EFFECT OF ZINC AND BORON FERTILIZERS AND THEIR APPLICATION METHODS ON THE GROWTH AND YIELD OF Okra (*Abelmoschus esculentus*)

A Thesis
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CERTIFICATE

This is to certify that the thesis entitled, **"EFFECT OF ZINC AND BORON FERTILIZERS AND THEIR APPLICATION METHODS ON THE GROWTH AND YIELD OF Okra (*Abelmoschus esculentus*)"**submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirement for the degree of **Master of Science in Soil Science,** embodies the result of a piece of *bona fide* research work carried out by **Nazia Farha,** Registration No.:**19-10367**, under my supervision and my 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 by her.

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DEDICATED TO

MY

BELOVED PARENTS

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ABSTRACT

The experiment was conducted at Sher-e-Bangla Agricultural University (SAU) farm, Dhaka during the period from march 2021 to July 2021 in order to effect of Zn and B on the growth and yield of okra (BARI dheros 2). The experiment consisted of two factors: Factor A: Zn application as (i) Zn_0 : 0 kg Zn ha^{-1} (ii) Zn_1: 3 kg Zn ha^{-1} as soil application (iii) Zn_2: 3 kg Zn ha^{-1} as foliar application. Factor B: B application as (i) B_0 : 0 kg B ha^{-1} (ii) B_1: 2 kg B ha^{-1} as soil application (iii) B_2 : 2 kg B ha^{-1} as foliar application. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Data on the growth, yield contributing characters and yield were recorded statistically significant variation in results was observed between the treatments. In terms of Zn effect, the highest plant height (167 cm), number of leaves $plant^{-1}$ (44.8) and number of branches $plant^{-1}$ (3.78) were observed in Zn_2 (3 kg Zn ha^{-1} as foliar application) treatment. Again the highest number of fruits (26.9), yield (14 t ha^{-1}) were noted for Zn_2 (3 kg Zn ha^{-1} as foliar application) treatment. In terms of B effect, the highest plant height (156 cm), number of leaves $plant^{-1}$ (47) and number of branches $plant^{-1}$ (3.83), numbers of fruits $plant^{-1}$ (27.2) and yield (11.8 t ha^{-1}) were recorded with B_2 (2 kg B ha^{-1} as foliar application) treatment. Combined effect of Zn and B fertilizer application on yield showed statistically significant variation compared with control. The highest plant height (180 cm), number of leaves $plant^{-1}$ (50.0) and number of branches $plant^{-1}$ (4.40), number of fruits $plant^{-1}$ (30.0) and yield (17.5 t ha^{-1}) was noted with the treatment combination Zn_2B_2 (3 kg Zn ha^{-1} with 2 kg B ha^{-1} as foliar application).

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LIST OF ACRONYMS

AEZ	**Agro Ecological Zone**
B	Boron
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
Cu	Copper
cm	Centimeter
$CaCl_2$	Calcium chloride
DAS	Days after sowing
DMRT	Ducans Multiple Range Test
Et al	And others
FAO	Food and Agriculture Organization
Fe	Iron
$FeSO_4$	Ferrous sulphate
IBPGR	International Board for Plant Genetic Resources
IU	International Unit
K	Potassium
kg	kilogram
ha	Hectare
H_2SO_4	Sulphuric acid
IAA	Indole acetic acid
$K_2Cr_2O_7$	Potassium di chromate
l	litre
mg	Milligram
Mn	Manganese
Mo	Molybdenum
m^2	Meter Square
P	Phosphorus
PPM	Parts per million
RDF	Recommended Dose of Fertilizer

RCBD	Randomized Complete Block Design
SPAD	Soil Plant Analysis Development
t	ton
Viz	Videlicet
YVMV	Yellow Vein Mosaic Virus
Zn	Zinc
^{0} C	Degree centigrade
%	Percentage

CHAPTER 1

INTRODUCTION

CHAPTER I

INTRODUCTION

Okra (*Abelmoschus esculentus*) known as lady's finger in many English-speaking countries, bhindi in India and locally known as Dherosh in Bangladesh. It is an important summer vegetable in Bangladesh (Rashid,1999). Okra can be grown year round, however, it is mainly produced during the summer, due to the demand of certain climatic factors such as light, temperature and water. Okra is a commercial vegetable crop belongs to family Malvaceae. It originates from Ethiopia and is widely spread all over tropical subtropical and warm temperate regions of the world (Singha, 2014).

Okra plant is a shrub, with a height of 1 to 2 m, ramified, with large leaves ranging from 20 to 40 cm in length and 3-7 lobes each, they have cross pollination, the seeds are round, large, and grey in color (Akinyele and Osekita, 2006). The weight of the fruit is directly related to the yield (Ariyo, 1987).

The present consumption of vegetables in Bangladesh is 112 g/day/capita (23 g leafy vegetables, 89 g non-leafy vegetables), which is far below the minimum average requirement of 400 g/day/capita (FAO/WHO, 2003). Thus, there is a big gap between the requirement and the supply of vegetables in Bangladesh. As a result, malnutrition is evident in the country. Successful okra production may contribute partially to solving vegetable scarcity in summer (Chowdhury, 2014). On the other hand, vegetable production in Bangladesh is not found uniform round the year. Vegetables are plenty in winter but are insufficient in summer. Out of the total vegetable production, around 30% is produced during Kharif season and around 70%

is produced in Rabi season. So, okra has got an importance on a summer season vegetables production (Anonymous,1993). Okra production in the country is low compared to other countries. Total production of okra was about 240 thousand tons from 7287.5 ha in 2009 and the average yield was about 3.38 t ha^{-1} (BBS, 2010). The application of fertilizers in okra is important for proper vegetative growth and yield.

Okra provides an important source of vitamins, calcium, potassium and other mineral matters which are often lacking in the diet in developing countries (IBPGR, 1990). It is a good source of protein, vitamin C and A, iron, calcium (Aworh, 1980) and dietary fiber (Adom, 1996). It is known as powerhouse of valuable nutrients having low calories and is fat-free. It is the best source of iodine and calcium. Consumption of 100 g of fresh okra fruit provides 20, 15 and 50% of the daily requirement of calcium, iron and ascorbic acid, respectively (Schippers, 2002). Okra is a popular food due to its high fiber, and vitamin C content. It is also known for being high in antioxidants. It is a good source of calcium and potassium (Duvauchelle, 2011). Greenishyellow edible okra oil is pressed from okra seeds; it has a pleasant taste and odor, and is high in unsaturated fats such as oleic acid and linoleic acid (Franklin, 1982). The green fruits (per 100 g edible portions) of okra contains 89.6 per cent of moisture, 1.9 g protein, 88 IU of vitamin A, 0.07 mg thiamine, 0.1 mg riboflavin, 13 mg vitamin C, 0.7 g minerals like 103 mg potassium, 6.9 mg sodium, 56 mg phosphorus, 66 mg calcium, 1.5 mg iron, 30 mg sulphur and other nutrients (Aykroyed, 1963). Besides, its seed is the good source of protein (Adelakun, 2009). 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 (Savello, 1980), against gastric and inflammatory diseases (Lengsfeld, 2004).

In 2012-13, okra production was 44.0 thousand metric tons from 10.66 thousand hectors of land in Bangladesh (BBS, 2015). Despite its importance, the production of okra is very low in Bangladesh compared to other countries of the world because it is frequently infected by a number of systemic diseases caused by fungi, viruses, bacteria, mycoplasma and nematodes. Among them Yellow Vein Mosaic Virus (YVMV) transmitted by whitefly is the most serious disease of okra. It may reduce the production up to 90% (Pullaiah et al., 1998; Kucharek, 2004).

It is realized that productivity of crop is being adversely affected in different areas due to deficiencies of micronutrients (Bose and Tripathi, 1996). The deficiency of micronutrients increased markedly due to intensive cropping, loss of top soil by erosion, loss of micronutrients by leaching and lower availability and use of farm yard manure (Fageria *et al.*, 2002). Micronutrients are usually required in minute quantities, nevertheless are vital to the growth of plant (Benepal, 1967).

Among all micronutrients, the deficiency of zinc and boron in Bangladesh soils was most prevalent which are important in seed formation and seed quality (Begum, 2015). 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 (Katyal, 1983). 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 (Kallo, 1985).

Zinc mainly functions as the metal component of a series of enzymes. The most important enzymes activate by this element are carbonic anhydrase and a number of dehydrogenases. Zinc deficiency is thought to restrict RNA synthesis, which in turn inhibits protein synthesis (Katyal, 1983). 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 (Keren, 1985). It 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 (Welch, 1982). Foliar application is the best way to nourish plants that grow in soil with poor quality due to adverse pH (Ishii et al., 2002) . the benefits of foliar fertilization in improving plant growth, crop yield, nutrient uptake and product quality (Mahmoud, 2010).

Therefore, the present study was designed with the following objectives:

Objectives:

1. To evaluate the effect of Zn and B on the groeth and yield of okra.
2. To identify better method of Zn and B application in terms of growth rate of okra.

CHAPTER 2

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

Okra is one of the important summer vegetables in Bangladesh as well as many countries of the world. Micronutrients are required for optimal growth (Ahmad, 2011) specifically six micronutrients (Zn, B, Fe, Cu, Mo & Mn) play vital roles in plant physiology and biochemical processes (Putra, 2012). Zinc influences on basic plant life processes, nitrogen metabolism, uptake of nitrogen and protein quality, photosynthesis, chlorophyll synthesis, carbon anhydrase activity, resistance to abiotic and biotic stresses, protection against oxidative damage (Cakmak, 2008), membrane integrity and phytochrome activities (Shkolnik, 1984). Boron (B) for reproductive plant parts, cell wall formation and stabilization, membrane integrity, carbohydrate utilization, stomatal regulation and pollen tube formation (Marschner, 1995). Nevertheless, some of the important and informative works and research findings related to the effect of boron and zinc fertlizer and their application methods so far been done at home and abroad have been reviewed in this chapter.

2.1: Effects of zinc and boron on yield and quality of okra

Sharma et al. (2018) carried out an experiment which was consisted of four zinc levels (control, 2.5 kg ha^{-1}, 5.0 kg ha^{-1} and 7.5 kg ha^{-1}) in Randomized Block Design with three replications. Results indicated that soil application of 7.5 kg zn ha^{-1} significantly enhanced the plant height (118 cm), number of branches per plant (2.6), leaf area (117 cm), chlorophyll content (1.6 mg g^{-1}), fruit length (11.7 cm), number of fruit per plant (22.3), fruit yield (13 t ha^{-1}), protein (1.40%) and crude fiber content in fruits (1.40 %).

Ghritlahare et al. (2015) concluded that the application of $ZnSO_4$ @ 50 kg ha^{-1} significantly increased plant height, number of leaves per plant, immature green fruit girth, immature green fruit yield, dry pod yield, stalk yield and protein content at harvest. Among different levels of iron application of 50 kg $FeSO_4$ ha^{-1} significantly increased number of leaves per plant, immature green fruit girth, immature green fruit yield, dry pod yield, stalk yield and protein content at harvest of okra.

Naser H. N. (2021) observed a significant effects of combined treatment on proline with zinc sulphate (P_2Zn_2) on all measured indicators. The treatment with proline concentration (80 mg L^{-1}) was superior in the percentage of nitrogen, phosphorus and potassium in leaves, number of branches, leaf area and plant yield (g) (3.09%, 0.44%, and 2.88%, 9.04 branch $plant^{-1}$, 0.723 m^2 , 303g $plant^{-1}$) respectively. Zn (40 mg. L^{-1}) treatment elevated all measured indicators (3.29%, 0.37%, 2.83%, 8.76 branches $plant^{-1}$, 0.763 m^2 , 334.35 g $plant^{-1}$).

Alrawi and Aljumail (2018) reported that the potassium spray with concentrations 4000 mg l^{-1} and the zinc spray with 30 mg l^{-1} was superior in plant height (114 and 112 cm $plant^{-1}$). Leaf area (830102 and 267.86 dcm^2 $plant^{-1}$), total chlorophyll (60.5 and 52.1 mg $100g^{-1}$ fresh weight). Fresh pods number (59.2 and 56.8 pod $plant^{-1}$). Fresh pod weight (5.5 and 5.1 g pod^{-1}). Plant yield (331.8 and 301.3 g. $plant^{-1}$) respectively. While the potassium spray with concentration of 6000 mg l^{-1} and the zinc spray with 60 mg l^{-1} was superiored in seeds germination (92.2 and 90.6 %). Oil in seeds 21.8 and 21.7 %. Carbohydrate in seeds (33.9 and 33.4 %). Protein in seeds 22 and 21.7 %, respectively. It could be recommended to use foliar of 4000 mg l^{-1} potassium and 30 mg l^{-1} zinc to increase growth and green pod yield.

Farooq et al. (2018) noticed that increased yield and yield parameter with increasing levels of S and B when 40 kg ha^{-1} S and 1.5 kg ha^{-1} B were applied. Soil analysis showed that both B an S contents in soil increased by increasing level of applied S and B.

Aduayi and Adegbite (2008) investigated that the response of okra plants to root and foliar applied B at 0, 2 and 4 ppm was investigated in solution culture. Root B application was higher than 2 ppm resulted in severe root burn and toxicity in the plants, whereas foliar B application up to 4 ppm produced adequate plant growth. Chlorophyll and carotene content of leaves, flower number, stem diameter, plant height and dry matter production were drastically reduced at high root-applied B when compared to the foliar treatments. Significant negative correlation between root applied B and plant height, stem diameter, leaf and flower number was noticed. Except for a significant negative correlation with leaf number, all other growth components were positively correlated with foliar application of B. Foliar application of B was superior to root application as was observed in the healthy growth of the okra plant.

Aktar et al. (2015) reported the interactive effects of nitrogen (0, 30, 60 and 120 kg ha^{-1}) and boron (0, 0.5, 1 and 2 kg ha^{-1}) fertilizers on the growth and nutrient content of okra (*Abelmoschus esculentus L.).* The increase in plant height of okra was significant

($p<0.05$) due to combined application of nitrogen and boron fertilizers. Maximum height, shoot and root dry matter yield and uptake of nutrients in root and shoot of okra were observed in treatment 30 kg N ha^{-1} with 1 kg B ha^{-1}. But, higher doses of fertilizer combinations (60 and 120 kg of N ha^{-1} with B) performed differently. Higher doses of fertilizer combinations significantly ($p<0.05$) reduced shoot and root growth as well as the concentration and uptake of nitrogen, phosphorus potassium in okra. It was concluded that the treatment combination of 30 kg N ha^{-1} with 1 kg B ha^{-1} can be used for better growth of okra.

2.2: Effects of zinc and boron application methods on yield and quality of okra

Jahan et al. (2020) reported the effect of zinc (Zn) and boron (B) on growth and yield of okra (BARI Dherosh 1). The highest plant height was found in 30 kg Zn ha^{-1} and 20 kg B ha^{-1} but the highest number of leaves/plant was recorded with 30 kg Zn ha^{-1} and 10 kg B ha^{-1}. On the other hand, the maximum leaf area index, SPAD value, mean fruit weight, fruit length, fruit diameter, fruit dry matter (%), number of fruits $plant^{-1}$, fresh fruit weight $plant^{-1}$ and fruit yield ha^{-1} were found in 30 kg Zn ha^{-1} with 10 kg B ha^{-1}. It is concluded that 30 kg Zn ha^{-1} with 10 kg B ha^{-1} combination may be helpful for okra cultivation at the field.

Rahman et al. (2017) noticed that individual and combined application of B and Zn resulted improved yield and quality of okra while higher doses of B and Zn resulted in negative effect on yield and quality of okra seed. The highest seed yield, germination, seedling vigour index and protein content were noted with 2 kg B ha^{-1}or 4 kg Zn ha^{-1}.

The foliar application of 0.2 % B and 0.2 % Zn individually and combinedly produced the maximum yield and quality of okra.

Rahman et al. (2020) studied that the foliar application of boron and zinc either single or in combination had significant effect on yield, yield attributes and quality of okra seed. Most of the yield attributes of okra were significantly increased by the combined foliar application of borax and zinc sulphate up to 0.2% borax and 0.2% zinc sulphate spray. The highest seed yield (2.52 t/ha) was obtained from the treatment combination of 0.2% borax and 0.2% zinc sulphate followed by the treatment combination of 0.2% borax and 0.3% zinc sulphate. The highest oil content (16%) in seed was also produced from the same treatment (0.2% borax and 0.2% zinc sulphate). The improved protein content (17.8%) was found in combination of 0.1% borax and 0.3% zinc sulphate. The combined foliar applications of zinc and boron fertilizers were detected superior to their single application. The foliar fertilization rates of zinc sulphate should be increased for okra production.

Kumar et al. (2021) evaluated that two micronutrients (zinc and boron) in the form of zinc sulphate and borax were taken in different concentrations (0.5, 1.0 and 1.5%) and applied at 30 and 60 DAS respectively. The results indicated that among different treatments the highest plant height (141 cm) at final harvest, number of nodes per plant (16.3), inter nodal length (8.9 cm) and number of branches per plant (1.9) were recorded the highest with the treatment receiving borax 1.0%. The least days taken to first flowering (52.8) and fifty per cent flowering (60.1) were also recorded with the same treatment (borax 1.0%). All other parameters found significantly lowest under control treatment.

As reported by Mahesh et al. (2004) the interaction effect of boron and zinc on okra that might be helpul for better pollen germination and growth of pollen tube and more number of fruit sets. Boron facilitates the reduction of male sterility and increases normal fruit. Zinc is involved in the biochemical synthesis of phytohormone, IAA through the pathway of conversion of tryptophan to IAA, which help improved yield and its attributes.

Rahman et al. (2021) investigate the effects of boron, zinc, and NPK on the yield and quality of okra. Application of 2 kg B ha^{-1} and 4 kg Zn ha^{-1} in combination with the recommended dose of NPK fertilizers demonstrated the highest seed yield (2.7 t ha^{-1}), seed germination (97.0%), seedling vigour index (2845) and seed protein content (19.9%) whereas the lowest seed yield (1.9 t ha^{-1}), seed germination (78.5%), seedling vigour index (1954) and seed protein content (16.3%) were found from 0 kg B ha^{-1} and 0 kg Zn ha^{-1} with 50% less than the recommended dose of NPK application. The maximum yield and good quality of okra seed was obtained from the application of 2 kg B and 4 kg Zn ha^{-1}, in combination with the recommended dose of NPK fertilizers.

Mehraj et al. (2015) investigated the performance of foliar feeding of micronutrients on the growth and yield of okra. Foliar application of 100 ppm of six micronutrients (Zn, B, Fe, Cu, Mo and Mn) mixture were done and conrol treatment was considered as fresh water spray, one time foliar application (20 days after sowing (DAS) and two times foliar application (20 DAS and 35 DAS). The tallest plant, longest petiole, longest internode and longest pods were also found from two times foliar application, while the shortest parameters from control. The maximum stem diameter, number of leaves, leaf area, number of branches, number of internodes, weigth, dry weight, number of pods, pod diameter and pod yield were found from two times foliar application, whereas the minimum from control. Foliar feeding of micronutrients mixture can increases the growth and yield of okra.

Abbasi et al. (2010) evaluated that the foliar fertilization can successfully supplement plant nutrition, integration with soil applied chemical fertilizers. The results endorsed the benefits of foliar fertilization of crops by witnessing the improved growth traits of okra plants, viz. days to flowering, plant height, number of branches plant^{-1}, number of fruits/plant and fruit length, coupled with the better crop yield of okra by the integration of all three foliar fertilizers with the recommended soil applied chemical fertilizers. The regular testing of such effective foliar fertilizers and their use, after extensive controlled condition and field scale studies, is recommended for sustainable okra production.

Mohammadi et al. (2016) concluded that the main value of foliar application of micronutrients was to increase germination percentage and reduce hard seedness. In some cultivars (Pylaias and Veloudo) micronutrients may also increase seed yield by increasing pod set.

Sharangi et al. (2002) evaluated that spraying of 0.2% Zn can lead to increase in plant height. The maximum number of fruit plant^{-1} was recorded from the plants receiving foliar spray of 0.2% borax with 0.2% zinc sulphate. Combined of boron and zinc application might be helpful balanced absorption of nutrients, increasing the rate of photosynthesis, as a result fruit per plant was the highest.

2.3: Foliar spray in vegetables

Lenka et al. (2019) reported that application of both zinc and boron improved the growth and yield of potato significantly. Zinc and boron acted synergistically in increasing the tuber yield. The highest total tuber yield (30.1 t ha^{-1}) of potato was recorded with foliar application of 0.1% boron + 0.1% zinc along with recommended dose of fertilizer (RDF) of NPK. Soil application of only boron, only zinc and boron + zinc increased the total yield of tubers by 12.7%, 3.23% and 22.41%, respectively, over RDF of NPK only. Foliar application of only boron, only zinc and boron + zinc increased the total yield of tubers by 18.7%, 7.70% and 29.6%, respectively, over RDF of NPK only. The effect of boron in increasing tuber yield of potato was found more pronounced than zinc in our study experimental situation. Foliar application of B and Zn was found superior in increasing tuber yield to their soil application. The highest uptake of N, P, K, B and Zn was noted with foliar application of B and Zn over RDF. Soil application of B and Zn significantly increased their concentration in soil. Foliar application of B and Zn over RDF of NPK resulted in the highest net returns.

Krishnasree et al. (2020) state that foliar application of nutrients at proper growth stage of crop is important. It is not an alternative to soil application, but supplement soil application especially when secondary and micronutrient deficiencies arise. In spite of a few limitations foliar nutrition serves as an efficient means of nutrient management in vegetables. To combat the wide spread deficiencies of nutrients especially arising at the critical stages of crop growth foliar nutrition can be successfully adopted.

Haytova (2013) reported that the application of foliar sprays is an important crop management strategy, which may help maximizing crop yield and quality. Foliar applications are often timed to meet the demand of nutrients at specific vegetative or fruiting stages of growth, and the fertilizer formula is adjusted accordingly. Applications may also be used to aid plants recovering from transplant shock, hail damage, and other damaging environmental conditions. It is proposed that this treatment should be recommended in integrated plant production, because it is more environmentally friendly and may increase productivity and quality of crops. It is concluded that foliar fertilization has a definite place in vegetable crop production.

Channakeshava et al. (2017) noticed that the increase in yield was 13.9 percent with foliar application of vegetable special at 5g lit^{-1} along with recommended doses of fertilizer compared to farmers' practice. However, significantly higher number of fruits were recorded with RDF+ foliar spray of vegetable special at 5g/lit (9.7 and 1.46 kg) compared to farmers practice (4.5 and 0.62 kg). As regard to micronutrient content in tubers higher concentration of Zn, Cu, Mn, Fe, B and Mo were recorded in the treatment where foliar application of vegetable special at 5g/lit along with RDF (22.2, 8.3, 21.5, 25.0 and 16.6) than recommended practice and farmers' practice.

Rab et al. (2012) reported that calcium chloride (0.3% and 0.6%) and borax (0.2% and 0.4%) solutions were applied as foliar sprays either alone or in combination and data were recorded for plant height, branches per plant, flowers per cluster, fruits per plant, yield, fruit weight, fruit firmness, and total soluble solid content of the fruit. The application of $CaCl_2$ alone significantly increased the plant height and fruits per plant and decreased the incidence of blossom end rot. Borax alone significantly enhanced the number of branches per plant, number of flowers per cluster, fruits per cluster, fruits per plant, fruit weight, fruit firmness, and total soluble solid content of the fruits. Foliar application of $CaCl_2$ (0.6%) + borax (0.2%) resulted in the maximum plant height (86.6 cm), branches plant^{-1} (7.2), flowers cluster^{-1} (32.3), fruits plant $^{-1}$ (96.4), fruit weight (96.3 g), yield (21.3 t ha^{-1}), fruit firmness (3.5 kg cm^2), and total soluble solids (6.10%) and the lowest blossom end rot incidence (6.25%). However, the difference among 0.6% $CaCl_2$ + 0.2% borax, 0.3% $CaCl_2$ + 0.2% borax, and 0.6% $CaCl_2$ + 0.4% borax was nonsignificant.

Sultana et al. (2014) experimented with the micronutrients zinc (Zn) in the form of zinc sulphate ($ZnSO_4.7H_2O$) at the rate of 0.05 % and boron (B) in the form of boric acid (H_3BO_3) at the rate of 0.03% that applied as foliar spray at three different stages of plant growth. The yield and its contributing yield traits were significantly affected by foliar fertilizer treatments as against soil application of B and Zn fertilizers. Among various treatments, foliar application of Zn (0.05 %) + B (0.03%) produced maximum fruit yield (85.5 and 81.7 t ha^{-1} in 2013 and 2014, respectively) while no application of Zn (0.0) and B (0.0) produced 66.8 and 60.7 t ha-1 in 2013 and 2014, respectively and it was statistically identical with soil application of B and Zn at 2 and 6 kg ha^{-1} respectively. The increment of yield was 19.2 to 31.1% and 7.57 to 18.3% respectively, over control and soil application. The integrated use of foliar application of micronutrients and soil application of macronutrients are recommended to enhance yield.

Taheri et al. (2020) identifid a suitable and effective application method to improve the overall soil nutrient up gradation for crop production. The source of zinc at 3 kg ha^{-1} and boron at 2 kg ha^{-1} as a basal dose were zinc sulphate and borax, respectively. Foliar application of zinc and boron was done at 45 and 60 days after transplanting at 1% and the sources were chelated zinc and solubor, respectively. The result of the experiment was concerning the highest plant height, plant spreading, the number of leaves, stem length, stem diameter, fresh weight of loose leaves and yield. The highest yield was found with the treatment of foliar application of zinc and boron. The results of this investigation revealed that the application methods of zinc and boron affected the growth and yield whereas foliar application of these nutrients always the higher growth parameters and yield.

CHAPTER 3

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

This chapter includes a brief description of the experimental site, experimental period, climatic condition, crop or planting materials, land preparation, experimental design and layout, crop growing procedure, treatments, intercultural operations, data collection and chemical analysis of soil.

3.1 Soil description of experimented area

The research work was done to study the effects of Zn and B fertilization on the growth, and yield of okra at Sher-e-Bangla Agricultural University (SAU) farm, Dhaka during Kharif I season on 2021. The experimental location situated at $23^{0}77$ N and $90^{0}33$ E longitude with an elevation of 1 meter from sea level.

3.1.1 Description of soil

Soil of the experimented field belongs to the Tejgaon soil series under the Agro ecological Zone, AEZ-28 (Madhupur Tract). In this series soil types are in general is shallow deep red brown terrace Soils. A composite sample was made by collecting soil from several spots of the field at a depth of 0-15 cm before the initiation of the experiment. The collected soil was air dried, ground and passed through 2 mm sieve and analyzed for some important physical and chemical parameters. The morphological, physical and chemical characteristics of the initial of the experimental field of the soil are presented below (Tables 3.1 & 3.2)

Table 3.1 Morphological characteristics of experimental field

Morphological features	Characteristics
Location	Sher-e-Bangla Agricultural University
AEZ No. and name	AEZ-28, Madhupur Tract
General Soil type	Shallow Red Brown Terrace Soil
Soil series	Tejgaon
Topography	Fairly leveled
Depth of inundation	Above flood level
Drainage condition	Well drained
Land type	Medium high land

Table 3.2 Chemical characteristics of the initial soil of the experimental field

pH	6.20
Total N (%)	0.17
Available P (ppm)	19.28
Available S (ppm)	16.54

3.2 Climate

The experimental area has sub-tropical humid climate characterized by medium temperature, Winter which begins in November and ends in February. Temperature ranges from minimum of 7^0C-13^0C to a maximum of 24^0C-31^0C. The maximum temperature recorded in summer is 37^0C. Monsoon starts in July to October. The average annual rainfall varies from 1429-4338 mm. The average maximum temperature is 26-32^0C and average mean temperature is 28.12^0C (BBS, 2021).

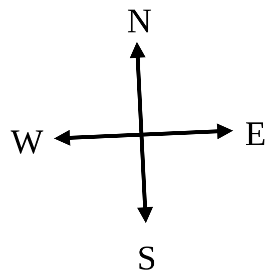
3.3 Plant material

Okra (BARI dheros-2) was used as experimental material.

3.4 Preparation of the field

The selected plot for conducting the experiment was opened in the first week of march 2021, with a power tiller and left exposed to the sun for a week to kill soil borne pathogens and soil inhabitant insects. After one week the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain until good tilth. The land was leveled, corners were shaped and the clods were broken into pieces. Weeds, crop residues and stubles were removed from the field. The basal dose of manure and fertilizers were applied at the final ploughing. The plots were prepared according to design and layout of the experiment (Fig 3.1).

R1	R2	R3
Zn_1B_2	Zn_0B_0	Zn_2B_1
Zn_2B_1	Zn_2B_2	Zn_1B_2
Zn_0B_0	Zn_1B_1	Zn_2B_0
Zn_1B_0	Zn_1B_2	Zn_0B_2
Zn_1B_1	Zn_2B_1	Zn_0B_1
Zn_0B_1	Zn_0B_2	Zn_0B_0
Zn_0B_2	Zn_0B_1	Zn_1B_1
Zn_2B_0	Zn_1B_0	Zn_2B_2
Zn_2B_2	Zn_2B_0	Zn_1B_0



Each plot area: 1.75 m x 2.5 m = 4.375 m^2

Plot to plot distance: 0.3 m

Plot distance from border: 0.50 m

Block to block distance: 0.6 m

Fig: 3.1: Layout of the experimental plot

3.5 Design of field experiment

The experimental design was a Randomized Complete Block Design (RCBD).

3.6 Treatments

Fertilizer treatment consisted of 3 levels of Zn and B application with different methods were applied in the experiment. The following treatments were applied in the experiment,

Factor A:

Different level of Zn

Zn_0: Control

Zn_1: 3kg ha^{-1} (Mixed with soil at final land preparation)

Zn_2: 3kg ha^{-1} (Foliar application in plant)

Factor B:

Different level of B

B_0: Control

B_1: 2 kg ha^{-1} (Mixed with soil at final land preparation)

B_2: 2 kg ha^{-1} (Foliar application in plant)

Combination of treatments:

Zn_0B_0= Control (No Zn & B)

Zn_1B_0= 3 kg Zn ha^{-1} as soil application with 0 kg B ha^{-1}

Zn_2B_0= 3 kg Zn ha^{-1} as foliar application with 0 kg B ha^{-1}

Zn_0B_1= 0 kg Zn ha^{-1} with 2 kg B ha^{-1} as soil application

Zn_0B_2= 0 kg Zn ha^{-1} with 2 kg B ha^{-1} as foliar appliction

Zn_1B_1= 3 kg Zn ha^{-1} with 2 kg B ha^{-1} as soil application

Zn_2B_1= 3 kg Zn ha^{-1} as foliar application with 2 kg B ha^{-1} as soil application

Zn_1B_2= 3 kg Zn ha^{-1} as soil application with 2 kg B ha^{-1} as foliar application

Zn_2B_2= 3 kg Zn ha^{-1} with 2 kg B ha^{-1} as foliar application

3.7 Application of fertilizers

Recommended doses of cow dung, nitrogen, phosphorus, potassium and sulphur (10 ton, 100 kg N from Urea, 30 kg P from TSP, 70 kg from MoP and 15 kg S from gypsum respectively) were applied. The required amounts of TSP, MoP and gypsum and one third of the recommended dose of urea fertilizer were applied as basal dose during final land preparation. The remaining second one third of urea was top dressed after 30 days of seed after sowing and final dose was applied in 50 days after seed sowing.

3.7.1 Zn and B application

Zn_1 (3 kg Zn ha^{-1}) and B_1 (2 kg B ha^{-1}) were mixed with soil as a source of zinc Sulphate (monohydrate) and boric Acid. Similar rate of Zn_2 (3 kg Zn ha^{-1}) and B_2 (2 kg B ha^{-1}) were applied through foliar application for two times (20 DAS & 35 DAS) as a source of Zinc Sulphate (monohydrate) and Boric Acid.

3.8 Seed sowing

The seed should be treated with 3g of Captain per kg seed before sowing for having good crop. Seeds should be soaked in clean water for 24 hours before sowing. Seeds were sown on 24 march 2021 in the seedbed. Sowing was done in lines spaced at 5 cm distance. Seeds were sown at a depth of 2 cm and covered with a fine layer of soil followed by light watering by watering can. 2-3 seeds per hill were sown. Seedling emerged after 3 days of seed sowing.

3.9 Intercultural operations

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

3.9.1 Gap filling

The seedlings in the experimental plot were kept under careful observation. Seedling was planted earlier on the border of the experimental plots same as planting time treatment. Replacement was done with healthy seedling. The gap fillings and watering were done for 7 days for their proper establishment.

3.9.2 Weeding and thinning

Weeds of different types were controlled manually and removed from the field. The weeding and thinning were done after 20 days of sowing. Care was taken to maintain constant plant population (18 plants) per plot.

3.9.3 Irrigation

Light watering was given by a watering cane at every morning.

3.9.4 Pest management

To rescue the plant from the infested pest at the seedling stage application of emitaph 1 ml with 5 litre water was done twice on 26 April and 02 May , 2021. Special care was taken to protect the crop from birds especially after sowing and germination stages.

3.10 Harvesting

Flowering begins from 35 to 40 days after sowing and fruits are ready for harvest 4-5 to five days after flowering. Okra pods may be harvested continuously at alternate days. The young fruits can be harvested in the morning. Delay in harvesting may made the fruits fibrous and they lost their tenderness and taste.

3.11 Collection of samples

Samples were collected from different places of each plot. 5 plants from each plot were selected as samples.

3.12 Collection of data

Five (5) plants were randomly selected for data collection from the middle rows of each unit plot for avoiding border effect, except yields of fruits, which was recorded plot wise. Data were collected in respect of the following parameters to assess plant growth, yield attributes and yields.

Data were collected on the following parameters:

Plant height (cm)

Number of leaves plant^{-1}

Number of branches plant^{-1}

Number of fruits plant^{-1}

Yield (t ha^{-1})

3.12.1 Plant height

The plant height was measured from the ground level to the top of the plant. Five plants were selected randomly from each plot at harvesting stage. Plant height was measured and averaged.

3.12.2 Number of leaves plant^{-1}

Numbers of leaves were counted at harvesting stage. Five plants were selected randomly from each plot and number of leaves were counted and averaged.

3.12.3 Number of primary branches plant^{-1}

Five plants were selected randomly from each plot at harvesting stage. Number of branches were counted and averaged.

3.12.4 Number of fruits plant^{-1}

It was done at harvesting stage. Five plants were selected randomly from each plot. At first, number of fruits plant^{-1} were counted and averaged. Then it was multiplied with number of fruits plant^{-1} and averaged.

3.12.5 Yield

The yield per hectare was calculated from per plot yield data and their average was taken. It was measured by the following formula,

$$\text{Yield per hectare (ton)} = \frac{Yield\ plot^{-1} \times 10000}{Area\ of\ plot\ in\ m^2 \times 1000}$$

3.13 Chemical analysis of the soil samples

a) Nitrogen

Soil samples were digested with 30% H_2O_2, cone. H_2SO_4 and a catalyst mixture (K_2SO_4: $CuSO_4.5H_2O$: Selenium powder in the ratio 100: 10: 1, respectively) for the determination of total nitrogen by Micro-Kjeldal method. Nitrogen in the digest was determined by distillation with 40% NaOH followed by titration of the distillate absorbed in H_3BO_3 with 0.01N H_2SO_4 (Jackson. 1973).

% N= (T-B)* N* 0.014* 100/S

Where,

T= Sample titration value (ml) of standard H_2SO_4

B= Blank titration value (ml) of standard H_2SO_4

N= Normality of H_2SO_4

S= Sample weight in gram

b) Phosphorous

Phosphorous was extracted by 0.5M $NaHCO_3$(Olsen *et al*., 1954) and determined by spectophotometer.

C) Sulphur

Sulphur content in the extract was determined by turbid metric method as described by Hunter (1980) using a spectrophotometer.

Table 3.3 Chemical characteristics of the post harvest soil of the experimental field

pH	5.99
Total N(%)	0.17
Available P (ppm)	12.08
Available S (ppm)	20.09

3.14 Statistical analysis

The data obtained from the experiment were analyzed statistically to find out the significance of the difference among the treatments. The significance of the differences among pairs of treatments was estimated by DMRT at *5%* and 1% level of probability by using MStat-C.

CHAPTER 4

RESULTS AND DISCUSSION

CHAPTER IV

RESULTS & DISCUSSION

The experiment was conducted at Sher-e-Bangla Agricultural University (SAU) farm to determine the effects of Zn and B on the growth and yield of okra. Data on different yield contributing characters and yield were recorded to find out the suitable level and application methods of Zn and B fertilizer on okra.

4.1 Effects of Zn & B on the plant height of okra

4.1.1 Effects of Zn

Different Zn level and application methods showed significant variation on plant height of okra. Significant variation was observed on the plant height of okra when the field was fertilized with 3 application methods of Zn (control, soil application, foliar application). Among the different application of Zn, Zn_2 (3 kg Zn ha^{-1} as foliar treatment) showed the highest plant height (167 cm). On the other hand, the lowest plant height (145 cm) was observed in the Zn_0 treatment where no Zn was applied (table 4.1.1). This might be due to the deficiency of Zn in soil which reduced the cell division, carbohydrate and protein synthesis and also lowered the normal growth of plant. Sharma et al. (2018) reported that zinc application significantly enhanced the plant height of okra.

Table 4.1.1 Effects of Zn

Treatment	Plant Height (cm)
Zn_0	145 c
Zn_1	151 b
Zn_2	167 a
SE (±)	1.01

Zn_0= Zinc Control; Zn_1= 3 kg Zn ha^{-1} as soil application of Zinc; Zn_2= 3 kg Zn ha^{-1} as foliar application; SE= Standard Error

4.1.2 Effects of B

A significant variation was observed on okra in respect of plant height when B fertilizers were applied in different methods. Among the different methods , B_2 (2 kg B ha^{-1} as foliar application) showed the highest plant height (156 cm), On the contrary, the lowest plant height (151 cm) was observed in the B_0 (No application) treatment (table 4.1.2) where B was not applied. Boron is required for proper development and differentiation of plant tissues. In its absence, abnormal growth and development were affected. Aduayi et al. (2008) concluded that root B application higher than 2 ppm resulted in severe root burn and toxicity in the plants, whereas foliar B application up to 4 ppm produced adequate plant growth.

Table 4.1.2 Effects of B

Treatment	Plant height (cm)
B_0	151
B_1	155
B_2	156
SE (±)	NS

B_0= Boron Control; B_1=2 kg B ha^{-1} as soil application of Boron; B_2= 2 kg B ha^{-1} as foliar application; SE= Standard Error; NS=Not Significant

4.1.3 Interaction effects of Zn and B

Combined application of different methods of Zn and B fertilizers had significant effect (table 4.1.3) on the plant height of okra. The lowest plant height (133 cm) was observed in the treatment combination of Zn_0B_0. On the other hand, the highest plant height (180 cm) was recorded with Zn_2B_2 where 3 kg Zn ha^{-1} was applied as foliar and 2 kg B ha^{-1} was applied as foliar (Haytova D, 2013). The Zn_2B_2 (3 kg Zn ha^{-1} with 2 kg B ha^{-1} as foliar application) treatment showed the highst plant height, which was statistically significant over the treatment.

Table 4.1.3 Interaction effects of Zn and B

Treatment	Plant Height (cm)
Zn_0B_0	133 e
Zn_0B_1	151 c
Zn_0B_2	143 d
Zn_1B_0	169 b
Zn_2B_1	152 c
Zn_1B_2	140 d
Zn_2B_0	157 c
Zn_1B_1	165 b
Zn_2B_2	180 a
SE (±)	1.75

Zn_0B_0= Zinc & Boron control; Zn_0B_1= No Zinc with 2 kg B ha^{-1} as soil application; Zn_0B_2= No Zinc with 2 kg B ha^{-1}as foliar application of Boron; Zn_1B_0= 2 kg Zn ha^{-1} as soil application with no Boron; Zn_2B_1=3 kg Zn ha^{-1}as foliar application with 2 kg B ha^{-1} as soil application; Zn_1B_2= 3 kg Zn ha^{-1} as soil application with 2 kg B ha^{-}1 as foliar application; Zn_2B_0= 3 kg Zn ha^{-1} as foliar application with no Boron; Zn_1B_1= 3

kg Zn ha^{-1} & 2 kg B ha^{-1} as soil application; Zn_2B_2=3 kg Zn ha^{-1} & 2 kg B ha^{-1} as foliar application; SE= Standard Error

4.2 Effects of Zn & B on the number of leaves plant^{-1} of okra

4.2.1 Effects of Zn

A non significant variation was observed due to the application methods of zinc. Maximum number of leaves plant^{-1} (44.8) was observed in Zn_2 (3 kg Zn ha^{-1} as foliar application). The lowest number of leaves plant^{-1} (43.6) was recorded in the Zn_0 (control) treatment (table 4.2.1). Ghritlahare et al. (2015) investigated that Zn significantly increased number of leaves per plant of okra.

Table 4.2.1 Effects of Zn

Treatment	Number of leaves plant^{-1}
Zn_0	43.6
Zn_1	43.6
Zn_2	44.8
SE (±)	NS

Zn_0= Zinc Control; Zn_1= 3 kg Zn ha^{-1} as soil application; Zn_2= 3 kg Zn ha^{-1} as foliar application; SE= Standard Error; NS= Non significance

4.2.2 Effects of B

A significant variation was observed due to the application methods of Boron. The maximum number of leaves per plant (47.3) was recorded in B_2 (2 kg ha^{-1} boron as foliar application). It was also observed that the minimum number of leaves per plant (42.1) was recorded where no boron (B_0) was applied (table 4.2.1). Increase doses of boron results maximum number of leaves by cell wall formation and setting of young leaves. Abbasi et al. (2010) reported that foliar fertilizers is recommended for sustainable okra production.

Table 4.2.2 Effects of B

Treatment	**Number of leaves plant^{-1}**
B_0	42.1 b
B_1	42.6 b
B_2	47a
SE (±)	0.52

B_0= Boron Control; B_1=2 kg B ha^{-1} as soil application; B_2= 2 kg B ha^{-1} as foliar application; SE= Standard Error

4.2.3 Interaction effects of Zn and B

When different application methods of Zn and B fertilizers are mixed, the number of leaves plant^{-1} of okra varies significantly. The highest number of leaves plant^{-1} (50) was recorded with the treatment combination of Zn_2B_2 (3 kg Zn ha^{-1} & 2 B kg ha^{-1} as foliar application) which was statistically different from Zn_2B_1 (3 kg Zn ha^{-1} as foliar application & 2 kg B ha^{-1} as soil application) (40.9), Zn_1B_2 (3 kg Zn ha^{-1} as soil application with 2 kg B ha^{-1} as foliar application) (44.8) and Zn_1B_1(3 kg Zn ha^{-1} & 2 kg B ha^{-1} as soil application) (41.4) treatment combination. The lowest number of leaves plant^{-1}(37.4) was observed in control (Zn_0B_0). It was also observed that the increasing dose of Zn and B combination treatment results increasing the number of leaves plant^{-1} of okra (Jahan et al. , 2020). The Zn_2B_2 (3 kg Zn ha^{-1} with 2 kg B ha^{-1} as foliar application) treatment showed the highst no. of leaves plant^{-1}, which was statistically significant over the treatment.

Table 4.2.3 Interaction effects of Zn and B

Treatment	Number of leaves plant^{-1}
Zn_0B_0	37.4 f
Zn_0B_1	46.3 bc
Zn_0B_2	47.2 ab
Zn_1B_0	46 ab

Zn_2B_1	40.9 ef
Zn_1B2	44.7 bcd
Zn_2B_0	42.9 cde
Zn_1B_1	41.4 de
Zn_2B_2	50.00 a
SE (±)	1.75

Zn_0B_0= Zinc & Boron control; Zn_0B_1= No Zinc with 2 kg B ha^{-1} as soil application; Zn_0B_2= No Zinc with 2 kg B ha^{-1}as foliar application of Boron; Zn_1B_0= 2 kg Zn ha^{-1} as soil application with no Boron; Zn_2B_1=3 kg Zn ha^{-1}as foliar application with 2 kg B ha^{-1} as soil application; Zn_1B_2= 3 kg Zn ha^{-1} as soil application with 2 kg B ha-1 as foliar application; Zn_2B_0= 3 kg Zn ha^{-1} as foliar application with no Boron; Zn_1B_1= 3 kg Zn ha^{-1} & 2 kg B ha^{-1} as soil application; Zn_2B_2=3 kg Zn ha^{-1} & 2 kg B ha^{-1} as foliar application; SE= Standard Error

4.3 Effects of Zn & B on the number of branches $plant^{-1}$ of okra

4.3.1 Effects of Zn

Different application of Zn fertilizer resulted in substantial differences in the number of branches on $plant^{-1}$. Among the different application of Zn, Zn_2(3 kg ha^{-1} of zinc as foliar application) showed the highest number of branches $plant^{-1}$ (3.78).

Table 4.3.1 Effects of Zn on

Treatment	Number of Branches plant^{-1}
Zn_0	3.48
Zn_1	3.53
Zn_2	3.78
SE (±)	NS

Zn_0= Zinc Control; Zn_1= 3 kg Zn ha^{-1} as soil application; Zn_2= 3 Zn kg ha^{-1} as foliar application; SE= Standard Error; NS= Non significance

4.3.2 Effect of B

A Significant variation was observed in the number of branches plant^{-1} of okra when three B treatments were applied. The highest number of branches plant^{-1}(3.88) was recorded in B_2 (2 kg ha^{-1} as foliar treatment) treatment where lower number of branch plant^{-1} (3.47) was observed in control. Kumar et al (2021) reported that Number of branches per plant were recorded the highest with the treatment of Boric acid.

4.3.2: Effects of B

Treatment	**Number of Branches plant^{-1}**
B_0	3.46
B_1	3.50
B_2	3.83
SE (±)	NS

B_0= Boron Control; B_1= 2 kg B ha^{-1} as soil application; B_2= 2 B kg ha^{-1} as foliar application; SE= Standard Error; NS= Non significance

4.3.3 Interaction effects of Zn and B

A notable variation was observed in the combined effect of Zn and B on the number of branches plant^{-1} of okra. The maximum number of branches plant^{-1} (4.40) was recorded with the treatment combination of Zn_2B_2 (3kg Zn ha^{-1} with 2 kg B ha^{-1} as foliar treatment) which was statistically identical with Zn_2B_0 (3kg ha^{-1} as foliar treatment of Zn with control B) (3.53) and Zn_1B_2 (3 kg ha^{-1} as soil tratment of Zn with 2 kg ha^{-1} as foliar treatment of B) (3.33) treatment combinations. On the other hand, the lowest number of branches plant^{-1} (3.13) was found in Zn_0B_0 treatment (control treatment). High level of Zn and B in the soil helps in plant root formation,carbohydrate metabolism, protein synthesis and growth promoters activations which ultimately produces healthy plant with the maximum productive branches of the crop. Deficiency of Zn and B results in low rate of plant growth and plant branching. Rahman et al. (2020) reported that the foliar application of boron and zinc had significant effect on number of branches. The Zn_2B_2 (3 kg Zn ha^{-1} with 2 kg B ha^{-1} as foliar application) treatment showed the highst number of branches $plant^{-1}$, which was statistically significant over the treatment.

4.3.3 Interaction Effects of Zn and B

Treatment	**Number of Branches $plant^{-1}$**
Zn_0B_0	3.13 b
Zn_0B_1	3.53 ab
Zn_0B_2	3.76 ab
Zn_1B_0	3.73 ab
Zn_2B_1	3.53 ab
Zn_1B_2	3.33 b
Zn_2B_0	3.53 ab
Zn_1B_1	3.43 b

Zn_2B_2	4.40 a
SE (±)	0.21

Zn_0B_0= Zinc & Boron control; Zn_0B_1= No Zinc with 2 kg B ha^{-1} as soil application; Zn_0B_2= No Zinc with 2 kg B ha^{-1}as foliar application of Boron; Zn_1B_0= 2 kg Zn ha^{-1} as soil application with no Boron; Zn_2B_1=3 kg Zn ha^{-1}as foliar application with 2 kg B ha^{-1} as soil application; Zn_1B_2= 3 kg Zn ha^{-1} as soil application with 2 kg B ha-1 as foliar application; Zn_2B_0= 3 kg Zn ha^{-1} as foliar application with no Boron; Zn_1B_1= 3 kg Zn ha^{-1} & 2 kg B ha^{-1} as soil application; Zn_2B_2=3 kg Zn ha^{-1} & 2 kg B ha^{-1} as foliar application; SE= Standard Error

4.4 Effect of Zn & B on the number of fruits plant^{-1} of okra

4.4.1 Effect of Zn

Application of Zn fertilizer with different application methods showed significant variation on the number of fruits plant^{-1} of okra. Among the different methods of Zn fertilizer , Zn_2 (3kg ha^{-1} of zinc as foliar treatment) showed the maximum fruit number plant^{-1} (26.9), Similarly Zn_1 (3 kg ha^{-1} of zinc as soil treatment) showed (25.9). The lowest fruit number plant^{-1} (23.5) was recorded in the Zn_0 (control) treatment where no Zn was applied. This might be occurred due to Zn helps in fruit setting on plant.

Table 4.4.1 Effects of Zn

Treatment	Number of fruits plant^{-1}
Zn_0	23.5 b
Zn_1	25.9 ab
Zn_2	26.9 a
SE (±)	0.46

Zn_0= Zinc Control; Zn_1= 3 kg Zn ha^{-1} as soil application; Zn_2= 3 kg Zn ha^{-1} as foliar application; SE= Standard Error

4.4.2 Effects of B

The number of fruits plant^{-1} of okra as varied significantly by different application of B. Among the different application of B the maximum fruits number plant^{-1} (27.2) was observed in B_2 treatment which was statistically different (24.7) from B_1 treatment. Rab et al. (2012) reported that Calcium chloride (0.3% and 0.6%) and borax (0.2% and 0.4%) solutions were applied as foliar sprays either alone or in combination number of fruits per plant was increased. The lowest fruit number plant^{-1}(24.40) was recorded in the B_0 (control) treatment. Mahesh et al. (2004) concluded that Boron facilitates the reduction of male sterility and increase normal fruit.

Table 4.4.2 Effects of B

Treatment	Number of fruits $plant^{-1}$
B0	24.4 a
B1	24.7 a
B2	27.2 b
SE (±)	0.46

B_0= Boron Control; B_1= 2 kg B ha^{-1} as soil application; B_2= 2 kg B ha^{-1} as foliar application; SE= Standard Error

4.4.3 Interaction effects of Zn and B

Combined effect of Zn and B fertilizers on number of fruits $plant^{-1}$ showed a statistically significant variation (Mehraj et al., 2015) The highest fruit number $plant^{-1}$ (30.0) was recorded in the treatment combination of Zn_2B_2 (3kg Zn ha^{-1} with 2 kg B ha^{-1} as foliar treatment) which was statistically similar with Zn_2B_1 (3 kg Zn ha^{-1} as foliar treatment with 2 kg B ha^{-1} as soil application) (26.5) treatment combinations. On the other hand, the lowest fruit number (20.1) was found in Zn_0B_0 treatment (control) (table 4.4.3). It might be occurred due to combined effect of Zn and B helps in fruit setting on plant and develop healthy fruit. Rahman et al. (2020) reported that the combined foliar applications of zinc and boron fertilizers were detected superior to their single application.

Table 4.4.3 Interaction effects of Zn and B

Treatment	Number of fruits $plant^{-1}$
Zn_0B_0	20.1 e
Zn_0B_1	23.7 cd
Zn_0B_2	26.9 abc
Zn_1B_0	29.5 ab
Zn_2B_1	26.5 bcd
Zn_1B_2	24.8 cd
Zn_2B_0	23.6 de
Zn_1B_1	24.0 cd
Zn_2B_2	30.0 a
SE (±)	0.81

Zn_0B_0= Zinc & Boron control; Zn_0B_1= No Zinc with 2 kg B ha^{-1} as soil application; Zn_0B_2= No Zinc with 2 kg B ha^{-1}as foliar application of Boron; Zn_1B_0= 2 kg Zn ha^{-1} as soil application with no Boron; Zn_2B_1=3 kg Zn ha^{-1}as foliar application with 2 kg

B ha^{-1} as soil application; Zn_1B_2= 3 kg Zn ha^{-1} as soil application with 2 kg B ha^{-}1 as foliar application; Zn_2B_0= 3 kg Zn ha^{-1} as foliar application with no Boron; Zn_1B_1= 3 kg Zn ha^{-1} & 2 kg B ha^{-1} as soil application; Zn_2B_2=3 kg Zn ha^{-1} & 2 kg B ha^{-1} as foliar application; SE= Standard Error

4.5 Effects of Zn & B on the yield of okra

4.5.1 Effects of Zn

Application of Zn fertilizers at different doses showed significant variation on the yield of okra. Among the different Zn fertilizer application, Zn_2 (3 kg Zn ha^{-1} as foliar treatmet) showed the highest yield (13.95 t ha^{-1}). The lowest yield (7.73 t ha^{-1}) was recorded in the Zn_0 (control) treatment where no Zn was applied (Table 4.5.1 & Fig 4.1). Rahman. et al. , 2017 investigated that the foliar application of 0.2 % Zn individually produced maximum growth and yield of okra.

Table 4.5.1 Effect of Zn

Treatment	Yield (t ha^{-1})
Zn_0	7.73 c
Zn_1	9.19 b
Zn_2	13.95 a
SE (±)	0.19

Zn_0= Zinc Control; Zn_1= 3 kg Zn ha^{-1} as soil application; Zn_2= 3 kg Zn ha^{-1} as foliar application; SE= Standard Error

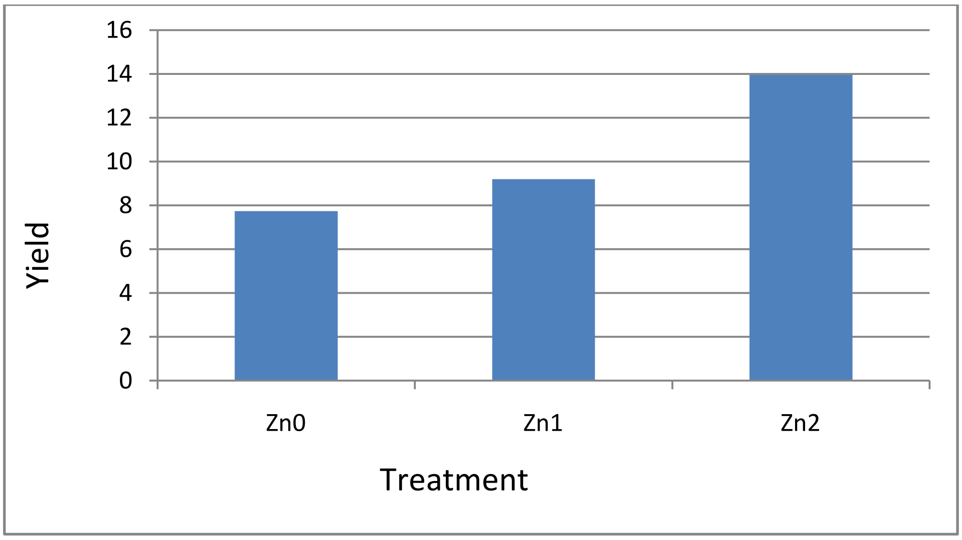


Fig 4.1 Effects of Zn on the yield of okra

Zn_0= Zinc Control (7.73 t ha^{-1}); Zn_1= 3 kg Zn ha^{-1} as soil application 9.19 t ha^{-1}) ; Zn_2= 3 kg Zn ha^{-1} as foliar application (13.95 t ha^{-1})

4.5.2 Effect of B on the yield (t ha^{-1}) of okra

The yield affected by different application of B showed significant variance. Among the different application of B the highest yield (11.82 t ha^{-1}) was observed in B_2 (2 kg ha^{-1} of boron as foliat application) treatment (Rahman et al. , 2017) and the lowest yield (9.39 t ha^{-1}) was observed B_0 (no application) treatment (table 4.5.2 & fig 4.2).

Table 4.5.2 Effects of B

Treatment	**Yield (t ha^{-1})**
B_0	9.39 b
B_1	9.61 b
B_2	11.82 a
SE (±)	0.19

B_0= Boron Control; B_1= 2 kg B ha^{-1} as soil application; B_2= 3 kg B ha^{-1} as foliar application; SE= Standard Error

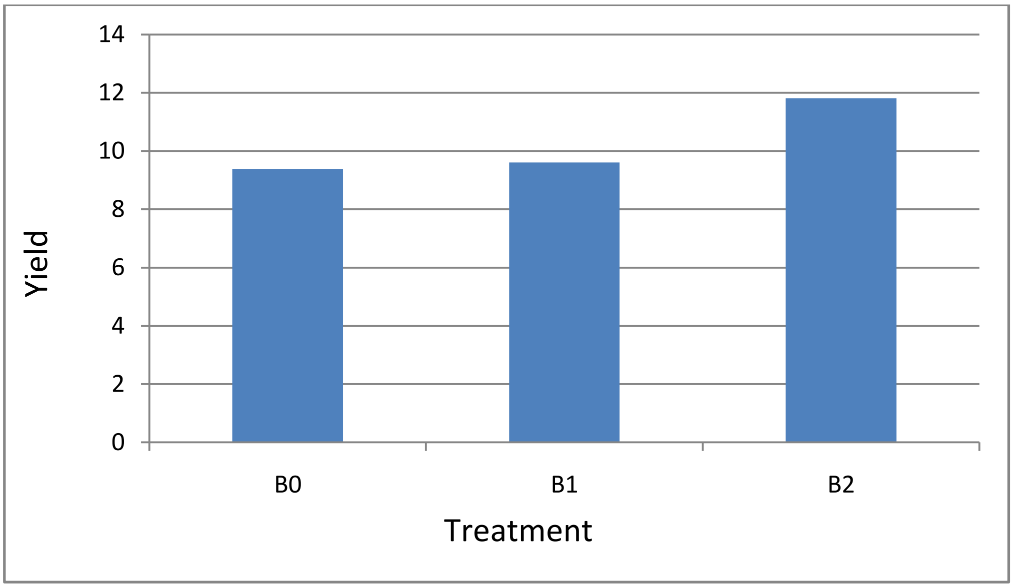


Fig 4.2 Effect of B on the yield (t ha^{-1}) of okra

B_0= Boron Control (9.39 t ha^{-1}); B_1= 2 kg B ha^{-1} as soil application (9.61 t ha^{-1}); B_2= 3 kg B ha^{-1} as foliar application (11.82 t ha^{-1})

4.5.3 Interaction effects of Zn and B

Combined effect of Zn and B fertilizer application yield showed a statistically significant variation compare with control. The highest yield (17.51 t ha^{-1}) was recorded in the treatment combination of Zn_2B_2 (3 kg ha^{-1} of zinc with 2 kg ha^{-1} of boron as foliar application) which was statistically similar (8.35 t ha^{-1}) with Zn_2B_1 (3 kg ha^{-1} of zinc as foliar treatment with 2 kg ha^{-1} of boron as soil treatment) treatment combination. The lowest yield (5.92 t ha^{-1}) was found in Zn_0B_0 treatment (table 4.5.3 & fig 4.3). Rahman H. Md. et al (2020) reported that the foliar application of boron and zinc either single or in combination had significant effect on yield, yield attributes and quality of okra.

Table 4.5.3 Interaction effects of Zn and B

Treatment	**Yield (t ha^{-1})**
Zn_0B_0	5.92 e
Zn_0B_1	7.10 d
Zn_0B_2	10.16 e

Zn_1B_0	11.43 c
Zn_2B_1	8.37 d
Zn_1B_2	7.79 d
Zn_2B_0	10. 83 c
Zn_1B_1	13.52 b
Zn_2B_2	17.51 a
SE (±)	0.34

Zn_0B_0= Zinc & Boron control; Zn_0B_1= No Zinc with 2 kg B ha^{-1} as soil application; Zn_0B_2= No Zinc with 2 kg B ha^{-1}as foliar application of Boron; Zn_1B_0= 2 kg Zn ha^{-1} as soil application with no Boron; Zn_2B_1=3 kg Zn ha^{-1}as foliar application with 2 kg B ha^{-1} as soil application; Zn_1B_2= 3 kg Zn ha^{-1} as soil application with 2 kg B ha^{-}1 as foliar application; Zn_2B_0= 3 kg Zn ha^{-1} as foliar application with no Boron; Zn_1B_1= 3 kg Zn ha^{-1} & 2 kg B ha^{-1} as soil application; Zn_2B_2=3 kg Zn ha^{-1} & 2 kg B ha^{-1} as foliar application; SE= Standard Error

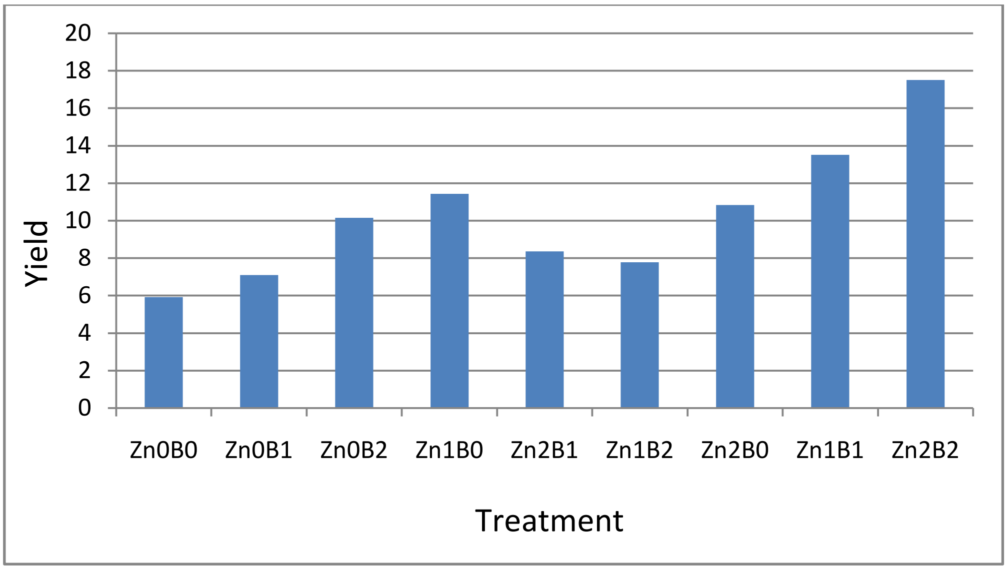


Fig 4.3 Interaction effect of Zn and B on the yield (t ha^{-1}) of okra

Zn_0B_0= Zinc & Boron control (5.92 t ha^{-1}); Zn_0B_1= No Zinc with soil application of Boron (7.10 t ha^{-1}); Zn_0B_2= No Zinc with Foliar application of Boron (10.16 t ha^{-1}); Zn_1B_0= Soil application of Zinc with no Boron (11.43 t ha^{-1}); Zn_2B_1= Foliar application of Zinc with Soil application of Boron (8.37 t ha^{-1}); Zn_1B_2= Soil application of Zinc with Foliar application of Boron (7.79 t ha^{-1}); Zn_2B_0= Foliar application of Zinc with no Boron (10.83 t ha^{-1}); Zn_1B_1= Soil application of Zinc (13.52 t ha^{-1}) & Boron; Zn_2B_2= Foliar application of Zinc & Boron (17.51 t ha^{-1}).

CHAPTER 5

SUMMARY AND CONCLUSION

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at Sher-e-Bangla Agricultural University (SAU) Farm, Sher-e-Bangla Nagar, Dhaka, (AEZ 28) during the period from March 2021 to July 2021 to study the effect of Zn and B fertilizers and their application methods on the growth and yield of okra (*Abelmoschus esculentus).*

The variety BARI dheros 2 was used in the experiment. The experiment consisted of two factors: Factor A: Zn application as; (i) Zn_0: 0 kg zn ha^{-1} (ii) Zn_1: 3 kg Zn ha^{-1} as soil application (iii) Zn_2: 3kg Zn ha^{-1} as foliar application. Factor B: B application as;(i) B_0: 0 kg B ha^{-1} (ii) B_1: 2 kg B ha^{-1} as soil application (iii) B_2: 2 kg B ha^{-1} as foliar application. The two factor experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications.

Recommended doses of cow dung, nitrogen, phosphorus, potassium and sulphur (10000 kg, 100 kg N from Urea, 30 kg P ha^{-1} from TSP, 70 kg K ha^{-1} from MoP and 15 kg S ha^{-1} from gypsum, respectively) were applied. Zn_1 (3 kg Zn ha^{-1}) and B_1 (2 kg B ha^{-1}) were mixed with soil as a source of zinc Sulphate (monohydrate) and boric acid. Similar rate of Zn_2 (3 kg Zn ha^{-1}) and B_2(2 B kg ha^{-1}) were applied through foliar application as a source of zinc Sulphate (monohydrate) and boric Acid.

The seeds were treated with 3g of Captain per kg seed before sowing for having good crop. Seeds should be soaked in clean water for 24 hours before sowing. Seeds were sown on 24 march 2021 in the seedbed.

Five (5) plants were randomly selected for data collection from the middle rows of each unit plot for avoiding border effect, except yield of fruits, which was recorded plot wise. Data were collected in respect of the following parameters plant height (cm), number of leaves plant^{-1}, number of branches plant^{-1}, number of fruits plant^{-1}, yield (t ha^{-1}).

The data obtained from the experiment were analyzed statistically to find out the significance of the difference among the treatments. The significance of the differences among pairs of treatments was estimated by DMRT at *5%* and 1% level of probability by using MStat-C.

Data on growth, yield contributing characters and yields were recorded and statistically significant variation was observed for different treatments. Results showed that in terms of Zn effect, the highest plant height (167 cm), number of leaves plant^{-1}(44.8) and number of branches plant^{-1} (3.78) were recorded from Zn_2 (3 kg Zn ha^{-1} of zinc as foliar application) treatment. Again the highest number of fruits (26.9), yield (14 t ha^{-1}) were observed from Zn_2. Results showed that in terms of B effect, the highest plant height (156 cm), number of leaves plant^{-1}(47) and number of branches plant^{-1} (3.83), number of fruits plant^{-1}(27.2) and yield (11.8 t ha^{-1}) were recorded from B_2 (2 kg B ha^{-1} of boron as foliar application) treatment. Combined effect of Zn and B fertilizer application yield showed a statistically significant variation compare with control. The highest plant height (180 cm), number of leaves plant^{-1}(50.0) and number of branch plant^{-1} (4.40), number of fruit plant^{-1} (30.0) and yield (17.5 t ha^{-1}) was recorded in the treatment combination of Zn_2B_2 (3kg Zn ha^{-1} with 2 kg B ha^{-1} as foliar application).

The result of present study generated some information which may help on efficient okra fruit (BARI dheros 2) production. Among the different level application methods of zinc and boron, foliar appication methods showed the highest plant height, number of okra $plant^{-1}$, number of branch, number of leaves and yield where 3 kg Zn ha^{-1} and 2 kg B ha^{-1} were applied. Yield (t ha^{-1}) was significantly affected by the fertilizer application methods. Foliar application of zinc and boron gave the highest yield over soil application. Considering all the parameters evaluated, foliar application of Zn and B is recommended for obtaining the best result.

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APPENDICES

APPENDICES

Appendix I: Combined effects of Zn and B on plant height, number of leaves plant^{-1}, number of branches plant^{-1}, number of fruits plant^{-1} & yield of okra

Treatment combination	Plant height (cm)	Number of leaves plant^{-1}	Number of branches plant^{-1}	Number of fruits plant^{-1}	Yield (t ha^{-1})
Zn_0B_0	132.77 e	37.40 f	3.13 b	20.10 e	5.92 e
Zn_0B_1	150.73 c	46.30 bc	3.53 ab	23.66 cd	7.10 d
Zn_0B_2	142.73 d	47.20 ab	3.76 ab	26.86 abc	10.16 e
Zn_1B_0	168.53 b	45.96 ab	3.73 ab	29.53 ab	11.43 c
Zn_2B_1	152.03 c	40.86 ef	3.53 ab	26.50 bcd	8.37 d
Zn_1B_2	140.33 d	44.73 bcd	3.33 b	24.76 cd	7.79 d
Zn_2B_0	156.80 c	42.86 cde	3.53 ab	23.56 de	10.83 c
Zn_1B_1	165.26 b	41. 40 de	3.43 b	24.03 cd	13.52 b
Zn_2B_2	179. 70 a	50.00 a	4.40 a	30.00 a	17.51 a
SE (±)	1.75	1.75	0.21	0.81	0.34
Cv (%)	1.97	3.58	10.48	5.53	5.79

*SE= Standard Error *CV= Coefficient of variation

Zn_0B_0= Zinc & Boron control; Zn_0B_1= No Zinc with 2 kg B ha^{-1} as soil application; Zn_0B_2= No Zinc with 2 kg B ha^{-1}as foliar application of Boron; Zn_1B_0= 2 kg Zn ha^{-1} as soil application with no Boron; Zn_2B_1=3 kg Zn ha^{-1}as foliar application with 2 kg B ha^{-1} as soil application; Zn_1B_2= 3 kg Zn ha^{-1} as soil application with 2 kg B ha-1 as foliar application; Zn_2B_0= 3 kg Zn ha^{-1} as foliar application with no Boron; Zn_1B_1= 3 kg Zn ha^{-1} & 2 kg B ha^{-1} as soil application; Zn_2B_2=3 kg Zn ha^{-1} & 2 kg B ha^{-1} as foliar application.

Appendix II: Pictorial view of experimental plot

Experimental plot of okra

Seedling emergence from okra seed

Single okra plant

Experimental site of okra plant

Reproductive stage of okra plant

Harvested okra fruit

Appendix III: Pictorial view of laboratory work