavy metal concentration of groundnut seed.

Neocleous (2019) investigated the effect of individual and combined applications of manganese (Mn) and zinc (Zn) chelates on common bean grown in hydroponics (nutrient film technique—NFT) on physiological and agronomical responses. Inorganic sulphate forms of Mn and Zn were compared to their synthetic chelate forms, in the replenishment nutrient solution (RNS). Nutrient (N, P, K, Ca, Mg, Fe, Mn, Zn and Cu) to water uptake ratios (termed uptake concentrations; UCs), growth, pods yield and quality, photosynthetic parameters and tissue nutrient status were evaluated in different cropping seasons (spring-summer and autumn-winter crops). Mean UCs of nutrients ranged as follows: 10.1–12.4 (N), 0.8–1.0 (P), 5.2–5.6 (K), 1.8–2.2 (Ca), 0.9–1.0 (Mg) mmol L^{-1}; 12.2–13.4 (Fe), 5.2–5.6 (Mn), 4.4–4.9 (Zn), 0.9–1.0 (Cu) µmol L^{-1}. Tissue macronutrient status remained unaffected in both seasons, however, Mn chelates in the RNS affected Fe within plants. Pod yield and quality, growth, photosynthesis and water uptake did not differ among treatments; however, seasonal variations are presented. Results suggest that the chelate forms of Mn and/or Zn in the refill solution for NFT-grown beans do not lead to any changes, adding superiority in the yield, photosynthesis, and nutritional status of the crops compared to their mineral forms.

Hacisalihoglu (2019) reported that at a global scale, about three billion people have inadequate zinc (Zn) and iron (Fe) nutrition and 500,000 children lose their lives due to this. In recent years, the interest in adopting healthy diets drew increased attention to mineral nutrients, including Zn. Zn is an essential micronutrient for plant growth and development that is involved in several processes, like acting as a cofactor for hundreds of enzymes, chlorophyll biosynthesis, gene expression, signal transduction, and plant defense systems. Many agricultural soils are unable to supply the Zn needs of crop plants, making Zn deficiency a widespread nutritional disorder, particularly in calcareous ($pH > 7$) soils worldwide. Plant Zn efficiency involves Zn uptake, transport, and utilization; plants with high Zn efficiency display high yield and significant growth under low Zn supply and offer a promising and sustainable solution for the production of many crops, such as rice, beans, wheat, soybeans, and maize. The goal of this review is to report the current knowledge on key Zn efficiency traits including root system uptake, Zn transporters, and shoot Zn utilization. These mechanisms will be valuable for increasing the Zn efficiency of crops and food Zn contents to meet global needs for food production and nutrition in the 21st century. Furthermore, future research will address the target genes underlying Zn efficiency and the optimization of Zn efficiency phenotyping for the development of Zn-efficient crop varieties for more sustainable crop production under suboptimal Zn regimes, as well food security of the future.

Marzouk and Abd-Alrahman (2019) reported that Nanotechnology introduces smart agricultural products which may be a milestone in solving many common economic and ecological issues. Nano-fertilizers show unique characters which do not exist in their conventional counterparts. This work aimed to determine the effects of three foliar spraying of nano micronutrient fertilizers iron, manganese, and zinc as well as the controlon the vegetative growth, productivity, physical quality, and pod nutritional value of two snap bean cultivars Bronco and Flantino and also their interactions. Flantino cultivar recorded the highest values of vegetative growth, fresh pod yield, pod physical quality (length, diameter, and fresh weight), dry weight, and pod nutritional value content expressed as P, K, Zn, Mn, Fe, Cu, crude protein, total soluble solids, and fiber. Foliar application of zinc nano-fertilizer increased the studied characteristics significantly compared with other nano micronutrients. Also, the combined effect of Flantino cultivar with zinc nano-fertilizer treatment recorded the highest values of vegetative growth, fresh pod yield, pods physical quality and nutritional value.

Wong (2019) reported that Zn is an important element in both industrial and biological sense. The great industrial importance of Zn has made this element a potential hazard to vegetable consuming humans. In this review, the important biological role of Zn and the human Zn dietary requirement as well as its toxicity are discussed. The Zn in various commonly consumed vegetables have also been reviewed. Based on a range to previous studies, it is confirmed that human activities such as metal mining and smelting as well as the application of manure fertilizer could contribute to Zn enrichment in both cultivation soil and the vegetable tissues. Zn in vegetable tissues also been discovered to have a strong and positive correlation with some element such as K, Fe, Mn and Cd. Due to Zn’s industrial importance, it will always be a possibility of the occurrence of high Zn enrichment due to anthropogenic activities. Despite the biological importance, the constant monitoring of Zn in various food crops should not be neglected.

Vegetable representing a significant portion of recommended human daily diet due to its richness in essential nutrients while low in fat, sodium and calories

(Devine *et al*., 1998). As discussed in previous section, Zn is considered as an essential element for human survival.

Zn is essential not only to humans, but also to food crops them. There are a numerous studies that confirms the positive correlation of Zn in plant tissues and Zn in surrounding habitat. An experimental exposure of 5 mM and 10 mM of Zn to common bean, *Phaseolus vulgaris*, has revealed a positive Zn accumulation in consequence of the exposure (de-Figueiredo *et al*., (2017). Another study that samples common purslane *Portulaca oleracea* in Costa da caparica, Portugal, also revealed similar pattern of Zn accumulation. However, due to high Zn contamination in two of their sites, the *P. oleracea* from those sites were highly contaminated and consumption was deemed unsafe (Reboredo *et al*., 2019).

Ribwort plantain, *Plantago lanceolata* L., is a roadside and grassland flora that is widely used as food and herbal preparation in various countries. Drava *et al*. (2019) compared the Zn levels in *P. lanceolata* in a series of sites with varying anthropogenic characteristics. They revealed that higher in Zn concentration compared to rural area. A collective of vegetables were also been discovered to have elevated Zn concentration near Zhuzhou Smelter, Zhuzhou, Hunan Province, China (Li *et al*., 2018).

Zn enrichment could lead to alteration in food crops' physiology. Study has associated Zn exposure to *P. vulgaris* with lower phytic level. Lowered phytic level could lead to increase of bioavailability of several micronutrients, including Zn since phytic acid is an antinutritive agent capable of blocking mineral absorption [64- 66]. Reduced Zn during pods was also observed (de-Figueiredo *et al*., 2017).

Zn tolerance differs among plants that are closely related genetically. The physiological impact of Zn exposure of two related vegetable species *Brassica juncea* and *B. napus* was investigated by exposing them to varying Zn concentrations up to 300 µM. This study revealed that in term of root damage, and microelement homeostasis alteration, *B. juncea* is more Zn tolerant than *B. natus*. The physiology of their root was also observed. It was discovered that the oxidative components were predominant compared with nitrosative component in root (Feigl *et al*., 2015).

The impact of Zn to the physiology of a food crops isn't limited to the elevation of its concentration in response of its exposure. In cooperation with other physiological significant element, varying physiological responses may be revealed. Zn (200 ppm) was coexposed with varying concentration if potassium (K) to wheat (*Triticum aestivum* L.). It was observed that in consequence of Zn and K co-exposure, oxidative stress was minimized, root, shoot and root lengths were improved. Another wheat physiological parameter, such as wet and dry biomass, photosynthetic pigments, osmolyte regulators and membrane stability index were also improved. Reduction of MDA content was also observed [68]. Inter-species correlation analysis on the heavy metal contents among wide range of vegetable and fruits also unveiled a strong and positive correlation between Zn and Cd (Parveen *et al*., 2003).

Zn is also found to have a strong and positive relationship with Fe and Mn, which are another physiological significant nutrient (Shukla *et al*., 2006). Zn concentration in soil has also been discovered to be one of the factor influencing Cd accumulation in cabbage (Li *et al*., 2016). The utilization of manure as fertilizers is one of the major factors impacting Zn availability to vegetable crops. A collective of closed greenhouse cultivated vegetables in Nanjing, China, was investigated by Chen *et al*. (2013).

It was concluded that the Zn in cultivation soil was originated from chicken manure. The application of manure in agriculture isn't only contribute to elevation of heavy metal accumulation. The application of cow manure biochar was revealed to be able to reduce the bioavailability and translocation factors of several heavy metals in Zucchini (*Cucurbita pepo* L.), including Zn. Mining and smelting activity is another major Zn source for vegetable. The Zn level along with Pb and Cd in ribwort plantain (*Plantago lanceolate* L.) near mines and smelting plants were found to be enriched up to 15 times beyond rural areas in Genoa and province, Liguria, NorthWestern Italy (Drava *et al.*, 2019).

Another studies has shown that the soil Zn level has been significantly enriched due to smelting activity nearby Huludao Zinc Plant, Liaoning Province, China (Li *et al.*, 2016). Several recent studies have been conducted to investigate the potential human health risks of metals in vegetables. The Zn in Bok Choy (*Brassica campestris* L. ssp. chinensis Makino), Water Spinach (*Ipomoea aquatica* Forsk.), Shanghai green cabbage (*Brassica chinensis* L.), leaf lettuce (*Lactuca sativa* L. var. ramosa Hort.) from Shanghai, China. It was determined that the Zn concentrations in these vagetables were below the food safety limit set in China (Bi *et al.*, 2018).

The Zn levels in Lettuce (*Lactuca sativa* var. crispa), Ethiopian mustard (*Brassica carinata*) and Beet (*Beta Vulgaris* var. cicla) from wastewater-irrigated urban vegetable farming site in Addis Ababa, Ethiopia was also investigated for possible human health hazard. There was no Zn hazard discovered (Woldetsadik *et al.*, 2017). Wastewater irrigated coriander, mint and fenugreek in Faisalabad, Pakistan was found to be a potential hazard to consumers due to their higher-than- permissible-limit Cd, Pb and Zn concentration (Anwar *et al.*, 2016).

2.3 Combined effect of boron and zinc

Badini *et al*. (2018) reported that the increase plant height (cm), number of branches plant^{-1}, number of pods plant^{-1}, weight of pods plant^{-1} (g), pod length (cm), single pod weight (g), pod yield ha^{-1} (t), pod yield plot^{-1} (kg). Among the different levels of different Zinc and Boron, the number of branches plant^{-1} and the increased application plant height cm immature, the Zn and Boron to improve the different recommended dose of fertilizer and yield of okra.

Rahman (2017) conducted a study in order to investigate the okra 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^{-1} and 4 kg Zn ha^{-1}. The foliar application of 0.2 % B and 0.2 % Zn individually and combined produced maximum yield and quality of okra seed.

The application of zinc and boron increases the number of mature fruits plant^{-1} in tomato (Yadav *et al*. 2001). Srivastava *et al*. (2005) recorded that the foliar application of $ZnSO_4$ and boric acid increases the TSS content in garlic.

Salam *et al*. (2011) investigated that the combination of boron and zinc @ 2.5 kg B ha^{-1} + 6 kg Zn ha^{-1}, resulted the highest pulp weight, dry matter content, ascorbic acid, lycopene content, chlorophyll content in tomato.

Kant *et al*. (2013) revealed that the plant height, number of leaves plant^{-1}, biological yield, curd weight and marketable yield were found highest with combined application of zinc and boron in cauliflower.

Shil *et al*. (2013) evaluated the interaction effect between zinc and boron in the yield of dry chilli and weight of ripe chilli plant^{-1}. The highest yield (1138 kg ha^{-1}) was recorded from Zn, B @ 3.91:1.70 kg ha^{-1} and the lowest in case of control.

Abdel *et al*. (2014) studied that application of zinc (100 and 200 ppm) and boron (50 and 100 ppm) significantly affected the growth, head yield, yield components and quality of broccoli (*Brassica oleracea* L. var. italica.).

Acharya *et al*. (2015) revealed that foliar application of zinc sulphate at 0.5%

results maximum plant height, number of leaves plant^{-1}, fresh leaf weight, fresh bulb weight, bulb yieldplot^{-1} and bulb yieldhectare^{-1}, while soil application of borax @ 10 kg/h showed highest polar and equatorial diameter and the highest TSS content was also observed in the soil application of zinc sulphate (10 kg ha^{-1}) in onion.

Ali *et al.* (2015) indicated that the maximum plant height, number of leaves, leaf area, number of fruits, fruit length, fruit diameter and yield and early flowering with minimum diseased infested plant were found from foliar application of $ZnSO_4$ @12.5 ppm + H_3BO_3 @12.5ppm while minimum from control in tomato.

Mansourabad *et al.* (2016) evaluated the effects of some micronutrients like iron, zinc and silicon on the root-knot nematode and plant growth parameters of cucumber. Micronutrients (iron, zinc and silicon) at 5mg/kg of soil significantly reduced the number of galls/g of root and also improved the shoot dry and fresh weights and fruit yield

Haleem *et al.* (2017) found that the interaction of B and Zn increases the plant height, number of primary and secondary branches, number of leaves plant^{-1}, number fruits plant^{-1} in tomato.

Sidhu (2019) reported that proper plant nutrition is essential for successful production of vegetable crops. Integrated supply of micronutrients with macronutrients in adequate amount and suitable proportions is one of the most important factors that control the plant growth and development. Micronutrients are usually required in minute quantities, nevertheless, are vital to the growth of plant. Judicious use of micronutrients is essential for vegetable cultivation to get maximum yield of high quality produce. Plant metabolism, nutrient regulation, chlorophyll synthesis, reproductive growth, flower retention, fruit and seed development etc., are such effective functions performed by various micronutrients. Micronutrients which are essential for all higher plants are boron (B), chlorine (Cl), copper (Cu), iron (Fe), zinc (Zn), manganese (Mn), molybdenum (Mo) and nickel (Ni). Micronutrients like Cl, Cu, Fe and Mn are involved in various photosynthetic processes and Zn, Cu, Fe and Mn are associated with various enzymatic activities, Mo is specific for nitrate reductase only. Boron is associated with the carbohydrate metabolism and reproductive phase of the plants along with photosynthesis or enzymatic activities. Taking this into consideration, in the current review focus on major functions of micronutrients in vegetable production and also gives a brief overview of recent research findings related to role of micronutrients on vegetable production, which can contribute to a better understanding of the role of micronutrients in vegetable plants.

Kumar (2016) reported that micronutrients are present in lower concentrations in soil than macronutrients but are equally significant in plant nutrition, since, plants grown in micronutrient-deficient soils show similar reductions in productivity as those grown in macronutrient-deficient soils. Solanaceous vegetables are the part of diet of all over the world. With growing demand for quality of vegetables as people are becoming more health conscious, there is a need to go for balanced fertilization of both macro and micronutrients. Since, micronutrients play a profound role in various metabolic functions of plant; therefore, without micronutrient application there occurs deficiency and eventually reduction in yield and quality. Foliar application of micronutrients shows better efficacy than soil application as the uptake and assimilation of micronutrients by later method takes more time. Owing to intensive agriculture and high yielding varieties of vegetables extra mining of nutrients takes place which leads to negative nutrient balance in the soil. Hence, to cope up with the needs of the crop, application of micronutrients in addition to macronutrients must be ensured.

Osman (2019) conducted the present experiment to investigate the effect of boron and zinc on the growth and yield of tomato. Three levels of boron (*viz.*, 0, 1 and 2kg H_3BO_3 ha^{-1}) and zinc (*viz*., 0, 1 and 2kg $ZnSO_4$ ha^{-1}) were applied for each experiment. Results revealed that boron had significant effect on all yield attributes and yield of tomato. Application of 2kg H_3BO_3/ha produced the highest tomato yield (79.2 ton ha^{-1}) through increasing plant height, number ofleaves per plant, number of branches per plant, number of flower clusters per plant, number fruits per plant, weight of fruits per plant, fruit weight, individual fruit length, fruit diameter and yield ha-1 of fruits. On the other hand, maximum yield of tomato was obtained from 2kg $ZnSO_4$ ha^{-1}. A combination of 2kg H_3BO_3 and 2kg $ZnSO_4$ ha^{-1} gave the highest yield of Tomato (83.50 ton ha^{-1}). So, application of 2kg H_3BO_3 along with 2kg $ZnSO_4$ ha^{-1} was the best for growth and yield of tomato.

Khan and Hayat (2019) conducted a field experiment entitled “Effect of foliar application of Zinc and Boron on growth and yield components of wheat” at Bacha Khan Agricultural Research Farm (BARF), Bacha Khan University, Charsadda during the winter season 2015-16. The aim of the experiment was to investigate the effect of foliar application of Zinc and Boron on growth and yield components of wheat. Treatments included zinc (as zinc sulfate 25g/L^{-1}), boron (as boric acid 20g/L^{-1}) and zinc plots boron (as zinc sulfate and boric acid 25 g/L^{-1} and 20g/L^{-1}, respectively). Water spray and no spray were used as control. The experiment was planned according to randomized complete block design (RCBD) consisting of three replications. Seed was applied at the rate of 100kg ha^{-1}. The recommended dose of NPK was applied at the rate of 60, 75 and 0kg ha^{-1} respectively. It was revealed from that the results of the experiments that foliar application of zinc + boron in wheat showed significant variation for all of the parameters recorded during the course of study except days to emergence. In case of interaction, maximum plant height (103cm), grains spike^{-1} (45), 1000 grains weight (37g), grain yield (5966.67kg ha^{-1}), biological yield (19059kg ha^{-1}) and harvest index (31.30%) were recorded with foliar application of zinc + boron. Maximum plant height (102cm), grains spiek^{-1} (44.6), 1000 grains weight (36g), grain yield (5743kg ha^{-1}), biological yield (14707.7kg ha^{-1}) and harvest index (39.06 %) were recorded with foliar application of zinc.

Sarkar *et al*. (2019) conducted a field experiment at the Instructional Farm, Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal to study the effect of boron and zinc application on growth, seed yield and its quality of water spinach (Ipomoea reptans Poir.). The study consisted of borax @ 0 (B_0), 25 kg/ha through soil (B_1) and 1.5 g/litre twice through foliar sprays at 15 days interval (B_2) and $ZnSO_4$ @ 0 (Zn_0), 15 kg/ha through soil (Zn_1) and 1.5 g/litre twice foliar sprays at 15 days interval (Zn_2) and their nine treatment combinations (viz. B_0 Zn_0, B_1 Zn_0, B_2 Zn_0, B_0Zn_1, B_1 Zn_1, B_2 Zn_1, B_0Zn_2, B_1 Zn_2 and B_2 Zn_2. The results revealed that application of boron and zinc at all rates alone and as combinations markedly influenced all growth, seed yield and its quality parameters as compared with the control. Soil application of borax @ 25 kg/ha and $ZnSO_4$ @ 15 kg/ha alone and as combination recorded maximum number of flowers/hill (282.6, 275.1 & 311.5), number of capsules/hill (238.2, 220.7 & 257.8), seed yield (1.22 t/ha, 1.21 t/ha & 1.32 t/ha), shelling percentage (67.14%, 67.06% & 68.76%), 1000 seed weight (38.05 g, 38.25 g & 41.16 g), germination percentage (86.6%, 86.3% & 90.0%), seedling vigour index (6.20, 6.26 & 6.63) and seedling growth rate (0.123, 0.123 and 0.127 g/plant/day), respectively over control. Maximum vine length, number of nodes per plant, average internode length and chlorophyll content of leaf were found in twice foliar sprays of borax @ 1.5 g/litre (B_2) and twice foliar sprays of $ZnSO_4$ @ 1.5 g/litre (Zn_2) individually as well as their combination (B_2Zn_2). Considering the benefit : cost ratio (B: C ratio), combination of both soil application of borax @ 25 kg/ha and $ZnSO_4$ @ 15 kg/ha (B_1Zn_1) was found most economical (2.60).

Mohammadi (2016) carried out the present study to investigate the effect of foliar application of micronutrient fertilizers on okra plants. Four okra cultivars (‘Boyiatiou’, ‘Veloudo’, ‘Clemson’ and ‘Pylaias’) were sprayed weekly throughout the duration of the cultivation with two commercial micronutrient fertilizers (F_1 and F_2) [e.g. M_1= control (0 ml); M_2= 40 ml (20 ml of each fertilizer); M_3 = 80 ml (40 ml of each fertilizer). From the results of the present study, it was observed that plant height of ‘Boyiatiou’ and ‘Pylaias’ was increased by application of M2 whereas plant height of ‘Clemson’ and ‘Veloudo’ was either unaffected or reduced. Flower induction increased at both micronutrient levels (M_2 and M_3) only in ‘Pylaias’. Pod set was higher in treatment M_3 in ‘Veloudo’ and ‘Pylaias’ and resulted in higher seed yield. Pod length and diameter were not affected by micronutrient application, as well as 100-seed mean weight and moisture content; however the number of seeds per pod in ‘Pylaias’ was significantly lower in M_2 and M_3 than in M_1, whereas the percent seed germination of all cultivars was higher following micronutrient application. Germination differed between the control and the micronutrient treatments at all times of harvest and plant parts. In conclusion, the main value of foliar application of micronutrients was to increase germination percentage and reduce hardseedness, especially for cv. ‘Veloudo’, since the occurrence of hard seeds in susceptible cultivars reduces germination, and therefore seed quality. In some cultivars (‘Pylaias’ and ‘Veloudo’ here) micronutrients may also increase seed yield by increasing pod set.

CHAPTER II

MATERIALS AND METHODS

The experiment was carried out at the Central farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from April to August 2018 to study the effect of zinc (Zn) and boron (B) on growth and yield of okra. The details of the materials and methods have been presented below:

3.1 Location of the experimental site

The experimental field was located in 24°09′N latitude and 90°26′E longitudes. The altitude of the location was 8 m from the sea level**.**

3.2 Climatic condition

Experimental location is situated in the sub-tropical climate zone, which is characterized by heavy rainfall during the months of March to September and scanty rainfall during the rest period of the year. Details of the meteorological data during the period of the experiment were collected and presented in Appendix I.

3.3 Soil characteristics of the experimental site

Selected land of the experimental field was medium high land in nature with adequate irrigation facilities and remained utilized for crop production during the previous season. The soil is belongs to the Modhupur Tract (UNDP, 1988) under AEZ No. 28. The soil texture of the experimental soil was sandy loam. The nutrient status of the farm soil under the experimental plot with in a depth 0-20 cm were collected and analyzed in the Soil Resources Development Institute (SRDI) Dhaka, and result have been presented in Appendix II.

3.4 Planting materials and collection of seeds

The test crop used in the experiment was BARI Dherosh-1. The seeds of okra variety BARI Dherosh-1 was collected from BARI (Bangladesh Agricultural Research Institute), Joydebpur, Gazipur, Bangladesh.

3.5 Treatment of the experiment

Single factor experiment was initiated for the present study which was as follows:

1. T_0 = Control
2. T_1 = 20 kg Zn ha^{-1}
3. T_2 = 30 kg Zn ha^{-1}
4. T_3 = 10 kg B ha^{-1}
5. T_4 = 20 kg B ha^{-1}
6. T_5 = 20 kg Zn ha^{-1} + 10 kg B ha^{-1}
7. T_6 = 20 kg Zn ha^{-1} + 20 kg B ha^{-1}
8. T_7 = 30 kg Zn ha^{-1} + 10 kg B ha^{-1}
9. T_8 = 30 kg Zn ha^{-1} + 20 kg B ha^{-1}

3.6 Land preparation

The plot selected for conducting the experiment was opened before one week of seed sowing in the field with a power tiller, and left exposed to the sun. After one week the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain good tilth. Weeds and stubbles were removed and finally obtained a desirable tilth of soil was obtained for sowing okra seeds. The soil was treated with insecticides (cinocarb 3G @ 4 kg ha^{-1}) at the time of final land preparation to protect young plants from the attack of soil inhibiting insects such as cutworm and mole cricket.

3.7 Application of manure and fertilizers

Urea, triple super phosphate (TSP), muriate of potash (MP), $ZnSO_4$ and boric acid were used as source of N, P, K, Zn and B respectively. Manures and fertilizers that were applied to the experimental plot presented as follows.

Manure/fertilizer	**Rate ha^{-1}**	**Nutrients ha^{-1}**
Cowdung	10 t	--
Urea	150 kg	N = 69 kg
TSP	100kg	P_2O_5 = 45 kg
MoP	150kg	K_2O = 90
Borax	As per treatment	B = As per treatment
$ZnSO_4$	As per treatment	Zn = As per treatment

Source: Krishi Projukti Hat Boi, (2017)

The total amount of cowdung, TSP and MP was applied as basal dose at the time of final land preparation. Urea was applied at 15, 30 and 45 days after sowing (DAS).

3.8 Design and layout of the experiment

The single factor experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The total area was divided into three equal blocks. Each block was divided into 9 plots where 9 treatments were allotted at random. There were 27 unit plots altogether in the experiment. The size of the each plot was 3.0 m × 1.5 m. The distance maintained between two blocks and two plots were 0.5 and 0.5 m, respectively. The spacing was at 60 × 50 cm.

3.9 Seeds sowing

Firstly the seed were soaked with water for six hours to inhance quick seed germination. The okra seeds were sown in the main field as treatment^{-1}. Seeds were treated with Bavistin @ 2ml/L of water before sowing the seeds to control the seed borne diseases. The seeds were sown in rows having a depth of 2-3 cm with maintaining distance from 50 cm and 60 cm from plant to plant and row to row, respectively.

3.10 Intercultural operation

After raising seedlings, various intercultural operations such as gap filling, weeding, earthing up, supporting by bamboo stalk, tagging irrigation pest and disease control etc. were accomplished for better growth and development of the okra seedlings.

3.10.1 Gap filling

The seedlings in the experimental plot were kept under careful observation. Very few seedlings were damaged after germination and such seedling were replaced by new seedlings replacement was done with healthy seedling in the afternoon having a ball of earth which was also planted on the same date by the side of the unit plot. The seedlings were given watering for 7 days starting from germination for their proper establishment.

3.10.2Weeding

After seedling raising, when okra plant is four inches tall, first weeding done and then 30 and 45 days by the help of nirani with roots to keep the plots free from weeds.

3.10.3 Irrigation

Light watering was given by a watering cane at every morning and afternoon and it was continued for a week for rapid and well establishment of the germinated seedlings.

3.10.4 Pest and disease control

Okra plant is succumbr to pests and diseases. Stink bug causes misshappen pods. Insect infestation was a serious problem during the period of establishment of seedings in the field. Here few young plants were damaged due to attack of mole cricket and cut worm. Cut worms were controlled both mechanically and spraying Darsban29 EC @ 3%. Some discolored and yellowish diseased leaves and plants uprotted and removed were from the field, that were for virus infestation (Okra mosaic virus disease) as the plot wasn’t isolated from other crop plants like tomato.

3.11 Harvesting

Fruits were harvested at 5 days interval based on eating quality at soft and green condition. Harvesting was started at eating quality level regarding sowing time by continuous checking fruits were collected at 2 or 3 days interval. Some pods loss its edible quality but it was not so more in number.

3.12 Data collection

Five plants were randomly selected from the middle rows of each unit plot for avoiding border effect, except yields of plots, which was recorded plot wise. Data were collected in respect of the growth, yield attributes and yields as affected by different treatments of the experiment.

3.12.1 Plant height (cm)

Plant height was measured from sample plants in centimeter from the ground level to the tip of the longest stem of five plants and mean value was calculated. Plant height was also recorded at 30 days interval starting from 30 days after sowing (DAS) up to 90 days to observe the growth rate of plants.

3.12.2 Number of leaves per plant

The total number of leaves per plant was counted from each selected plant. Data were recorded as the average of 5 plants selected at random from the inner rows of each plot from 30 DAS to 90 DAS at 30 days interval.

3.12.3 Leaf area index

Leaf area index was recorded with the instrument of LAI-2200C Plant Canopy Analyzer in the central lab of Sher-E-Bangla Agricultural University. It was measured at 60 DAS from each replication.

3.12.4 SPAD value

SPAD value was measured from okra leaves from each replication with the help of SPAD meter and it was measured at 50 DAS.

3.14.5 Fruit length (cm)

The length of fruit was measured with a meter scale from the neck of the fruit to the bottom of 10 selected marketable fruits from each plot and there average was taken and expressed in cm.

3.12.5 Fruit diameter (cm)

Diameter of fruit was measured at the middle portion of 10 selected marketable fruit from each plot with a digital calipers-515 (DC-515) and average was taken and expressed in cm.

3.12.6 Number of fruits plant^{-1}

The number of fruits per plant was counted from the sample plants for the whole growing period and the average number of fruits produced per plant was recorded and expressed as number of fruits per plant.

3.12.7 Fresh weight of fruits plant^{-1} (g)

The weight of fresh fruits was measured with a digital weighing machine from 5 selected plants from each selected plots and there average was taken and expressed in gram.

3.12.8 Yield plot^{-1}

Yield of okra per plot was recorded as the whole fruit per plot by a digital weighing machine for the whole growing period and was expressed in kilogram.

3.12.9 Yield ha^{-1}

Yield per hectare of okra fruits was estimated by converting the weight of plot yield into hectare and was expressed in ton.

3.13 Statistical analysis

The data obtained for different characters were statistically analyzed by using MSTAT-C software to find out the significance of the difference for nitrogen and phosphorus fertilizer on growth and yield of okra. The mean values of all the recorded characters were evaluated and analysis of variance was performed by the „F‟ (variance ratio) test. The significance of the difference among the means of treatment combinations was estimated by Duncan’s Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

To assess the effect of zinc (Zn) and boron (B) on growth and yield of okra, the present study was performed. The results obtained from the study have been presented, discussed and compared in this chapter through different tables, figures and appendices.

4.1Growth parameters

4.1.1 Plant height (cm)

There was significant influence on plant height of okra at different growth stages affected by different levels of boron (B) and zinc (Zn) application (Table 1). Results revealed that the highest plant height was found from the treatment T_8 (30 kg Zn ha^{-1} + 20 kg B ha^{-1}) at all days after sowing. At 30 DAS, the tallest plant (33.15 cm) was recorded from the treatment T_8 (30 kg Zn ha^{-1} + 20 kg B ha^{-1}) that was statistically same with T_7 (30 kg Zn ha^{-1} + 10 kg B ha^{-1}). On the other hand, the smallest plant (28.79 cm) was found from T_0 (control) treatment. Similar trend was also found at 60 and 90 DAS. At 60 DAS, the tallest plant (95.22 cm) was recorded from treatment T_8 (30 kg Zn ha^{-1} + 20 kg B ha^{-1}) which was statistically similar with T_7 (30 kg Zn ha^{-1} + 10 kg B ha^{-1}) but the smallest plant (58.82 cm) was recorded from T_0 (control) treatment. Moreover, at 90 DAS, the highest plant height (33.15 cm) was observed from treatment T_8 (30 kg Zn ha^{-1} + 20 kg B ha^{-1}) which was followed by T_7. On the other hand, the lowest plant height (83.45 cm) was recorded from T_0 (control) treatment. As a result the tallest plant (53.15, 95.22 and 118.30 cm at 30, 60 and 90 DAS, respectively) was recorded from T_8 (30 kg Zn ha^{-1} + 20 kg B ha^{-1}) whereas the smallest plant (28.9, 58.82 and 83.45 cm at 30, 60 and 90 DAS, respectively) was observed from the treatment T_0 (control). Similar results also reported by Sharma (1999) was stated that 20 kg ha^{-1} boron influence plant height which supported the present study. Kalroo *et al*. (2013) also revealed that high concentration of zinc increased plant height.

Table 1. Plant height of okra as influenced by different levels of Zn and B application

Treatments	Plant height (cm)		
	30 DAS	60 DAS	90 DAS
T_0	28.79 f	58.82 f	83.45 e
T_1	36.95 d	71.30 d	92.27 d
T_2	41.47 c	79.66 c	101.5 c
T_3	33.62 e	66.69 e	90.69 d
T_4	38.20 d	77.32 c	98.37 c
T_5	45.27 b	85.35 b	105.7 b
T_6	46.81 b	87.56 b	108.1 b
T_7	51.34 a	92.74 a	115.3 a
T_8	53.15 a	95.22 a	118.3 a
$LSD_{0.05}$	2.790	3.396	3.534
CV(%)	7.03	8.71	10.01

In a column, means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% levels of probability

T_0 = Control, T_1 = 20 kg Zn ha^{-1}, T_2 = 30 kg Zn ha^{-1}, T_3 = 10 kg B ha^{-1}, T_4 = 20 kg B ha^{-1}, T_5 = 20 kg Zn ha^{-1} + 10 kg B ha^{-1}, T_6 = 20 kg Zn ha^{-1} + 20 kg B ha^{-1}, T_7 = 30 kg Zn ha^{-1} + 10 kg B ha^{-1}T_8 = 30 kg Zn ha^{-1} + 20 kg B ha^{-1}

4.1.2 Number of leaves plant^{-1}

Number of leaves plant^{-1} of okra at different days after sowing presented in Table 2. There was a significant variation on no. of leaves plant^{-1} due to boron (B) and zinc (Zn) application (Appendix IV). The highest number of leaves plant^{-1} was found from the treatment T_7 (30 kg Zn ha^{-1} + 10 kg B ha^{-1}) at all growth stages whereas control treatment showed lowest of leaves plant^{-1}. At 30 DAS, the highest number of leaves plant^{-1} (20.85) was observed from treatment T_7 (30 kg Zn ha^{-1} + 10 kg B ha^{-1}) and that was significantly different from other treatments, but the lowest number of leaves plant^{-1} (11.75) was observed from T_0 (control) treatment. Similar trend was also observed at 60 and 90 DAS. At 60 DAS, the highest number of leaves plant^{-1} (28.53) was observed from treatment T_7 (30 kg Zn ha^{-1} + 10 kg B ha^{-1}) which was at par with T_8 (30 kg Zn ha^{-1} + 20 kg B ha^{-1}) but the lowest number of leaves plant^{-1} (16.18) was observed from T_0 (control) treatment. Yet again, at 90 DAS, the highest number of leaves plant^{-1} (30.06) was observed from treatment T_7 (30 kg Zn ha^{-1} + 10 kg B ha^{-1}) which was significantly same with T_8 (30 kg Zn ha^{-1} + 20 kg B ha^{-1}) but the lowest number of leaves plant^{-1} (17.93) was observed from T_0 (control) treatment. As a result at 30, 60 and 90 DAS, T_7 (30 kg Zn ha^{-1} + 10 kg B ha^{-1}) gave highest number of leaves plant^{-1} (20.85, 28.53 and 30.06, respectively) but the control treatment (T_0) showed lowest number of leaves plant^{-1} (11.75, 16.18 and 17.93, respectively). Manna *et al.* (2014) also reported that 0.5% boron significantly increased the no. of leaves plant^{-1} which supported the current study.

Table 2. Number of leaves plant^{-1} of okra as influenced by different levels of Zn and B application

Treatments	Number of leaves plant^{-1}		
	30 DAS	60 DAS	90 DAS
T_0	11.75 e	16.18 e	17.93 e
T_1	14.18 d	18.95 d	22.56 cd
T_2	14.96 d	21.76 c	23.76 bc
T_3	13.95 d	18.31 d	21.60 d
T_4	14.78 d	21.25 c	24.39 bc
T_5	17.19 c	24.02 b	25.34 b
T_6	17.45 c	24.71 b	25.41 b
T_7	20.85 a	28.53 a	30.06 a
T_8	19.61 b	26.90 a	28.96 a
$LSD_{0.05}$	1.185	2.021	2.112
CV(%)	5.26	8.24	6.99

In a column, means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% levels of probability

T_0 = Control, T_1 = 20 kg Zn ha^{-1}, T_2 = 30 kg Zn ha^{-1}, T_3 = 10 kg B ha^{-1}, T_4 = 20 kg B ha^{-1}, T_5 = 20 kg Zn ha^{-1} + 10 kg B ha^{-1}, T_6 = 20 kg Zn ha^{-1} + 20 kg B ha^{-1}, T_7 = 30 kg Zn ha^{-1} + 10 kg B ha^{-1}T_8 = 30 kg Zn ha^{-1} + 20 kg B ha^{-1}

4.1.3 Leaf area index at 60 DAS

Leaf area index of okra at 60 DAS showed significant difference presented in Figure 1. Results indicated that the highest leaf area index at 60 DAS (298.60) was found from T_7 (30 kg Zn ha^{-1} + 10 kg B ha^{-1}) followed by T_8 (30 kg Zn ha^{-1} + 20 kg B ha^{-1}). The lowest leaf area index at 60 DAS (187.80) was found from T_0 (control) which was significantly differed to other treatments. Here, it can also be stated that the variation on leaf area index at 60 DAS among the treatments might be due to cause of significant variation on Zn and B doses.

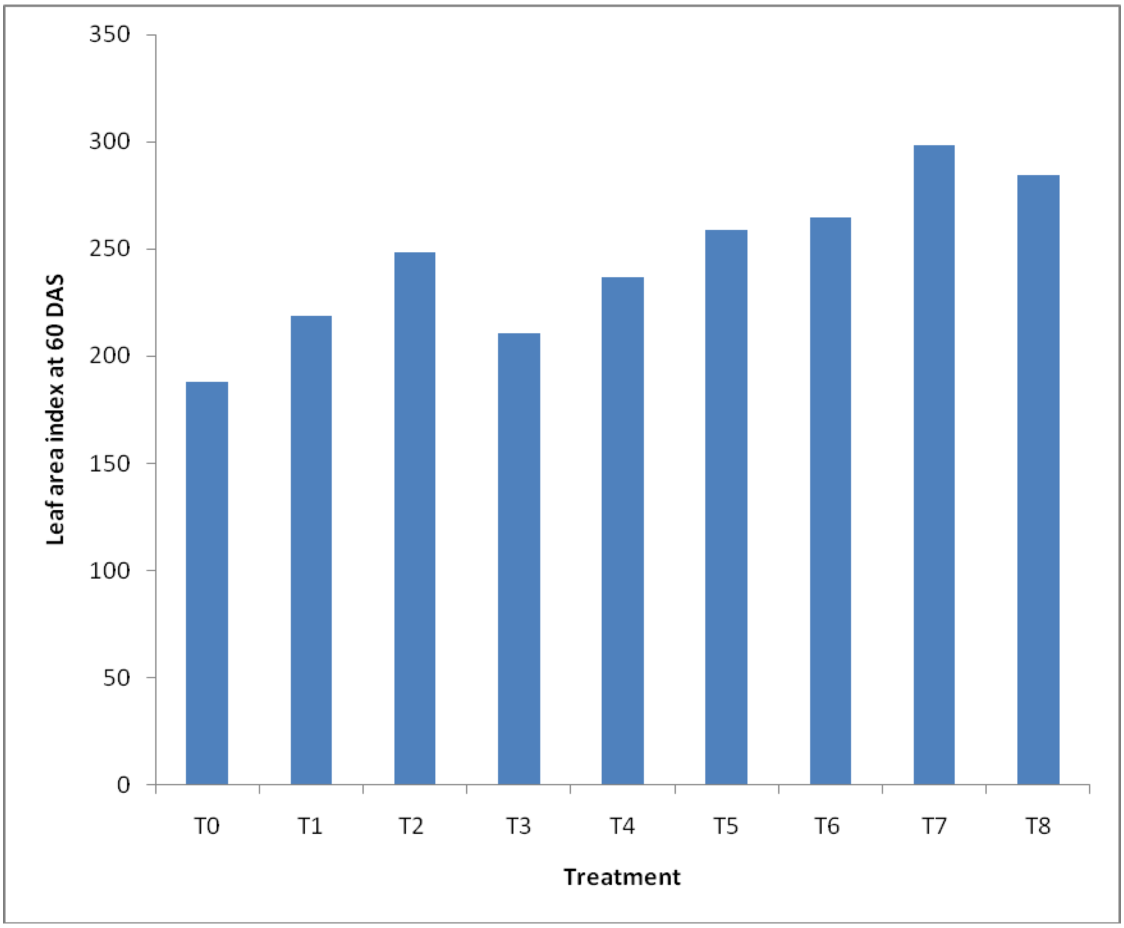

Table 1. Leaf area index of okra as influenced by different levels of Zn and B application

T_0 = Control, T_1 = 20 kg Zn ha^{-1}, T_2 = 30 kg Zn ha^{-1}, T_3 = 10 kg B ha^{-1}, T_4 = 20 kg B ha^{-1}, T_5 = 20 kg Zn ha^{-1} + 10 kg B ha^{-1}, T_6 = 20 kg Zn ha^{-1} + 20 kg B ha^{-1}, T_7 = 30 kg Zn ha^{-1} + 10 kg B ha^{-1}T_8 = 30 kg Zn ha^{-1} + 20 kg B ha^{-1}

4.1.4 SPAD value at 60 DAS

SPAD value of leaf of okra showed significant variation are presented in Figure 2. Results showed that the highest SPAD value at 60 DAS (65.73) was found from T_7 (30 kg Zn ha^{-1} + 10 kg B ha^{-1}) which were at par with the treatment T_8 (30 kg Zn ha^{-1} + 20 kg B ha^{-1}). The lowest SPAD value at 60 DAS (42.05) was found from T_0 (control) that was differed significantly with other treatments. The variation on SPAD value at 60 DAS among the treatments probably the cause of Zn and B application at different rates.

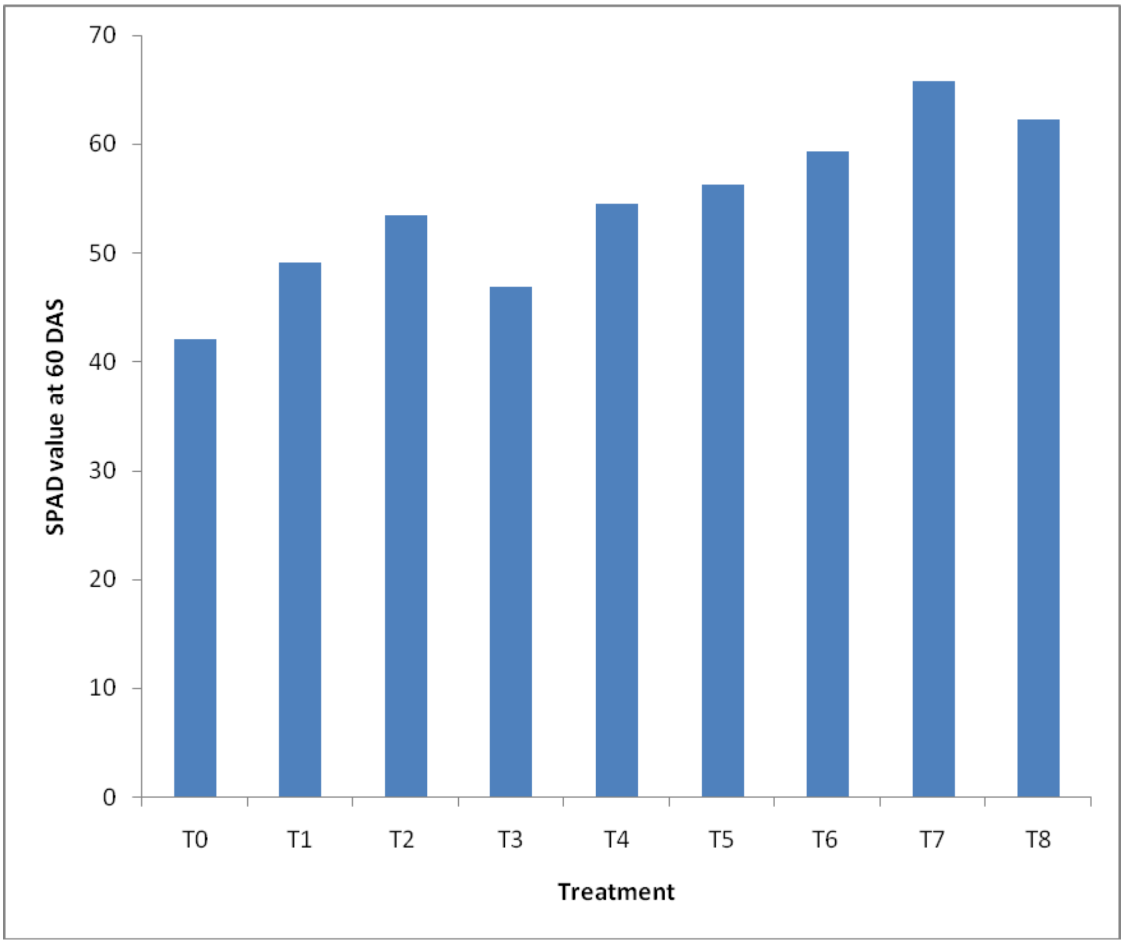

Figure 2. SPAD value of okra as influenced by different levels of Zn and B application

T_0 = Control, T_1 = 20 kg Zn ha^{-1}, T_2 = 30 kg Zn ha^{-1}, T_3 = 10 kg B ha^{-1}, T_4 = 20 kg B ha^{-1}, T_5 = 20 kg Zn ha^{-1} + 10 kg B ha^{-1}, T_6 = 20 kg Zn ha^{-1} + 20 kg B ha^{-1}, T_7 = 30 kg Zn ha^{-1} + 10 kg B ha^{-1}T_8 = 30 kg Zn ha^{-1} + 20 kg B ha^{-1}

4.2 Yield contributing parameters

4.2.1 Single fruit weight (g)

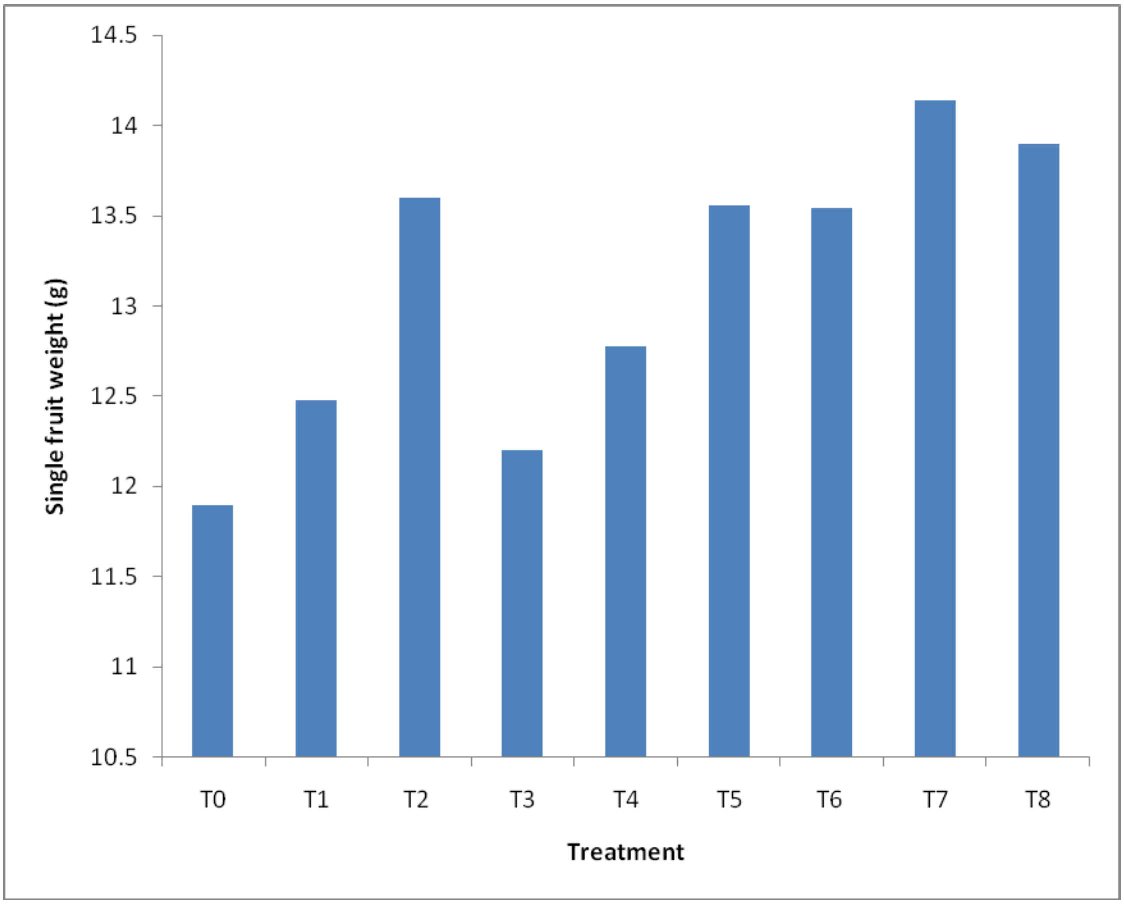

Figure 3. Single fruit weight per plant of okra as influenced by different levels of Zn and B application

T_0 = Control, T_1 = 20 kg Zn ha^{-1}, T_2 = 30 kg Zn ha^{-1}, T_3 = 10 kg B ha^{-1}, T_4 = 20 kg B ha^{-1}, T_5 = 20 kg Zn ha^{-1} + 10 kg B ha^{-1}, T_6 = 20 kg Zn ha^{-1} + 20 kg B ha^{-1}, T_7 = 30 kg Zn ha^{-1} + 10 kg B ha^{-1}T_8 = 30 kg Zn ha^{-1} + 20 kg B ha^{-1}

There was significant variation found for single fruit weight as affected by different Zn and B application (Figure 3 and Appendix VI). Results indicated that the highest single fruit weight (14.14 g) was found from T_7 (30 kg Zn ha^{-1} + 10 kg B ha^{-1}) which was statistically similar with T_8 (30 kg Zn ha^{-1} + 20 kg B ha^{-1}) whereas the lowest single fruit weight (11.90 g) was found from T_0 (control) which was statistically similar with T_3 (10 kg B ha^{-1}). Badini *et al*.

(2018) also found similar result with the present study who reported increased single pod weight (g) with increased Zinc and Boron to at a certain level.

4.2.2 Fruit length (cm)

Fruit length of okra showed significant variation among the treatments of zinc and boron (Table 3). It was observed that the highest fruit length (15.12 cm) was found from T_7 (30 kg Zn ha^{-1} + 10 kg B ha^{-1}) which was statistically identical with T_6 (20 kg Zn ha^{-1} + 20 kg B ha^{-1}) and T_8 (30 kg Zn ha^{-1} + 20 kg B ha^{-1}) and statistically similar with T_5 (20 kg Zn ha^{-1} + 10 kg B ha^{-1}) whereas the lowest fruit length (9.20 cm) was found from T_0 (control) which differed significantly to other treatments. Similar result was also observed by Badini *et al*. (2018).

4.2.3 Fruit diameter (cm)

Significant influence was recorded on fruit diameter of okra due to different Zn and B application (Table 3). Results indicated that the highest fruit diameter (1.96 cm) was found from T_7 (30 kg Zn ha^{-1} + 10 kg B ha^{-1}) and this treatment was statistically different from other treatments which was followed by T_8 (30 kg Zn ha^{-1} + 20 kg B ha^{-1}). It was also observed that the lowest fruit diameter (1.48 cm) was found from T_0 (control) which was not significantly similar to other treatments. Badini *et al*. (2018) also found similar result with the present study.

4.2.4 Percent (%) fruit dry matter

Percent (%) fruit dry matter affected significant due to different Zn and B application (Table 3). The recorded data on fruit dry matter showed that the highest (9.26 g) was found from T_7 (30 kg Zn ha^{-1} + 10 kg B ha^{-1}) which was at par with the treatment T_8 (30 kg Zn ha^{-1} + 20 kg B ha^{-1}) whereas the lowest % fruit dry matter (6.85 g) was found from T_0 (control) which differed significantly to other treatments.

4.2.5 Number of fruits plant^{-1}

Significant variation was observed for number of fruits plant^{-1} due to different Zn and B application (Table 3). Results revealed that the highest number of fruits plant^{-1} (36.12) was found from T_7 (30 kg Zn ha^{-1} + 10 kg B ha^{-1}) which was significantly same with T_8 (30 kg Zn ha^{-1} + 20 kg B ha^{-1}). The lowest number of fruits plant^{-1} (11.48) was recorded from T_0 (control) which was at par with the treatment T_3 (10 kg B ha^{-1}). Badini *et al.* (2018) reported variation in number of pods plant^{-1} with different levels of Zn and B.

Table 3. Fruit length, fruit diameter, % fruit dry matter, no of fruits per plant of okra as influenced by different levels of Zn and B application

Treatments	Yield contributing parameters			
	Fruit length (cm)	Fruit diameter (cm)	% fruit dry matter	Number of fruits plant^{-1}
T_0	9.20 e	1.48 f	6.85 g	22.48 f
T_1	11.72 cd	1.60 de	7.44 ef	25.30 de
T_2	12.60 bc	1.64 d	8.12 cd	27.60 cd
T_3	10.90 d	1.55 e	7.14 fg	24.80 ef
T_4	12.16 cd	1.60 de	7.72 de	27.20 d
T_5	13.88 ab	1.70 c	8.48 bc	29.80 bc
T_6	14.78 a	1.75 c	8.67 bc	31.66 b
T_7	15.12 a	1.96 a	9.26 a	36.12 a
T_8	14.90 a	1.88 b	8.92 ab	34.40 a
$LSD_{0.05}$	1.494	0.054	0.550	2.393
CV(%)	6.74	8.36	7.24	8.80

In a column, means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% levels of probability

T_0 = Control, T_1 = 20 kg Zn ha^{-1}, T_2 = 30 kg Zn ha^{-1}, T_3 = 10 kg B ha^{-1}, T_4 = 20 kg B ha^{-1}, T_5 = 20 kg Zn ha^{-1} + 10 kg B ha^{-1}, T_6 = 20 kg Zn ha^{-1} + 20 kg B ha^{-1}, T_7 = 30 kg Zn ha^{-1} + 10 kg B ha^{-1}T_8 = 30 kg Zn ha^{-1} + 20 kg B ha^{-1}

4.2.6 Fresh fruit weight plant^{-1} (g)

Figure 4 showed significant variations on fresh fruit weight plant^{-1} which influenced significantly due to different Zn and B application. Results indicated that the highest fresh fruit weight plant^{-1} (510.70 g) was found from T_7 (30 kg Zn ha^{-1} + 10 kg B ha^{-1}) which was significantly different from other treatments followed by T_8 (30 kg Zn ha^{-1} + 20 kg B ha^{-1}). The lowest fresh fruit weight plant^{-1} (267.50 g) was recorded from T_0 (control) which differed significantly to other treatments. The results achieved from the present study was conformity with the findings of Sarkar *et al*. (2019), Badini *et al*. (2018) and Mohammadi (2016).

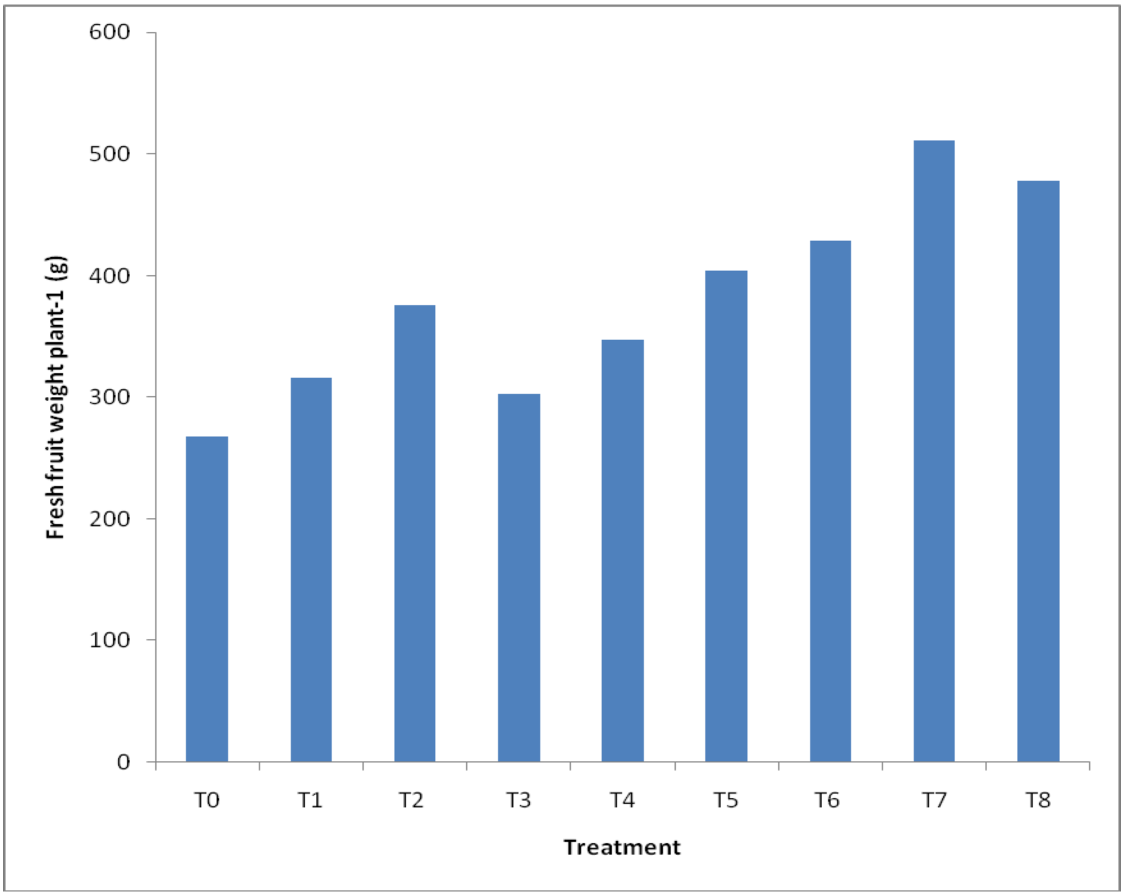

Figure 4. Fresh fruit weight plant^{-1} of okra as influenced by different levels of Zn and B application

T_0 = Control, T_1 = 20 kg Zn ha^{-1}, T_2 = 30 kg Zn ha^{-1}, T_3 = 10 kg B ha^{-1}, T_4 = 20 kg B ha^{-1}, T_5 = 20 kg Zn ha^{-1} + 10 kg B ha^{-1}, T_6 = 20 kg Zn ha^{-1} + 20 kg B ha^{-1}, T_7 = 30 kg Zn ha^{-1} + 10 kg B ha^{-1}T_8 = 30 kg Zn ha^{-1} + 20 kg B ha^{-1}

4.3 Yield parameters

4.3.1 Fruit yield plot^{-1} (kg)

The recorded data on fruit yield plot^{-1} differed significantly due to different Zn and B application (Table 4). Results showed that the highest fruit yield plot^{-1} (7.75 kg) was found from T_7 (30 kg Zn ha^{-1} + 10 kg B ha^{-1}) that was significantly same with T_8 (30 kg Zn ha^{-1} + 20 kg B ha^{-1}). Results also showed that the lowest fruit yield plot^{-1} (4.00 kg) was recorded from T_0 (control) which was significantly similar with T_3 (10 kg B ha^{-1}).

Table 4. Fruit yield plot^{-1} (kg), Fruit yield ha^{-1} (t) of okra as influenced by different levels of Zn and B application

Treatments	Yield parameters	
	Fruit yield plot^{-1} (kg)	Fruit yield ha^{-1} (t)
T_0	4.00 g	8.89 h
T_1	4.69 ef	10.42 fg
T_2	5.63 cd	12.50 de
T_3	4.50 fg	10.00 gh
T_4	5.25 de	11.67 ef
T_5	6.00 bc	13.33 cd
T_6	6.38 b	14.17 c
T_7	7.75 a	17.22 a
T_8	7.12 a	15.83 b
$LSD_{0.05}$	0.6815	1.272
CV(%)	7.91	6.80

In a column, means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% levels of probability

T_0 = Control, T_1 = 20 kg Zn ha^{-1}, T_2 = 30 kg Zn ha^{-1}, T_3 = 10 kg B ha^{-1}, T_4 = 20 kg B ha^{-1}, T_5 = 20 kg Zn ha^{-1} + 10 kg B ha^{-1}, T_6 = 20 kg Zn ha^{-1} + 20 kg B ha^{-1}, T_7 = 30 kg Zn ha^{-1} + 10 kg B ha^{-1}T_8 = 30 kg Zn ha^{-1} + 20 kg B ha^{-1}

4.3.2 Fruit yield ha^{-1} (t)

Different levels of Zn and B application showed significant variation on fruit yield ha^{-1} (Table 4). Results revealed that the highest fruit yield ha^{-1} (17.22 t ha^{-1}) was achieved from T_7 (30 kg Zn ha^{-1} + 10 kg B ha^{-1}) which differed significantly to other treatments followed by T_8 (30 kg Zn ha^{-1} + 20 kg B ha^{-1}). Reversely, the lowest fruit yield (8.89 t ha^{-1}) was observed from T_0 (control) which was significantly different from other treatments. Badini *et al*. (2018) reported that Zn and B had significant influence on fruit yield ha^{-1} who observed increased fruit yield ha^{-1} (t) with increased zinc and boron application to a certain level which was also supported by Sarkar *et al*. (2019), Osman (2019) and Mohammadi (2016).

CHAPTER V

SUMMARY AND CONCLUSION

The study was conducted at the Central Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from April to August 2018. The objective of the study was to effect of zinc (Zn) and boron (B) on growth and yield of okra. BARI Dherosh-1 was used as test crop in this experiment. The experiment consisted of single factor combine with Zn and B. Nine treatments were assigned *viz*. T_0 (control), T_1 (20 kg Zn ha^{-1}), T_2 (30 kg Zn ha^{-1}), T_3 (10 kg B ha^{-1}), T_4 (20 kg B ha^{-1}), T_5 (20 kg Zn ha^{-1} + 10 kg B ha^{-1}), T_6 (20 kg Zn ha^{-1} + 20 kg B ha^{-1}), T_7 (30 kg Zn ha^{-1} + 10 kg B ha^{-1}) and T_8 (30 kg Zn ha^{-1} + 20 kg B ha^{-1}) for the present study. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Size of each plot was 3 × 1.5 m. Data were collected in respect of growth, yield contributing characters and yield of okra and statistically analyzed. Different treatments showed variation on growth, yield contributing parameters and yield parameters of okra.

At 30, 60 and 90 DAS, T_8 (30 kg Zn ha^{-1} + 20 kg B ha^{-1}) gave the tallest plant (53.15, 95.22 and 118.30 cm, respectively) but the highest number of leaves $plant^{-1}$ (20.85, 28.53 and 30.06, respectively) was recorded from T_7 (30 kg Zn ha^{-1} + 10 kg B ha^{-1}) whereas the smallest plant (28.9, 58.82 and 83.45 cm, respectively) and number of leaves $plant^{-1}$ (11.75, 16.18 and 17.93, respectively) were observed from the control treatment (T_0). Accordingly, the treatment T_7 (30 kg Zn ha^{-1} + 10 kg B ha^{-1}) gave the highest leaf area index at 60 DAS (298.60) and SPAD value at 60 DAS (65.73) but the control treatment (T_0) gave the lowest leaf area index at 60 DAS (187.80) and SPAD value at 60 DAS (42.05).

The highest single fruit weight (14.14 g), fruit length (15.12 cm), fruit diameter (1.96 cm), % fruit dry matter (9.26 g), number of fruits $plant^{-1}$ (36.12) and highest fresh fruit weight plant^{-1} (510.70 g) were found from T_7 (30 kg Zn ha^{-1} + 10 kg B ha^{-1}). Reversely, the control treatment (T_0) showed lowest single fruit weight (11.90 g), fruit length (9.20 cm), fruit diameter (1.48 cm), % fruit dry matter (6.85 g), number of fruits plant^{-1} (11.48) and fresh fruit weight plant^{-1} (267.50 g).

Regarding, yield parameters of okra, T_7 (30 kg Zn ha^{-1} + 10 kg B ha^{-1}) gave the highest fruit yield plot^{-1} (7.75 kg) and fruit yield ha^{-1} (17.22 t ha^{-1}) but the lowest fruit yield plot^{-1} (4.00 kg) and fruit yield ha^{-1} (8.89 t ha^{-1}) were achieved from control treatment (T_0).

The result obtained from the present study, concluded that the treatment T_7 (30 kg Zn ha^{-1} + 10 kg B ha^{-1}) represented the best performance on different growth, yield contributing parameters and yield parameters of okra and this treatment showed highest fruit yield (17.22 t ha^{-1}). So, this treatment can be regarded as best among treatments studied under the present study.

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APPENDICES

Appendix I. Monthly records of air temperature, relative humidity and rainfall during the period from January 2018 to December 2018.

Year	Month	Air temperature (°C)			Relative humidity (%)	Rainfall (mm)
		Max	*Min*	*Mean*		
2018	April	34.70	24.60	29.65	65.40	165.0
2018	May	32.64	23.85	28.25	68.30	182.2
2018	June	27.40	23.44	25.42	71.28	190
2018	July	30.52	24.80	27.66	78.00	536
2018	August	31.00	25.60	28.30	80.00	348

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1212.

Appendix II. Characteristics of experimental soil analyzed at Soil Resources Development Institute (SRDI), Farmgate, Dhaka.

A. Morphological characteristics of the experimental field

Morphological features	**Characteristics**
Location	Agronomy Farm, SAU, Dhaka
AEZ	Modhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping pattern	Not Applicable

Source: Soil Resource Development Institute (SRDI)

B. Physical and chemical properties of the initial soil

Characteristics	**Value**
Partical size analysis % Sand	27
%Silt	43
% Clay	30
Textural class	Silty Clay Loam (ISSS)
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20
Exchangeable K (me/100 g soil)	0.1
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI)

Appendix III. Plant height of okra as influenced by different levels of Zn and B application

Sources	DF	Mean square of Plant height (cm)		
		30 DAS	60 DAS	90 DAS
Replication	2	7.490	0.185	18.317
Factor A	8	198.73*	444.48*	402.319*
Error	16	1.599	1.849	4.168

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix IV. Number of leaves plant^{-1} of okra as influenced by different levels of Zn and B application

Sources	DF	Mean square of Number of leaves plant^{-1}		
		30 DAS	60 DAS	90 DAS
Replication	2	9.359	10.338	45.252
Factor A	8	25.592*	50.514*	40.533*
Error	16	0.469	1.363	1.489

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix V. Leaf area index of okra as influenced by different levels of Zn and B application

Sources	DF	Mean square of Leaf area index at 60 DAS	Mean square of SPAD value at 60 DAS
Replication	2	49.111	1.721
Factor A	8	3827.35*	171.33*
Error	16	20.533	5.410

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix VI. Yield contributing parameters of okra as influenced by different levels of Zn and B application

Sources	DF	Mean square of yield contributing parameters					
		Single fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	% fruit dry matter	Number of fruits plant^{-1}	Fresh fruit weight plant^{-1} (g)
Replication	2	2.820	1.702	0.003	0.196	0.446	296.305
Factor A	8	1.916**	12.39**	0.073**	2.078**	62.367*	2006.705*
Error	16	0.078	0.745	0.020	0.341	1.912	36.256

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix VII. Yield parameters of okra as influenced by different levels of Zn and B application

Sources	DF	Mean square of yield parameters	
		Fruit yield plot^{-1} (kg)	Fruit yield ha^{-1} (t)
Replication	2	0.224	2.786
Factor A	8	4.623*	22.839*
Error	16	0.155	0.540

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level