EFFECT OF BORON AND ZINC ON GROWTH, YIELD AND NUTRIENT CONTENT OF BARI TOMATO-2

BY

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A Thesis

Submitted to the Department of Agriculture chemistry
Sher-e-Bangla Agricultural University, Dhaka
in partial fulfilment of the requirements for the degree of

MASTER OF SCIENCE (MS)

IN

AGRICULTURE CHEMISTRY

SEMESTER: JANUARY-JUNE, 2015

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CERTIFICATE

This is to certify that the thesis entitled, **"Effect of boron and zinc on growth, yield and nutrient content of BARI Tomato-2"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in the partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE (M.S.) IN AGRICULTURUL CHEMISTRY,** embodies the result of a piece of *bona fide* research work carried out by **Md. Mainuddin Shad,** Registration No. **08-03056** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that such help or source of information, as has been availed during the course of this investigation has been duly acknowledged and style of this thesis have been approved and recommended for submission.

Dated- June, 2015
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ACKNOWLEDGEMENT

All praises are due to Almighty Allah, the Great, Gracious and Merciful, Whose blessings enabled the author to complete this research work successfully.

*The author like to express his deepest sense of gratitude sincere appreciation to his respected Supervisor **Prof. Dr. Abdur Razzaque**, Department of Agriculture Chemistry, Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh, for his scholastic guidance, support, encouragement and invaluable suggestions and constructive criticism throughout the study period and successfully completing the research work and in the preparation of the manuscript.*

*The author also expresses his gratefulness and best regards to respected Co-Supervisor, **Prof. Dr. Rokeya Begum**, Department of Agriculture Chemistry, Sher-e Bangla Agricultural University, Dhaka for her scholastic guidance, helpful comments and constant inspiration, inestimable help, valuable suggestions throughout the research work and preparation of the thesis.*

The author also expresses heartfelt thanks to all the teachers of the Department of Agricultural Chemistry, SAU. The author expresses his sincere appreciation to her brother, sisters, relatives, well-wishers and friends for their inspiration, help and encouragement throughout the study period.

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ABSTRACT

An experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University, Dhaka during the period from November 2013 to March 2014 to find out the effect of boron and zinc on the growth, yield and nutrient content of BARI Tomato-2. The experiment consisted of four levels of boron i.e 0, 1.0, 1.5 and 2.0 kg B ha^{-1}; three different levels of zinc namely 0, 2.5 and 5.0 kg Zn ha^{-1}. The experiment was laid out in a RCBD with three replications. Both boron and zinc had significant influence on growth and yield contributing characters of tomato. At 75 DAT, the highest plant height (117.30cm), maximum number of leaves per plant (75.30) and highest yield (67.36 ton ha^{-1}) were recorded from boron application at 2.0 kg ha^{-1}. At 75 DAT, the highest plant height (113.60 cm), maximum leaves per plant (67.00) and yield (65.85 ton ha^{-1}) were recorded from zinc application at 2.5 kg ha^{-1}. The combined effect of 2.0 kg B ha^{-1} and 2.5 kg Zn ha^{-1} performed the highest yield (86.25 ton ha^{-1}) and lowest from B_0Zn_0 i.e.; control treatment. So, 2.0 kg B ha^{-1} and 2.5 kg Zn ha^{-1} may be used for higher yield of tomato.

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ABBREVIATIONS AND ACRONYMS

%	:	Percentage
@	:	At the Rate of
Abstr.	:	Abstract
AEZ	:	Agro-ecological Zone
Agric.	:	Agriculture
BARC	:	Bangladesh Agricultural Research Council
BARI	:	Bangladesh Agricultural Research Institute
BAU	:	Bangladesh Agricultural University
BBS	:	Bangladesh Bureau of Statistics
BCR	:	Benefit Cost Ration
cm.	:	Centimeter
cv.	:	Cultivar
DAS	:	Day After Sowing
et al.	:	et alii (and others)
FAO	:	Food and Agriculture Organization Of the United Nations
Fig.	:	Figure
FW	:	Fresh weight
FYM	:	Farm Yard Manure
G	:	Gram
Hort.	:	Horticulture
i.e.	:	That is
J.	:	Journal

K	:	Potassium
Kg	:	Kilogram
LSD	:	Least Significant Difference
M	:	Meter
MP	:	Murate of Potash
N	:	Nitrogen
NS	:	Non-significant
^{O}C	:	Degree Celsius
P	:	Phosphorus
RCBD	:	Randomized Complete Block Design
Sci.	:	Science
Soc.	:	Society
T	:	Tonne
ton/ha	:	Ton per hectare
Tk.	:	Taka
TSP	:	Triple Super Phosphate
UK	:	United Kingdom
UNDP	:	United Nations Development Program
Viz.	:	Namely

CHAPTER I

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.), a member of the family Solanaceae is one of the most popular and important vegetable crop grown in Bangladesh during rabi season. It is cultivated in almost all home gardens and also in the field due to its adaptability to wide range of soil and climate (Ahmed, 1976). It ranks next to potato and sweet potato in the world vegetable production and tops the list of canned vegetable (Choudhury, 1979). It has been originated in tropical America (Salunkhee*t al*., 1987) which includes Peru, Ecuador, Bolivia areas of Andes (Kalloo, 1985). Tomato is popular as salad in the new state and is used to make soup, juice, ketchup, pickle, sauce, conserved puree, paste, powder and other products (Ahmed, 1976). Tomato is highly nutritious as it contains 94.1% water, 23 calories energy, 1.90 g protein, 1 g calcium, 7 mg magnesium, 1000 IU vitamin A, 31 mg vitamin C, 0.09 mg thiamin, 0.03 mg riboflavin, 0.8 mg niacin per 100 g edible portion (Rashid, 1983). Therefore, it can be meet up some degree of vitamin A and vitamin C requirement and can contribute to solve malnutrition problem.

In Bangladesh, the statistics shows that tomato was grown in 19643 hectares (ha) of land and the total production was approximately 143,058 metric tons during the year 2007-2008 (BBS, 2008), which is very low in comparison to other countries namely, India (15.67 t/ha), Japan (52.82 t/ha) and USA (63.66 t/ha) (FAO, 1995). The yield of tomato in our country is not satisfactory in comparison to its requirement (Aditya *et al.,* 1999). The low yield of tomato in Bangladesh, however, is not an indication of low yielding ability of this crop, but of the fact that low yielding variety, poor crop management practices and lack of improved technologies.

Micronutrients play an important role in tomato production. It is well known that micronutrient deficiencies are one of the major limiting factors for crops production in most tropical woody deep peat soils (Tadano, 1985). Among the micro elements, boron and zinc play the important role directly and indirectly in improving the yield and quality of tomato in addition to checking various diseases and physiological disorders. Zinc mainly function as the metal component of a series of enzymes. The most important enzymes activate by this elements are carbonic anhydrase and a number of dehydrogenases. Zinc deficiency is through to restrict RNA synthesis which in turn inhibits protein synthesis (Katyal and Randhawa, 1983). Zinc is also involved in auxin production. Shoots and buds of zinc deficient plants contain very low auxin which causes dwarfism and growth reduction. The net results are stunted plants and prolonged duration of growth. Like boron, zinc deficiency is found to occur in high pH soils (Keren and Albright, 1985). Zinc also plays an important role in chlorophyll formation, cell division, meristematic activity of tissue expansion of cell and formation of cell wall.

Zinc application helps in increasing the uptake of N and P. Application of zinc sulphate, copper sulphate and ammonium molybdate increased chlorophyll synthesis and fruit quality to tomato (Kalloo, 1985). 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 phosphorus uptake by roots and the transport of phosphorus from roots to leaves (Noion and Islam, 1982). Again, deficiencies of Zinc and boron are also reported on some soils and crops (Islam *et al.*, 1997).

Crops differ in their sensitivity to boron deficiency. Tomatoes in general have a high boron requirement (Mengel and Kirkby, 1987). Fruit and seed set failure is a major reason for lower yield of rabi crops and this problem can be attributed to boron deficiency, as reported in tomato (Rahman *et* *al.*, 1993; Islam *et al.*, 1997). Boron deficiency may cause sterility i.e.; less fruits per plant attributing lower yield (Islam and Anwar, 1994). Deficiency of B causes restriction of water absorption and carbohydrate metabolism which ultimate affects fruit and seed formation and thus reduces yield. In fertilizer schedule, an inclusion of B often decides the success and failure of the crops (Dwivedi *et al.*, 1990). It is reported that the ranges between deficiency and toxicity of B are quite narrow and that an application of B can be extremely toxic to plants at concentrations only slightly above the optimum rate (Gupta *et al.*, 1985). This emphasizes the need for a judicial use of B fertilizer.

In Bangladesh, there is limited information on the effect of boron and zinc on growth and yield of tomato. In view of these limitations, a field experiment containing the treatments of boron and zinc was conducted with the following objectives:

1. To study the effect of zinc and boron doses on growth and yield of tomato,
2. To determine the optimum doses of zinc and boron on growth and yield of tomato and
3. To find out the contents of N, P, K, Zn and B in fruits of tomato.

CHAPTER II

REVIEW OF LITERATURE

Tomato is one of the most popular and widely grown vegetable of the world. It is a rich source of minerals and vitamins. Market price is dictated by the quality of a commodity and demand-supply. So, it is essential to know the physico-chemical properties, which determine the quality of fruits. The quality of tomato fruit is largely dependent on the macro and micro nutrient application. Available literature and finding on tomato, which are related to the present study has been cited in the following sections.

2.1 Effect of zinc (Zn) and boron (B) on tomato

Smit and Combrink (2004) observed insufficient fruit set of tomatoes owing to poor pollination in low cost greenhouse is a problem in South Africa, as bumble bee pollinators may not be imported. Since sub-optimum boron (B) levels may be also contributed to fruit set problems, this aspect was investigated. Four nutrients solution with only B at different levels (0.02, 0.16, 0.32 and 0.64 mg L^{-1}) were used. Leaf analyses indicated that the uptake of Ca, Mg. Na, Zn, B increased with higher B levels. At the low B level, leaves were brittle and appeared pale-green and very high flower abscission percentages were found. At 0.16 mg kg^{-1} B level, fruit set, fruit development, color, total soluble solids, firmness and shelf life seemed to be close to optimum. The highest B-level had no detrimental effect on any of the yield and quality related parameters.

Ben and Shani (2003) stated that Boron is essential to growth at low concentrations and limits growth and yield when in excess. The influences of B and water supply on tomatoes (*Lycopersicon esculentum* Mill.) were investigated in lysimeters. Boron levels in irrigation water were 0.02, 0.37 and 0.74 mol m^{-3}. Conditions of excess boron and water deficits were found to decrease yield and transpiration of tomatoes. Both irrigation water quantity and boron concentration influenced water use of the plants in the same manner as they influenced yield.

Chude *et al.* (2001) reported that plant response to soil and applied boron varies widely among species and among genotypes within a species. This assertion was verified by comparing the differential responses of Roma VF and Dandino tomato (*Lycopersicon esculentum*) cultivars to a range of boron levels in field trails Kadawa and Samaru in Sudan and Northern Guinea Savanna, respectively, in Nigeria. Boron levels were 0, 0.5, 1.0, 1.50, 2.0 and 2.5 kg ha^{-1} replicated three times in a RCB design. Treatment effects were evaluated on fruit yield and nutritional qualities of the two tomato cultivars at harvest. There was a highly significant ($P = 0.01$) interaction between B rates and cultivars, with Dandino producing higher yields than Roma VF in both years and locations. Total soluble solids, titratable acidity and reducing sugar contents of two cultivars differed significantly ($P = 0.05$). This cultivar seems to be more B efficient than Roma VF even at low external B level.

Yadav *et al.* (2001a) conducted an experiment during 1990 and 1991 in Hisar, Haryana, India to evaluate the effect of different concentrations of zinc and boron on the vegetables growth, flowering and fruiting of tomato. The treatments comprised five levels of zinc (0, 2.5, 5.0, 7.50 and 10.0 ppm) and four levels of boron (0, 0.50, 0.75 and 1.00 ppm) as soil application, as well as 0.5 % zinc and 0.3 % boron as foliar application. The highest values for secondary branches, leaf area, total chlorophyll content, fresh weight, fruit length, fruit breadth and fruit number were obtained with the application of 7.5 ppm zinc and 1.0 ppm boron.

A greenhouse experiment involving 4 rates of B (0, 5, 10 and 20 mg B kg^{-1}) and 3 rates of Zn (0, 10 and 20 mg Zn kg^{-1}) was conducted by Gunes *et al.* (2000) in tomato plants. The B toxicity symptoms occurred at B rate of 10 and 20 mg kg^{-1}. These symptoms were less in plants grown with applied Zn. Fresh and dry weights of the plants clearly decreased with application B. The Zn treatments partially depressed the inhibitory effect of B on growth. Increased rates of B increased the concentration of B in plant tissues, higher concentrations were observed in the absence of applied Zn. Zn and B treatments increased the concentration of Zn in plants.

A green house experiment was conducted by Singaram and Prabha (1999) on tomato hybrid Naveen (115 days duration) and non-hybrid cv. Co.3 (105 days duration) to evaluate the interaction of naturally occurring Ca with applied B. The Ca concentration is different parts of the tomato plant varied significantly among treatments. Foliar spray (0.3 %) accounted for higher content of B in the shoot. Application of boronated superphosphate and 30 kg borax/ha resulted in higher B content in shoots similar to that of foliar application. Soil application of borax at 30 kg/ha accounted for higher accumulation of B. The equivalent Ca: B ratio in the shoot was significantly and negatively correlated with the fruit yield.

Gunes *et al.* (1999) carried out a greenhouse experiment involving 4 levels of boron (0, 5, 10 and 20 mg/kg) and 3 levels of zinc (0, 10 and 20 mg/kg) on tomato cv. Lale. Boron toxicity symptoms occurred at 10-20 mg B/kg. These symptoms were partially alleviated in plants grown with applied Zn. Fresh and dry plant weight were strongly depressed by applied B. However, Zn treatments reduced the inhibitory effect of B on growth. Increased levels of B increased the concentrations of B in plant tissues to a greater extent in the absence of applied Zn. Both Zn and B treatments increased Zn concentration of the plants.

Plese *et al.* (1998) observed in a greenhouse trails in tomato cv. Viva on a sandy red-yellow podzol and supplied with 0, 1.0 and 2.0 g B/pit (containing 2 plants) as boric acid, with or without foliar applications of 0.6 % $CaCl_2$ at intervals of 7 days or 14 days. The application of 1.0 g B/pit with foliar application of 0.6 % $CaCl_2$ at 14 days intervals or application of 0.6 % $CaCl_2$ at 7 days intervals without B resulted in the lowest percentage of fruits affected by blossom-end rot (3.6 and 4.8 %, respectively).

Prasad *et al.* (1997) carried out a field experiment in rabi season 1991-1994 on an acidic red loma soil at Ranchi, India on tomato cv. Pusa Ruby plants with soil boron application (0, 4.45, 9.09, 13.63 and 18.18 kg borax/ha) at final field preparation or a foliar boron application (0, 1.0, 1.5, 2.0 and 2.5 kg borax/ha) at 25 days after transplanting. Boron application significantly increased tomato yield compared to the control treatment, with the highest yields produced on plots given a foliar application of 2.5 kg borax/ha (48.74, 152.61 and 227.67 q/ha in 1991-1992, 1992-1993 and 1993-1994, respectively). Foliar application of borax at 2.5 ka/ha also gave the highest average yield (143.06 q/ha) and the highest net additional income (Rs 7,324).

Oyewole and Aduayi (1992) conducted experiment with a local variety of tomato (Ife plum cv. 51691) in pots for 5 months in soil tested with B at concentrations of 0, 1, 2, 4, 8 and 16 ppm as H_3BO_3 and Ca at 0, 40, 80 and 160 ppm as $Ca(OH)_2$. The relationship between OM and water-soluble B was positive while that between $_{P}H$ and B was negative. Application of B at 2 ppm increased leaf number, stem diameter, number of flowers and fruit yield and reduces percent flower abortion. Boron application at rates higher than 2 ppm induced leaf chlorosis followed by necrosis of nodes and roots. Fruit yield correlated positively with soil B, stem diameter and floral number. Plant B was positively correlated with soil B. Ca when applied singly at higher levels (80 and 160 ppm) increased total chlorophyll content of the leaf. Tomato fruit yield was greatest (166 g/plant) at B: Ca treatment combination of 2 ppm B (4.48 kg/ha) and 160 ppm Ca (358.40 kg/ha).

Baevre (1990) reported from an experiment on growing the glasshouse cultivar Jet in peat with different levels of B (1.4, 2.2 and 4.6 g m^{-3}), reduced mean fruit weight and increased the proportion of fruits weighting between 5 and 30 g. Increased B supply improved fruit shape and reduced hollowness (puffiness), especially in fruits with a salable weight. The effect of B on seed development was most marked for small fruits. B rate had not significant effect on the relationship between seed weight/fruit and fruit weight.

Carpena and Carpena (1987) stated that tomatoes (cv. Marglobe) grown hydroponically with automatic control of solution composition and environment and the B supply was held constant at each of 5 levels (from 0.02 to 3.00 ppm). Data on the effects of B supply on the contents of 9 leaf macro and micro elements at 5 growth stages (from vegetative to full fruiting) are shown graphically and discussed and data on the rations between leaf B and the 9 other nutrients are tabulated for the same growth stages and discussed. Such data should assist in understanding the importance of B in the general metabolism of the plant and indicated more accurately than visual symptoms what levels of B adversely affect the fruit yield.

Efkar *et al.* (1995) carried out an experiment to study the response of tomato to the application of boron fertilizer in Pakistan using 4 levels of B (0, 1, 1.5 and 2 kg/ha). The crop also received a basal dressing of NPK fertilizers and FYM (5 t/ha). Application of 1.5 kg B/ha gave the highest fruit yield of 37.58 t/ha compared with the control yield 20.47 t/ha.

Lozek and Fecenko (1993) studied in a small plot trial on loamy brown soil in 1992-1993 potatoes were given foliar applications of 2 kg sodium humate and/or 0.5 kg Mn, 0.2 kg B or the both. Without foliar fertilizer application, fruit yield was average 83.47 t/ha. Yield increased by 4.2 % with sodium humate alone, 11.7-15.7 % with Mn and/or B and 45.5 mg/kg in the control and increased to 50.5 mg/kg with Mn alone and 47.2 mg with B alone, it decreased with the other treatments and was lowest (30.1 mg/kg) with sodium humate + boron.

Pregno and Arour (1992) conducted an experiment to find out boron deficiency and toxicity in tomato on an oxisol of the Atherton Tablelands at North Queensland, Australia. In this field trial 5 doses of boron (0, 2, 4, 8 and 12 kg B/ha) were used. It was observed that total fruit yield was highest when 2 kg B/ha was applied and it was followed by 4 kg B/ha. Plant height was not increased by low rates of boron but was reduced by 8 and 12 kg B/ha compared with no B.

Quaggio and Ramos (1986) studied the influence of micronutrient boron on the production of potato. Boron was applied at the rates of 0, 3, 6, 9 and 12 kg B/ha as boric acid. The authors found that the effect of boron was more pronounced on the yield of large sized fruit than on the small ones.

Palkovics and Gyori (1984) determined the effect of boron on the growth and yield of tomato cv. Somogy on rusty forest soil. It was observed that the application of boron contributed to yield increased and to the improvement of fruit quality. The critical level of B was 60 mg/kg of foliage and above this, B content depressed yield.

Omer *et al.* (1982) stated that the boron at any concentration had little effect on plant and fruit number, but marketable fruit yield was increased with increasing concentration of boron.

Grewal and Trehan (1981) studies the effect of trace elements on tomato and observed that some cultivars showed a marked response to Zn and B application while other showed little response.

Awasthi and Grewal (1977) worked with tomato on slightly acisic soils at Shillong, India, using soil application of 25 kg $ZnSO_4$/ha or foliar application of 0.1 % boron solution. The authors observed that both Zn and B application increased fruit yield by 100-150 kg/ha.

Yadav *et al.* (2001b) conducted a field experiment at Hisar, Haryana, India in 1999 and 2000 to study the effect of zinc (0, 5, 10, 15 and 20 kg zinc sulphate/ha) and boron (0, 1, 2, and 4 kg B/ha) on the yield and nutrient content and uptake by tomato plants cv. Pusa-120. All treatments significantly increased tomato yield. The maximum yield was obtained with 15 kg $ZnSO_4$/ha and 3kg B/ha. The highest concentration and uptake of zinc and boron were recorded for 20 kg $ZnSO_4$/ha and 4kg B/ha.

Mondal *et al.* (1992) reported that application of Ca, Mg, Mo and Zn increased the plant height, number of fruit branches and fruit per plant. The yield and size distribution of tomato were also improved due to the application of Ca, Mg, Mo and Zn.

The effects of Zn (0, 1.0, 2.5, 5.0 and 10.0 mg/kg soil as zinc sulphate) on the yield and quality of tomato (cv. Pusa Ruby) were studies in a pot experiment by Dube *et al.* (2003). The application of Zn significantly improved biomass, fruit yield and fruit quality. The highest biomass, fruit yield, total pulp weight, acidic and lycopene, ascorbic acid, total carotene and water contents were obtained with 5.0 mg Zn/kg soil. Zn at 10.0 mg/kg tended to have an adverse effect on fruit quality. The contents of P, Fe, Mn and Cu generally decreased with the increased in Zn concentration. The Zn content of levels was highest at the highest rate of Zn.

Patnaik *et al.* (2001) conducted field experiments during 1997-1998 in Hyderabad, Andhra Pradesh, India, to determine the effect of Zn and Fe on yield and quality of tomato cv. Marutham. The treatment comprised a control, soil application of 12.5 and 25 kg $ZnSO_4$/ha, soil application of 12.5 kg $ZnSO_4$/ha + foliar spray of 0.2 % $ZnSO_4$ (thrice at weekly interval), soil application of 12.5 kg$ZnSO_4$ + foliar spray of 0.5 % $ZnSO_4$ (thrice at weekly interval) and soil application of 12.5 kg $ZnSO_4$/ha Along with sprays of 0.2 % $ZnSO_4$ + 0.5 % $FeSO_4$. Among the treatments, soil application of 12.5 kg $ZnSO_4$/ha, followed by foliar sprays of 0.2 % $ZnSO_4$and 0.5 %$FeSO_4$thrice at weekly interval resulted in the highest fruit yield of 38.88 t/ha with a maximum yield response of 39 %. The Zn and Fe contents in index leaves of tomato were in the range of 18.5-27.3 mg/kg and 116-160 kg, respectively. The nutrients in index were higher in the treatment where Zn and Fe were applied either through soil or through foliar spray. A similar trend was observed in fruits when Zn and Fe were sprayed along with soil application. In general, Zn and Fe contents were less in fruits (14.1-17.6 mg/kg) compared to leaves (37.2-72.2 mg/kg). The highest uptake of Zn and Fe was recorded with 12.5 kg $ZnSo_4$ soil application along with 0.2 % $ZnSO_4$ and 0.5 % $FeSO_4$ spray.

A short term experiment was conducted by Kaya and Higgs (2001) with tomato cultivars Blizzard, Liberto and Calypso was carried out in a controlled room temperature to investigate the effectiveness of P and Fe supplemented in nutrient solution on plant growth at high zinc concentration. Application of supplement P and Fe resulted in marked increases in both dry weight and chlorophyll concentrations achieving values not significantly different to the control. Application of supplement P and Fe decreased Zn concentrations were still at toxic levels. P and Fe concentration in leaves declined to a deficient level in the high Zn treatment but was markedly increased in the roots. Application of supplementary P and Fe corrected both P and Fe deficiencies in leaves of plants grown at high Zn and reduced root P and Fe concentrations.

The effects of adding Zn (5 kg/ha), Cu (3 kg/ha) or FYM (30 t/ha) to the basic N:P:K (222:160:100 kg/ha) treatment as leaf transpiration and chlorophyll content and fruit ascorbic acid and sugar contents were studied by Annanurova *et al.* (1992). The treatment was generally beneficial and the number and mean weight of fruit were increased. Application of NPK alone increased yield/ plant 43.4 % compared with the untreated control.

Each nutrient has a positive impact on vegetative growth as well as on yield and yield attributes of tomato. Rahman *et al.* (1996) obtained the highest yield (45 t/ha) of tomato with 200 kg N, 100 kg P_2O_5, 150 kg K_2O, 20 kg Zn and 5 ton cowdung/ha.

Dry matter production uptake of NPK nutrient and the residual soil fertility are favorably influenced by NPK combined with boron and zinc (Balasubramaniam *et al.*, 2001). Application of soil test based NPK combined with B (10 kg/ha), $ZnSo_4$ (50 kg/ha) and composed coir pith (5 ton/ha) was reported to given the highest fruit yield of tomato.

Sommer and Lipman (1986) were the first to prove the essentiality of Zn as a nutrient requirement for higher plants. Plants absorb zinc in the form of Zn^{2+}. The functional role of Zn includes auxin metabolism, nitrogen metabolism, influence on the activities of enzymes, cytochrome C synthesis, stabilization of ribosomal fractions and protection of cells against oxidative stress (Tisdale *et al.*, 1997; Obata *et al.*, 1999). The normal conc. On Zn in dry matter of plant ranges from 25 to 150 mg/g. Deficiencies are usually associated with leaf concentration of less than 02 mg/g and toxicity may arise when the Zn level in leaf exceeds 400 mg/g.

Zinc concentration is higher in legume crops than in cereals, its concentrations were found to be on an average 18, 30, 39 and 55 mg/g in grain of corn, rice, dry bean and tomato (Frageria, 2007).

High grain Zn concentration is considered a desirable quality (Cakmak *et al.*, 1996; Graham *et al.*, 1992). High Zn seed concentrations are also a desirable trait to ensure seedling vigor and seed yield of the next crop when replanted on Zn deficient soil.

In micronutrient malnutrition, zinc is second to iron in terms of importance. Over the past many years, large efforts have been made to seek for breeding options to biofrotility major staple crops with Zn, Fe and Vit. A (Welch and Graham, 2004). Biofertilizer of food crops with Zn by either breeding for higher uptake efficiency or by fertilization can be an effective strategy to address widespread dietary deficiencies in human population (Graham *et al.*, 2001). Planting emerged from seed with low concentrations of Zn could be highly sensitive to biotic and abiotic stresses (Obata *et al.*, 1999). Zinc enriched seeds can perform better with respect to seed germination, seedling health growth and finally yield advantage (Cakmak *et al.*, 1996).

Yilmarz *et al.* (1997) stated that higher amounts of Zn in the grain, beyond levels required for optimum crop yield would be required to address Zn malnutrition in people and one important strategy to increase micronutrient concentration in grain could be fertilization of plants via soils and foliar application. There is an opportunity i.e.; an alternative way to develop new plant genotypes with high genetic capacity for enhanced root uptake, shoot translocation and seed loading of micronutrient (Cakmak *et al.*, 2004).

Hossain *et al.* (2008) conducted experiments over 3 years to find out an optimum rate Zn application for the maize-mungbean-rice cropping system in a calcareous soil of Bangladesh. Zinc application was made at 0, 2, 4 kg/ha for maize and at 0, 1 and 2 kg/ha for rice, with no Zn application for mungbean. Effects of Zn was evaluated in terms of yield and mineral nutrients contents (N, S, P and Zn). All the three crops responded significantly to Zn treatment. The optimum rate of Zn for the first year and 2-0-2 kg/ha for subsequent years particularly when mungbean residue was removed and such rates of mungbean residue incorporation being 4-0-1 and 2-0-1 kg/ha, respectively. For all crops, the Zn and N concentrations of grain were significantly increased with Zn application.

A study was conducted by Adilogul *et al.* (2005) to determine the effect of increasing N fertilizer doses on the Zn uptake of tomato in soils of different physical and chemical properties. Results showed that the dry matter content of the tomato plant increased with increasing of N and Zn doses. The N and Zn contents of the tomato plants increased with increasing doses of N and Zn, respectively.

CHAPTER III

MATERIALS AND METHODS

This chapter deals with the materials and methods that were used in carrying out the experiment. It includes a short description of location of the experiment, characteristics of soil, climate, materials used, land preparation, manuring and fertilizing, transplanting and gap filling, stalking, after care, harvesting and collection of data.

3.1 Location of the experiment field

The field experiment was conducted in the experimental farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka -1207 during the period from November 2013 to April 2014 to find out the effect of different doses of boron and zinc on the growth, yield and nutrient contents of tomato. The location of the experimental site was at $23^{0}74^{/}$ N latitude and $90^{0}35^{/}$ E longitude with an elevation of 8.45 meter from the sea level (Appendix V).

3.2 Climate of the experimental area

The climate of the experimental area was subtropical in nature. It is characterized by heavy rainfall, high temperature, high humidity and relatively long day during kharif season (April to September) and a scanty rainfall associated with moderately low temperature, low humidity and short day period during rabi season (October to March). Details of the meteorological data in respect of monthly maximum, minimum and average temperature, rainfall, relative humidity, average sunshine hours and soil temperature during the period of experiment is presented in Appendix I.

3.3 Soil of the experimental field

Soil of the study site was silty clay loam in texture. The area represents the Agro-Ecological Zone of Madhupur tract (AEZ-28) with pH 6.0-6.63, EC 25.28. The analytical data of the soil sample collected from the experimental area were determined in the Soil Resources and Development Institute (SRDI), Soil Testing Laboratory, Farmgate, Dhaka and have been presented in Appendix II.

3.4 Plant materials used:

The tomato variety "BARI Tomato-2" was used in the experiment. It was a high yielding, heat tolerant and indeterminate type variety. The seeds were collected from the Horticulture Research Centre, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur.

3.5 Raising of seedlings:

Tomato seedlings were raised in the seedbed situated on a relatively high land at Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka. The size of the seedbed was 3 m x 1 m. The soil was well prepared with the help of spade and made into loose friable and dried mass to obtain fine tilt. All weeds and stubbles were removed and 5 kg well rotten cow dung was applied during seedbed preparation. The seeds were sown on 01 November, 2013 and after sowing, seeds were covered with light soil to a depth of about 0.6 cm. Heptachlor 40 WP was applied @ 4 kg/ha around each seedbed as precautionary measure against ants and worm. The emergence of the seedlings took place within 5 to 6 days after sowing. Necessary shading by banana leaves was provided over the seedbed to protect the young seedlings from scorching sun or heavy rain. Weeding, mulching and irrigation were done from time to time as and when required and no chemical fertilizer was used in the seedbed.

3.6 Treatments of the experiment

The experiment consisted of two factors as follows:-

Factor A: Four different doses of boron (B) fertilizer

B_0 = 0 kg ha^{-1}
B_1 = 1.0 kg ha^{-1}
B_2 = 1.5 kg ha^{-1}
B_3 = 2.0 kg ha^{-1}

Factor B: Three different doses of zinc (Zn)

Zn_0 = 0 kg ha^{-1}
Zn_1 = 2.5 kg ha^{-1}
Zn_2 = 5.0 kg ha^{-1}

Total 12 treatment combinations were as follows:

B_0Zn_0, B_0Zn_1, B_0Zn_2, B_1Zn_0, B_1Zn_1, B_1Zn_2, B_2Zn_0, B_2Zn_1, B_2Zn_2, B_3Zn_0, B_3Zn_1 and B_3Zn_2

3.7 Design of the experiment

The experiment was laid out in a Randomized Complete Block Design (RCBD) having two factors with three replications. The treatment combinations were accommodated randomly in the unit plots.

3.8 Layout of the experiment:

An area of 31.5 m x 11.2 m was divided into three equal blocks. Each block consisted of 12 plots where 12 treatments were allotted randomly. There were 36 unit plots altogether in the experiment. The size of each plot was 2 m x 1.8 m. The distance between two blocks and two plots were 1 m and 0.5 m respectively.

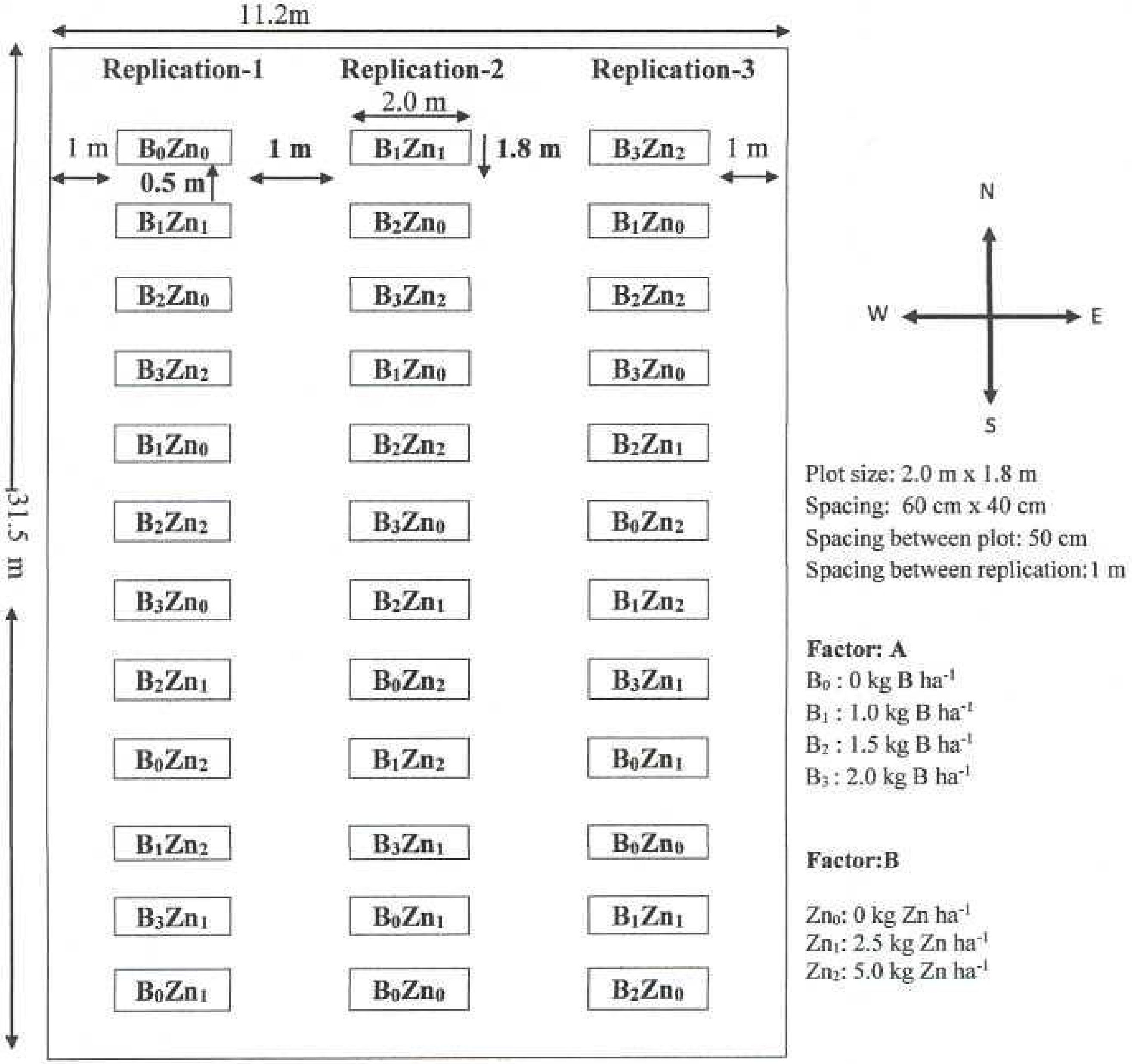


Figure 1: Layout of the experimental field

3.9 Cultivation procedure

3.9.1 Land preparation

The soil was well prepared and good tilth was ensured for tomato crop production. The land of the experimental field was ploughed with a power tiller. Later on the land was ploughed three times followed by laddering to obtain desirable tilt. The corners of the land were spaded and larger clods were broken into smaller pieces. After ploughing and laddering, all the stubbles and uprooted weeds were removed. Finally, the unit plots were prepared as 15 cm raised beds. Fifteen pits were made in each plot with in row-to-row and plant to plant spacing of 60 cm × 40 cm.

3.9.2 Manuring and Fertilizing

Manure and fertilizers such as cowdung, urea, triple super phosphate (TSP) and muriate of potash (MOP) were applied in the experimental field as per recommendation of BARI (2011).

Manure/ Fertilizer	Dose per hectare	Applied during land preparation (%)	Applied in pit a week before transplanting (%)	Applied as top-dressing in rows	
				1st installment at 30 DAT (%)	2nd installment at 60 DAT (%)
Cowdung	12 ton	100	-	-	-
Urea	450 kg	-	33.33	33.33	33.33
TSP	250 kg	100	-	-	-
MoP	260 kg	100	-	-	-

The entire amount of cowdung, TSP and MoP were applied as basal during land preparation. Ureawere used as pit placement and top dressing in two equal installments. First and second installments were done at 30 and 60 days after transplanting.The entire amount of B and Zn were applied as basal during land preparation each per treatment basis.

3.9.3 Transplanting of seedlings

Healthy and uniform 25 days old seedlings were uprooted separately from the seed bed and were transplanted in the experimental plots in the afternoon of 30 November, 2013 maintaining a spacing of 60 cm × 40 cm between the rows and plants, respectively. This allowed an accommodation of 15 plants in each plot. The seedbed was watered before uprooting the seedlings from the seedbed so as to minimize damage to the roots. The seedlings were watered after transplanting. Shading was provided using banana leaf sheath for three days to protect the seedling from the hot sun and removed after seedlings were established. Seedlings were also planted around the border area of the experimental plots for gap filling.

3.9.4 Intercultural operations

After transplanting the seedlings, various kinds of intercultural operations were accomplished for better growth and development of the plants, which are as follows.

3.9.4.1 Gap filling

When the seedlings were well established, the soil around the base of each seedling was pulverized. A few gap filling was done by healthy seedlings of the same stock where planted seedlings failed to survive.

3.9.4.2 Weeding

Weeding was done whenever it was necessary.

3.9.4.3 Stalking and pruning

When the plants were well established, stalking was given to each plant by bamboo sticks to keep them erect. Within a few days of stalking, as the plants grew up, the first pruning was done when the plant gave three branches and it was observed at 35 days after transplanting. The second pruning was done at 45 days after transplanting.

3.9.4.4Irrigation

Light watering was given with wateringcan immediately after transplanting the seedlings and then flood irrigation was done as and when necessary throughout the growing period upto harvest.

3.9. 5 Plant protection

Insect pests: Melathion 57 EC was applied @ 2 ml/Lof water against the insect pests like cut worm, leaf hopper, fruit borer and others. The insecticide application was made fortnightly after transplanting and stopped before second week of first harvest. Furadan10 G was also applied during final land preparation as soil insecticide.

Disease: During foggy weather precautionary measure against disease attack of tomato was taken by spraying Diathane M-45 fortnightly @ 2 g/Lof water, at the early vegetative stage. Ridomil gold was also applied @ 2 g/L of water against blight disease of tomato.

3.9.6 Harvesting

Fruits were harvested at 3 days interval during early ripe stage when they developed slightly red color. Harvesting was started from 15 February, 2014 and was continued up to 30 April, 2014.

3.10 Parameters assessed

Five plants were selected at random and uprooted carefully at the time of last harvesting and data of root from each plot and mean data on the following parameters were recorded:-

- Plant height
- Number of leaves per plant
- Number of branches per plant
- Number of clusters per plant
- Number of flowers per plant
- Number of fruits per plant
- Length of fruit
- Diameter of fruit
- Dry matter content of leaves
- Dry matter content of fruits
- Yield per plot
- Yield per hectare

3.8 Data collection

Five plants were selected randomly from each plot for data collection in such a way that the border effect could be avoided for the highest precision. Data on the following parameters were recorded from the sample plants during the course of experiment.

Plant height

Plant height at 30, 45, 60 and 75 DAT was measured from sample plants in centimeter from the ground level to the tip of the longest stem and the mean value for each treatment was calculated. Plant height was also recorded at 15 days interval starting from 30 days of transplanting upto 75 days to observe the growth rate of plants.

Number of leaves per plant

The number of leaves of the sample plants was counted at 30, 45, 60 and 75 DAT and the average number of leaves produced per plant was recorded. Number of leaves per plant was also recorded at 15 days interval starting from 30 days of transplanting up to 75 days to observe the growth rate of plants.

Number of branches per plant

The number of branches of the sample plants was counted and the average number of branches produced per plant was recorded.

Number of clusters per plant

The number of fruit clusters was counted from the sample plants and the average number of clusters borne per plant was recorded at the time of final harvest.

Number of flowers per plant

Total number of flowers was counted from selected plants and their average was taken as the number of flowers per plant.

Number of fruits per plant

Total number of fruits was counted from selected plants and their average was taken as the number of fruits per plant.

Length of fruit

The length of fruit was measured with slide-calipers from the neck to the bottom of 10 selected marketable fruits from each plot and their average was taken in cm as the length of fruit.

Fruit diameter

Diameter of fruit was measured at the middle portion of 10 selected marketable fruit from each plot with slide-calipers and their average was taken in cm as the diameter of fruit.

Dry matter content of leaves

Dry matter content of leaves was measured after last harvesting from randomly selected leaf samples put into envelop and placed in oven at 60°C for 72 hrs. The sample was then transferred into desiccators and allowed to cool down to the room temperature. The final weight of each sample was taken. The dry matter was calculated by the following formula:

$$\text{Dry matter content of leaves (\%)} = \frac{\text{Dry weight of the sample}}{\text{Fresh weight of the sample}} \times 100$$

Dry matter content of fruits

Immediately after harvest, a sample of 100 g fruits was taken randomly and cut into small pieces. The small pieces were sun dried for 3 days and then oven dried for 72 hours at 70 to 80°C taken into envelope until constant weight. The sample was then transferred into desiccators and allowed to cool down to the room temperature. The final weight of each sample was taken. The dry matter content of sample was calculated by the following formula:

$$\text{Dry matter content of fruit (\%)} = \frac{\text{Constant dry matter of fruits}}{\text{Fresh weight of fruits}} \times 100$$

Yield per plot

A balance was used to record the harvested fruits from 15 plants or per plot and expressed in kilogram.

Yield per hectare

From the yield per plot, yield per hectare was calculated.

3.11 Estimation of minerals

3.11.1 Equipments

For elementary composition analysis the equipment were used as electric balance, desiccators, atomic absorption spectrophotometer (AAS), spectrophotometer, porcelain crucible, beaker and flame photometer etc.

3.11.2 Determination of K, Zn, B, N and P

The sample was digested with nitric acid to release of K, Zn, B, N and P. B and Zn were determined by atomic absorption spectrophotometer, K was determined by flame photometry, N was determined by flame photometry and P by spectrophotometer.

3.11.2.1 Digestion

1. 0.500 g of dried sample was taken into each of 18 nitrogen digestion tubes. The two remaining tubes were kept blanks. 5 ml nitric acid were added to each of all 20 tubes. The tubes were left overnight mixing the contents in the tubes. Covering with the exhaust manifold, the tubes were placed in the digester and the temperature was set to 125°C, turning on the digester, the digestion was continued for 4 hours after boiling started.

2 After cooling, the digestion mixture was transferred with distilled water to a 100 ml volumetric flask water added to make the volume up to the mark.

3 Filtration was performed on a dry filter into a dry bottle, which could be closed with a screw cap. Keeping the filtrate in the closed bottle K, Zn, B and P were determined in the filtrate.

3.11.2.4 Estimation of K

10 ml diluted filtrate was transferred into a 50 ml volumetric flask using a pipette to volume with water and mixed. The content of K was measure by flame photometer.

3.11.2.5 Estimation of P

5 ml diluted filtrate was transferred into a 50 ml volumetric flask using a pipette. 30 ml water was added, mixed and then 10 ml ammonium molybdate-ascorbic acid solution was added to volume with water and mixed. After 15 minutes, the absorbance was measured on a spectrophotometer at 890 nm.

3.11.2.6 Estimation of Zn

The content of Zn elements were measured by atomic absorption spectrophotometer (AAS) directly in the undiluted filtrate.

3.11.2.7 Calculations: For K and P

$$\text{mg per kg sample} = \frac{a \times 25000}{b \times c}$$

Where, a = mg/L K or P measured on atomic absorption spectrophotometer, flame photometer or spectrophotometer

B = ml diluted filtrate transferred into the 50 ml volumetric flask for determination of K or P

c = g sample weighed into the digestion tube

If an additional dilution is made before the transfer to the 50 ml volumetric flask, the result is multiplied with the dilution factor. But the above elements were in trace. So addition of dilution was not to be performed.

For Zn

$$\text{mg per kg sample} = \frac{d \times 100}{c}$$

Zn measured on atomic absorption spectrophotometer

c = g sample weighed into the digestion tube

3.9.2.8 Estimation of N

50 ml diluted filtrate was transferred into a 50 ml volumetric flask using a pipette to volume with water and mixed.30 ml water was added, mixed and then 10 ml ammonium molybdate-ascorbic acid solution was added to volume with water and mixed. After 15 minutes, the absorbance was measured on a spectrophotometer at 890 nm.

3.12 Statistical analysis:

The data in respect of growth and yield components were statistically analyzed to find out the significance of the experimental results. The means of all the treatments were calculated and the analysis of variance for each of the characters under study was performed by F test. The difference among the treatment means was evaluated by Least Significant Difference (LSD) at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

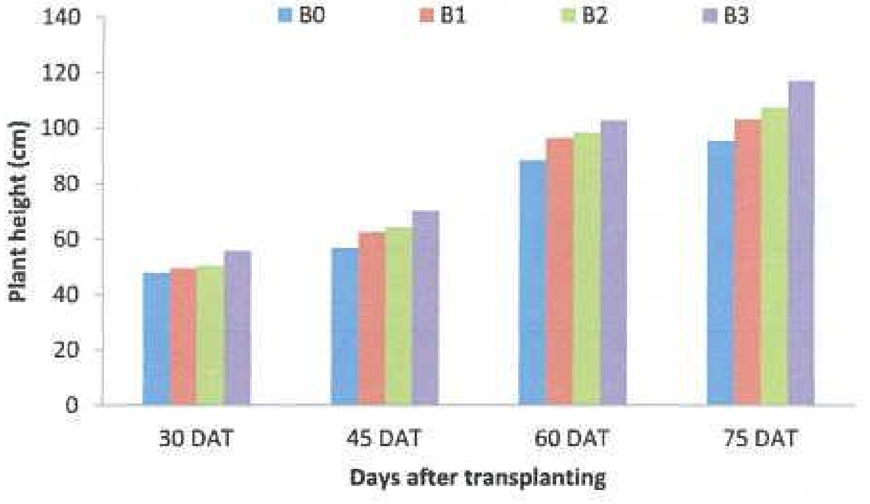
RESULTS AND DISCUSSION

The present study was conducted to find out the effect of boron and zinc on growth, yield and nutrient contents of tomato. Data on different growth and yield contributing characters were recorded to find out the optimum dose of boron and zinc for "BARI Tomato-2". The analysis of variance (ANOVA) of the data on different growth, yield and nutrient contents are given in Appendix III-IV. The results have been presented and discussed, and possible interpretations have been drawn under the following headings.

4.1 Plant height

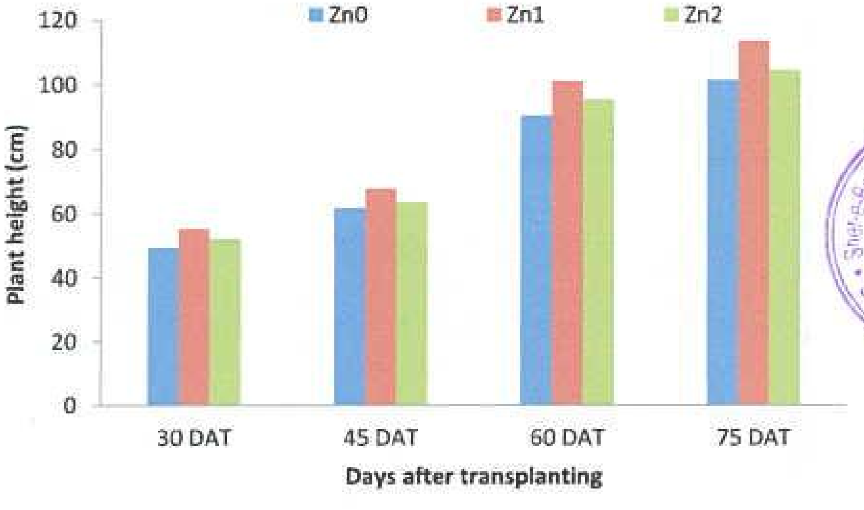
Plant height varied significantly at different days after transplanting (DAT) for different doses of boron (Appendix III and Figure 2). At 30, 45, 60 and 75 DAT, the maximum plant height (55.78, 70.44, 102.80 and 117.30 cm, respectively) was obtained from B_3 (2.0 kg B ha^{-1}), while the minimum (47.83, 56.84, 88.56 and 95.67 cm, respectively) was recorded from B_0 (0 kg B ha^{-1}). The effect of boron application on plant height was best at the concentration of 2.0 kg B ha^{-1}.

Due to different doses of zinc, plant height showed significant variation at different DAT (Appendix III and Figure 3). At 30, 45, 60 and 75 DAT, the maximum plant height (55.17, 67.75, 101.00 and 113.60 cm, respectively) was observed in Zn_1 (2.5kg Zn ha^{-1}) and the minimum (49.33, 61.77, 90.42 and 101.30 cm, respectively) was found from Zn_0 (0kg Zn ha^{-1}) which was statistically similar to Zn_2 (5.0 kg Zn ha^{-1})



B_0– 0 kg B ha^{-1}, B_1–1.0 kg B ha^{-1},B_2– 1.5 kg B ha^{-1} and B_3– 2.0 kg B ha^{-1}

Figure 2. Effect of boron application on plant height of tomato at different DAT



Zn_0–0 kg Zn ha^{-1}, Zn_1–2.5 kg Zn ha^{-1} and Zn_2–5.0 kg Zn ha^{-1}

Figure 3. Effect of zinc application on plant height of tomato at different DAT

The variation was found due to combined effect of boron and zinc application on plant height at 30, 45, 60 and 75 DAT (Appendix III and Table 1). At 30, 45, 60 and 75 DAT, the maximum plant height (61.00, 76.00, 108.70 and 125.00 cm, respectively) was recorded from the treatment combination B_3Zn_1

(2.0 kg B ha^{-1} with 2.5 kg Zn ha^{-1}), while the treatment combination of B_0Zn_0 (0 kg B ha^{-1} with 0 kg Zn ha^{-1}) gave the minimum (46.33, 54.23, 82.30 and 90.00 cm, respectively) plant height, which was statistically similar to B_1Zn_0, B_0Zn_1, B_0Zn_2, B_1Zn_2, B_2Zn_2 and B_2Zn_0 at 30 DAT, was statistically similar to B_0Zn_2 at 45 DAT and at 75 DAT.

Table1. Interaction effect of boron and zinc on plant height of tomato at different DAT

Treatments	Plant height (cm) at			
	30 DAT	45 DAT	60 DAT	75 DAT
B_0Zn_0	46.33d	54.23e	82.33g	90.00f
B_0Zn_1	50.00cd	59.33d	94.67cd	102.00e
B_0Zn_2	47.17d	56.97de	88.67f	95.00f
B_1Zn_0	47.67d	60.00cd	89.33ef	100.30e
B_1Zn_1	53.33bc	66.67b	99.00bc	113.30b
B_1Zn_2	49.27cd	59.83cd	94.00c-e	104.30de
B_2Zn_0	50.33cd	64.50bc	92.67d-f	102.70e
B_2Zn_1	56.33b	69.00b	101.70 b	114.00b
B_2Zn_2	49.33cd	64.67bc	95.33cd	108.00cd
B_3Zn_0	53.00bc	68.33b	97.33b-d	112.30bc
B_3Zn_1	61.00a	76.00a	108.70 a	125.00a
B_3Zn_2	53.33bc	67.00b	102.30 b	114.7b
$LSD_{(0.05)}$	4.21	5.01	5.12	5.04
CV (%)	4.83	4.63	3.17	2.79

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability

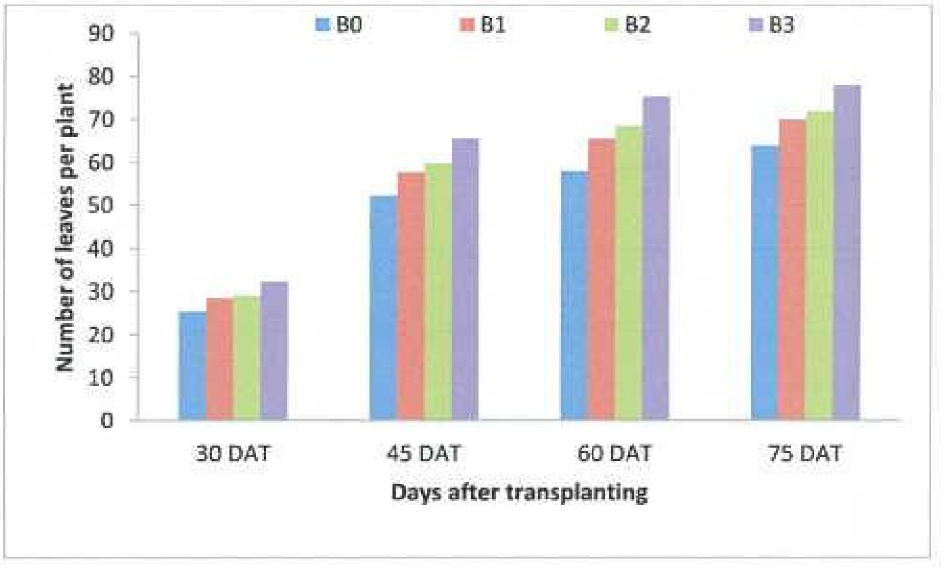
B_0– 0 kg B ha^{-1}, B_1–1.0 kg B ha^{-1}, B_2– 1.5 kg B ha^{-1} and B_3– 2.0 kg B ha^{-1}

Zn_0–0 kg Zn ha^{-1}, Zn_1–2.5 kg Zn ha^{-1} and Zn_2–5.0 kg Zn ha^{-1}.

4.2 Number of leaves per plant

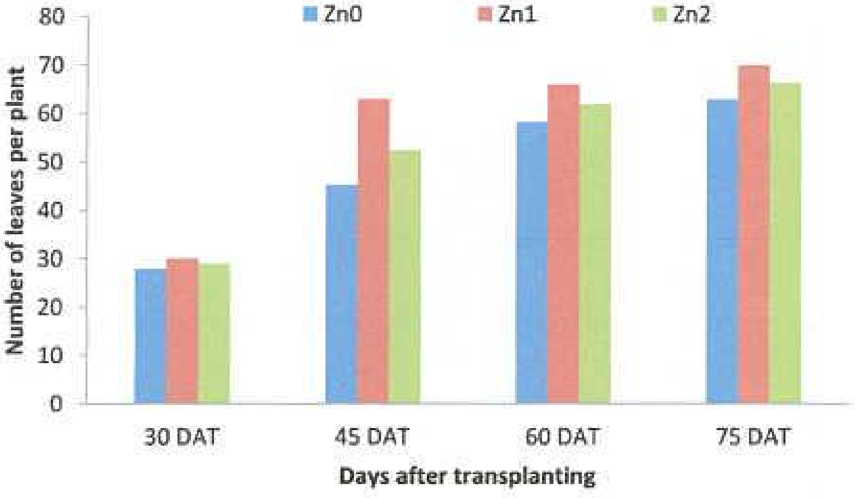
Number of leaves per plant varied significantly at different days after transplanting (DAT) for different doses of boron (Appendix III and Figure 4). At 30, 45, 60 and 75 DAT, the maximum number of leaves per plant (32.33, 65.44, 75.30 and 78.00, respectively) was obtained from B_3 (2.0 kg B ha^{-1}), while the minimum (25.33, 52.33, 58.00 and 64.00, respectively) was recorded from B_0 (0 kg B ha^{-1}).

Due to zinc application showed significant variation on number of leaves per plant at 30, 45, 60 and 75 days after transplanting (DAT) (Appendix III and Figure 5). At 30, 45, 60 and 75 DAT, the highest number of leaves per plant (30.08, 63.08, 66.07 and 70.01, respectively) was observed for Zn_1 (2.5kg Zn ha^{-1}) and the lowest number (27.87, 45.37, 58.33 and 63.00, respectively) was found for Zn_0 (0 kg Zn ha^{-1}). From the results it was found that both boron and zinc application favored plant growth which was ensured by maximum plant height.



B_0– 0 kg B ha^{-1}, B_1–1.0 kg B ha^{-1},B_2– 1.5 kg B ha^{-1}, andB_3– 2.0 kg B ha^{-1}

Figure 4. Effect of boron application on leaves per plant of tomato



Zn_0–0 kg Zn ha^{-1}, Zn_1–2.5 kg Zn ha^{-1} and Zn_2–5.0 kg Zn ha^{-1}

Figure 5. Effect of zinc application on leaves per plant of tomato

Table 2. Interaction effect of boron and zinc on leaves per plant of tomato at different days after transplanting (DAT)

Treatments	Leaves per plant at			
	30 DAT	45 DAT	60 DAT	75 DAT
B_0Zn_0	24.67g	40.67 h	45.80d	48.60e
B_0Zn_1	26.33e-g	55.00f	51.65bc	59.15c
B_0Zn_2	25.00fg	51.33g	48.62c	55.75d
B_1Zn_0	27.00d-g	57.67e	47.23c	49.11e
B_1Zn_1	29.00cd	63.67bc	59.08b	61.65c
B_1Zn_2	27.30d-f	60.67d	56.05b	58.25c
B_2Zn_0	28.50c-e	61.00d	54.32bc	57.61cd
B_2Zn_1	30.33bc	65.00b	66.17a	70.15a
B_2Zn_2	28.50c-e	62.00cd	63.14ab	66.75b
B_3Zn_0	31.67b	64.00bc	57.33b	60.61c
B_3Zn_1	34.67a	68.67a	69.18a	73.15a
B_3Zn_2	30.67bc	63.67bc	66.15a	69.75a
$LSD_{(0.05)}$	2.381	2.291	4.21	3.25
Significant level	**	**	*	**
CV (%)	4.91	2.24	6.79	6. 97

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability

B_0– 0 kg B ha^{-1}, B_1–1.0 kg B ha^{-1},B_2– 1.5 kg B ha^{-1} and B_3– 2.0 kg B ha^{-1}

Zn_0–0 kg Zn ha^{-1}, Zn_1–2.5 kg Zn ha^{-1} and Zn_2–5.0 kg Zn ha^{-1}

* - 1% level of significance, ** - 5% level of significance

The variation was found due to interaction effect of boron and zinc on number of leaves per plant at30, 45, 60 and 75 DAT (Appendix III and Table 2). At 30 and 45 DAT, the maximum number of leaves per plant (34.67 and 68.67, respectively) was obtained from the treatment combination B_3Zn_1 (2.0 kg B ha^{-1} with 2.5 kg Zn ha^{-1}),while the treatment combination B_0Zn_0 (0kg B ha^{-1} with 0 kg Zn ha^{-1}) gave the minimum (24.67 and 40.67, respectively) number of leaves per plant, which was statistically similar to B_0Zn_1, B_0Zn_2 and B_1Zn_0 at 30 DAT and which was statistically similar toB_0Zn_2 at 45 DAT. At 60 and 75 DAT, the treatment combination of B_3Zn_1 gave the maximum (69.18 and 73.15, respectively) number of leaves plant, which was statistically similar to B_2Zn_1, B_2Zn_2 and B_3Zn_2 at 60 DAT and which was statistically similar toB_2Zn_1 and B_3Zn_2 at 75 DAT whereas the minimum number of leaves per plant (45.80 and 48.60, respectively) was recorded from B_0Zn_0 which was statistically similar toB_1Zn_0 at 75 DAT. From the revealed it was found that both boron and zinc application favored plant growth which was ensured by maximum number of leaves per plant.

4.3 Number of branches per plant

Number branches per plant showed significant variation due to application of different levels of boron application (Appendix IV and Table 3). The maximum number of branches per plant (12.22) was obtained from B_3 (2.0 kg B ha^{-1}), while the minimum (8.00) was recorded for B_0 (0 kg B ha^{-1}). The effect of boron application on number of branches per plant was most effective at the level of 2.0 kg B ha^{-1} which was followed by 1.5, 1.0 and 0 kg B ha^{-1}.

Different levels of zinc application showed significant variation on number of branches per plant (Appendix IV and Table 4). The highest number of branches per plant (11.00) was found from Zn_1, which was followed by Zn_2 (10.42) and the lowest number (8.96) was found for Zn_0.

The variation was found due to combined effect of boron and zinc application on number of branches per plant (Appendix IV and Table 5). The maximum number of branches per plant (14.00) was recorded from the treatment combination of B_3Zn_1, while the treatment combination of B_0Zn_0 gave the lowest (7.33) number of branches per plant which was statistically similar to B_0Zn_1 andB_0Zn_2. From the results it was found that both boron and zinc application favored the plant growth which was ensured by highest number of branches per plant.

4.4 Number of cluster per plant

Number of fruit clusters per plant showed significant variation due to application of boron (Appendix IV and Table 3). The maximum number of fruit clusters per plant (9.74) was obtained from B_3whereas, the minimum (8.27) was recorded from B_0which was statistically similar to B_1 (8.89), B_2 (8.99). The effect of boron application on fruit clusters per plant was most effective at the concentration of 2.0 kg B ha^{-1}.

Different levels of zinc application showed significant variation on fruit clusters per plant (Appendix IV and Table 4). The highest number of clusters per plant (10.61) was observed in $Zn_1$and the lowest (7.49) was found for Zn_0.

The variation was found due to combined effect of boron and zinc application on clusters per plant (Appendix IV and Table 5). The maximum clusters per plant (11.64) was recorded from the treatment combination of B_3Zn_1,which was statistically similar to B_3Zn_2whereas, the treatment combination of B_0Zn_0 gave the lowest (6.34) number of clusters per plant. From the results it was found that both boron (2.0 kg B ha^{-1}) and zinc (2.5 kg Zn ha^{-1}) application favored the highest number of clusters per plant.

Table 3. Effect of boron application on different flower and fruit characteristics of tomato

Treatments	Number of branches per plant	Number of clusters per plant	Number of flowers per plant	Number of fruits per plant	Fruit length (cm)
B_0	8.00d	8.27 b	108.20d	26.83b	5.06d
B_1	9.39c	8.89 b	115.00c	32.87 ab	5.30c
B_2	10.89b	8.99 b	121.20b	33.04 ab	5.54b
B_3	12.22a	9.74 a	133.40a	42.07 a	6.18a
LSD $_{(0.05)}$	0.67	0.59	5.44	10.61	0.18
CV (%)	6.78	6.26	4.708	9.26	3.35

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability

B_0– 0 kg B ha^{-1}, B_1–1.0 kg B ha^{-1},B_2– 1.5 kg B ha^{-1} and B_3– 2.0 kg B ha^{-1}

Table 4. Effect of zinc application on different flower and fruit characteristics of tomato

Treatments	Number of branches per plant	Number of clusters per plant	Number of flowers per plant	Number of fruits per plant	Fruit length (cm)
Zn_0	8.96c	7.49 c	110.30c	31.63	5.31c
Zn_1	11.00a	10.61 a	129.80a	36.65	5.78a
Zn_2	10.42b	9.25 b	118.40b	32.83	5.48b
LSD $_{(0.05)}$	0.58	0.59	4.65	NS	0.16
CV (%)	6.78	6.26	4.708	9.26	3.35

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability

Zn_0–0 kg Zn ha^{-1}, Zn_1–2.5 kg Zn ha^{-1} and Zn_2–5.0 kg Zn ha^{-1}

4.5 Number of flowers per plant

Number of flowers per plant showed significant variation due to application of different concentration of boron application (Appendix IV and Table 3). The maximum number of flowers per plant (133.40) was obtained from B_3 (2.0 kg B ha^{-1}), while the minimum (108.20) was recorded from B_0 (0 kg B ha^{-1}).

Different levels of zinc application showed significant variation on flowers per plant (Appendix IV and Table 4). The highest number of flowers per plant (129.80) was counted from Zn_1(2.5kg Zn ha^{-1})and the lowest number (110.30) was recorded from Zn_0(0 kg Zn ha^{-1}).

The variation was found due to combined effect of boron and zinc application on flowers per plant (Appendix IV and Table 5). The maximum flowers per plant (144.70) was recorded from the treatment combination of B_3Zn_1, while the treatment combination of B_0Zn_0 gave the lowest (100.00) number of flowers per plant which was statistically similar to B_0Zn_2 and B_1Zn_0. From the revealed it was found that both boron and zinc application favored flower bearing which ensured more yield.

4.6 Number of fruits per plant

Number of fruits per plant showed significant variation on different levels of boron (Appendix IV and Table 3). The maximum number of fruits per plant (42.07) was obtained for B_3 (2.0 kg B ha^{-1}), which was statistically similar B_1 (32.87) and B_2 (33.04), while the minimum (26.83) was recorded for B_0 (0 kg B ha^{-1}). The effect of boron application on fruits per plant was most effective at the concentration of 2.0 kg B ha^{-1}which was followed by 1.5, 1.0 and 0 kg B ha^{-1}.

Different levels of zinc application showed not significant variation on fruits per plant (Appendix IV and Table 4). Numerically, the highest number of fruits per plant (36.65) was observed for Zn_2 (2.5 kg Zn ha^{-1}) and the lowest number (31.63) was found for Zn_0 (0 kg Zn ha^{-1}).

The variation was found due to combined effect of boron and zinc application on fruits per plant (Appendix IV and Table 5). The maximum fruits per plant (91.16) was recorded from the treatment combination of B_3Zn_1, while the treatment combination of B_0Zn_0 gave the lowest (26.40) number of fruits per plant which was statistically similar with B_0Zn_1, B_0Zn_2, B_1Zn_0, B_1Zn_1, B_1Zn_2,B_2Zn_1 andB_3Zn_0. From the results it was found that both boron and zinc application favored fruit setting which ensured the higher yield.

Table 5. Interaction effect of boron and zinc application on different flower and fruit characteristics of tomato

Treatments	Number of branches per plant	Number of clusters per plant	Number of flowers per plant	Number of fruits per plant	Fruit length (cm)
B_0Zn_0	7.33g	6.34 g	100.00g	26.40 e	4.93h
B_0Zn_1	8.33fg	7.27 f	118.00cd	26.89 e	5.27e-g
B_0Zn_2	8.33fg	7.73 f	106.70fg	30.75 e	4.97gh
B_1Zn_0	8.50f	8.40 e	106.70fg	28.75 e	5.07f-h
B_1Zn_1	9.67e	8.61 de	124.70bc	43.78 c-e	5.57de
B_1Zn_2	10.00de	8.99 cd	113.70de	41.16 de	5.27e-g
B_2Zn_0	9.67e	9.27 c	111.00ef	64.20 bc	5.33ef
B_2Zn_1	12.00bc	10.34 b	131.70b	36.44 de	5.77cd
B_2Zn_2	11.00cd	10.34 b	121.00cd	54.83 bd	5.53de
B_3Zn_0	10.33de	9.08 cd	123.30bc	38.20 de	5.90bc
B_3Zn_1	14.00a	11.64 a	144.70a	91.16 a	6.50a
B_3Zn_2	12.33b	11.37 a	132.30b	71.19 b	6.13b
$LSD_{(0.05)}$	1.163	0.5963	9.416	19.46	0.312
CV (%)	6.78	6.26	4.65	7.25	3.35

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability

Note: B_0– 0 kg B ha^{-1}, B_1–1.0 kg B ha^{-1}, B_2– 1.5 kg B ha^{-1}, and B_3– 2.0 kg B ha^{-1}

Zn_0–0 kg Zn ha^{-1}, Zn_1–2.5 kg Zn ha^{-1} and Zn_2–5.0 kg Zn ha^{-1}.

4.7 Length of fruit

Application of different levels of boron application showed significant variation on fruit length(Appendix IV and Table 3). The maximum fruit length (6.18 cm) was obtained from B_3 which was followed by B_2 (5.54 cm), while the minimum (5.06 cm) was recorded from B_0. The effect of boron application on fruit length was most effective at the level of 2.0 kg B ha^{-1}which was followed by 1.5, 1.0 and 0 kg B ha^{-1}.

Different levels of zinc application showed significant variation on fruit length (Appendix IV and Table 4). The maximum fruit length (5.78 cm) was recorded from Zn_1 which was followed by Zn_2 (5.48 cm) and the minimum (5.31 cm) was found for Zn_0.

The variation was found due to combined effect of boron and zinc application on fruit length. The maximum fruit length (6.50 cm) was recorded from treatment combination B_3Zn_1 which was followed by B_3Zn_2 (6.13 cm), while the treatment combination B_0Zn_0 gave the minimum (4.93 cm) fruit length, which was statistically similar to B_0Zn_2 and B_1Zn_0. From the results it was found that both boron and zinc application favored fruit length which ensured maximum yield.

4.8 Diameter of fruit

Fruit diameter varied significantly for different levels of boron (Appendix IV and Table 6). The maximum diameter of fruit (12.44 cm) was obtained from B_3 (2.0 kg B ha^{-1}) while the minimum (7.84 cm) was recorded for B_0 (0 kg B ha^{-1}). The effect of boron application on fruit diameter was most effective at the concentration of 2.0kg B ha^{-1} which was followed by 1.5, 1.0 and 0 kg B ha^{-1}.

Different levels of zinc showed significant variation on diameter of fruit (Appendix IV and Table 7). The maximum diameter of fruit (12.18 cm) was observed in Zn_1(2.5 kg Zn ha^{-1})and the minimum (7.83 cm) was found for Zn_0 (0 kg Zn ha^{-1}).

Due to combined effect of boron and zinc application showed significant variation on fruit diameter (Appendix IV and Table 8). The maximum fruit diameter (13.31 cm) was recorded from treatment combination of B_3Zn_1which was statistically similarwithB_1Zn_2 and B_3Zn_2 (12.70 and 11.83 cm, respectively), while the treatment combination B_0Zn_0 gave the minimum (6.60 cm) fruit diameter which was statistically similar to B_0Zn_1, B_0Zn_2 and B_1Zn_0.

Table 6. Effect of boron application on different yield contributing characteristics of tomato

Treatments	Fruit diameter (cm)	Dry matter content of leaves(%)	Dry matter content of fruit(%)	Yield per plot (kg)	Yield per ha (ton)
B_0	7.84 c	8.45 c	6.62 d	23.68 d	50.56 d
B_1	10.35 b	9.00 c	7.84 c	32.64 c	57.25 c
B_2	10.43 b	13.74 b	9.05 b	40.96 b	62.38 b
B_3	12.44 a	15.65 a	11.85 a	45.08 a	67.36 a
LSD $_{(0.05)}$	1.76	1.52	1.07	3.01	1.28
CV (%)	10.12	1.3	1.96	7.54	5.09

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability

Note: B_0– 0 kg B ha^{-1}, B_1–1.0 kg B ha^{-1},B_2– 1.5 kg B ha^{-1}, andB_3– 2.0 kg B ha^{-1}

Table 7. Effect of zinc application on different yield contributing characteristics of tomato

Treatments	Fruit diameter (cm)	Dry matter content of leaves(%)	Dry matter content of fruit(%)	Yield per plot (kg)	Yield per ha (ton)
Zn_0	7.83 c	9.66 c	7.04 c	34.86 c	59.48 c
Zn_1	12.18 a	13.23 a	11.09 a	43.90 a	65.85 a
Zn_2	9.18 b	10.13 b	9.08 b	40.26 b	62.45 b
LSD $_{(0.05)}$	1.761	6.52	7.88	3.01	1.12
CV (%)	10.12	1.3	1.96	7.54	5.09

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability

Note: Zn_0–0 kg Zn ha^{-1}, Zn_1–2.5 kg Zn ha^{-1} and Zn_2–5.0 kg Zn ha^{-1}.

4.9 Dry matter content of leaves

Dry matter content of leaves varied significantly in different parts of plant for different levels of boron application (Appendix III and Table 6). In leaf, the maximum dry matter content (15.65%) was obtained for B_3, while the minimum (8.45%) was recorded for B_0 which was statistically similar to B_1 (19.02%).

Different levels of zinc application showed significant variation on dry matter content of leaves (Appendix III and Table 7). The maximum dry matter content (13.23 %) was observed in Zn_1 and the minimum (9.66 %) was found for Zn_0 in leaf.

The variation was found due to combined effect of boron and zinc application on dry matter content of tomato leaves (Appendix III and Table 8). The maximum dry matter content (14.44 %) was recorded from treatment combination B_3Zn_1 (2.0 kg B ha^{-1} with 2.5 kg Zn ha^{-1}), while the treatment combination B_0Zn_0 (0 kg B ha^{-1} with 0 kg Zn ha^{-1})gave the minimum (9.02 %) dry matter content in leaf.

4.10 Dry matter content of fruit

Dry matter content of fruit varied significantly in different parts of plant for different levels of boron (Appendix III and Table 6). The maximum dry matter content (11.85 %) was observed for B_3 and the minimum (6.62 %) was found for B_0 in fruit. The effect of boron application on fruit diameter was most effective at the concentration of 2.0kg B ha^{-1} which was followed by 1.5, 1.0 and 0 kg B ha^{-1}.

Different levels of zinc showed significant variation on dry matter content in fruit of tomato (Appendix III and Table 7). In fruit the maximum dry matter content (11.09 %) was obtained for Zn_1, while the minimum (7.04 %) was recorded for Zn_0.

The variation was found due to combined effect of boron and zinc application on dry matter content of tomato fruit (Appendix III and Table 8). In fruit, the treatment combination B_3Zn_1gave the maximum (12.44 %) dry matter content whereas the minimum dry matter content (7.74 %) was observed for the combination B_0Zn_0.

4.11 Yield per plot

Yield per plant varied significantly influenced by the application of for different levels of boron (Appendix IV and Table 6). The highest yield per plot

(45.08 kg) was obtained from B_3 (2.0 kg B ha^{-1}) which was followed by B_2 (40.96 kg), while the lowest (23.68 kg) was recorded from B_0 (0 kg B ha^{-1}). The best effect of boron application on yield per plant was at the concentration of 2.0 kg B ha^{-1} which was followed by 1.5, 1.0 and 0 kg B ha^{-1}.

Due to different levels of zinc yield per plant showed significant variation on yield per plot (Appendix IV and Table 7). The highest yield per plot (43.90 kg) was observed in Zn_1 (2.5kg Zn ha^{-1}) and the lowest (34.86 kg) was found from Zn_0 (0kg Zn ha^{-1}).

The variation was found due to combined effect of boron and zinc on yield per plant (Appendix IV and Table 8). The maximum yield per plant (49.68 kg) was recorded from the treatment combination of B_3Zn_1, while the treatment combination of B_0Zn_0 gave the minimum (18.00 kg) yield per plot. From the revealed it was found that both boron and zinc application favored yield per plant which ensured the highest yield.

4.12 Yield per hectare

Yield per hectare varied significantly for different levels of boron application (Appendix IV and table 6). The highest Yield per hectare (67.36 ton) was obtained from B_3, while the lowest (50.56 ton) was recorded from G_0. The best effect of boron application on yield per hectare was at the concentration of 2.0 kg B ha^{-1} which was followed by 1.5, 1.0 and 0 kg B ha^{-1}.

Due to zinc application yield per hectare showed significant variation (Appendix IV and Table 7). The highest yield per hectare (65.85 ton) was observed in Zn_1 and the lowest (59.48 ton) was found from Zn_0.

The variation was found due to combined effect of boron and zinc application on yield per hectare (Appendix IV and Table 8). The maximum yield per hectare (86.25ton) was recorded from the treatment combination of B_3Zn_1, while the treatment combination of B_0Zn_0 gave the minimum (31.25 ton) yield per hectare. The results revealed that the interaction effect of 2.0 kg B ha^{-1} with 2.5 kg Zn ha^{-1} was gave the best yield of tomato.

Table 8. Interaction effect of boron and zinc application on different yield contributing characteristics of tomato

Treatments	Fruit diameter (cm)	Dry matter content of leaves(%)	Dry matter content of fruit(%)	Yield per plot (kg)	Yield per ha (ton)
B_0Zn_0	6.60 h	9.02 i	7.74 i	18.00g	31.25 j
B_0Zn_1	7.06gh	10.84 e	8.34 e	24.72 f	42.92 i
B_0Zn_2	7.39 gh	9.79 f	7.25 f	28.32 e	49.17 h
B_1Zn_0	8.14 f-h	9.33 h	7.33 h	28.56 e	49.58 h
B_1Zn_1	8.84 e-g	11.11 f	9.56 f	33.36 d	57.92 g
B_1Zn_2	12.7 ab	10.06 g	8.06 g	36.00c	62.50 f
B_2Zn_0	11.08 b-d	11.70 e	9.70 e	40.80b	71.25 c
B_2Zn_1	10.43 c-e	13.47 c	11.35 c	40.56 b	70.42 de
B_2Zn_2	10.34 c-e	12.48 d	10.24 d	42.00 b	72.92 b
B_3Zn_0	9.45 d-f	12.65 d	10.78 d	41.04 b	71.25 c
B_3Zn_1	13.31 a	14.44 a	12.44 a	49.68 a	86.25 a
B_3Zn_2	11.82 a-c	13.39 b	11.36 b	41.04 b	70.83 cd
$LSD_{(0.05)}$	1.76	0.02	0.02	3.01	1.12
CV (%)	10.12	6.52	6.52	7.54	9.21

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability

Note: B_0– 0 kg B ha^{-1}, B_1–1.0 kg B ha^{-1}, B_2– 1.5 kg B ha^{-1}, and B_3– 2.0 kg B ha^{-1}
Zn_0–0 kg Zn ha^{-1}, Zn_1–2.5 kg Zn ha^{-1} and Zn_2–5.0 kg Zn ha^{-1}.

4.13 Nitrogen content in tomato

The N concentration in tomato increased with increasing level of B up to 1.5 Kg B ha^{-1}. The highest nitrogen concentration in fruit (0.74 %) was recorded in B_1 (1.0 kg B ha^{-1}). On the other hand, the lowest nitrogen concentration in fruit (0.63 %) was recorded (Table 9) in the B_0 treatment where no B was applied.

The N content in tomato increased with increasing rate of Zn. The highest nitrogen concentration among the treatments of zinc (0.75 %) was observed in Zn_2 (5.0 kg Zn ha^{-1}). The lowest nitrogen concentration (0.61 %) was observed (Table 10) in Zn_0 (control) treatment.

Significant effect of combined application of different doses of B and Zn on the nitrogen concentration was observed in the fruit of tomato (Table 11). The highest concentration of nitrogen in tomato (0.82 %) was recorded with the highest dose of B_1Zn_2 (1.0 kg B ha^{-1} + 5.0 kg Zn ha^{-1}) and the lowest nitrogen concentration (0.53 %) was found in B_0Zn_0(0 kg B ha^{-1}+ 0 kg Zn ha^{-1})treatment.

Table 9. Effect of boron application on N, P, K,Zn and B concentrations intomato

Treatments	N (%)	P (%)	K(%)	Zn (%)	B (%)
B_0	0.63 c	0.40 c	0.81 c	0.10	0.33 c
B_1	0.74 a	0.55 a	1.12 b	0.31	0.47 ab
B_2	0.71ab	0.58 a	1.40 a	0.12	0.52 a
B_3	0.68bc	0.46 b	1.14 b	0.11	0.43 b
$LSD_{(0.05)}$	0.05	0.05	0.05	NS	0.05
CV (%)	3.89	5.05	2.02	2.07	6.75

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability

Note: B_0– 0 kg B ha^{-1}, B_1–1.0 kg B ha^{-1}, B_2– 1.5 kg B ha^{-1}, and B_3– 2.0 kg B ha^{-1}

NS- Not significant

Table 10. Effect of zinc application on N, P, K, Zn and B concentrations in tomato

Treatments	N (%)	P (%)	K(%)	Zn (%)	B (%)
Zn_0	0.61 b	0.44 b	1.04 c	0.09 b	0.34 c
Zn_1	0.70 a	0.52 a	1.13 b	0.11 ab	0.45 b
Zn_2	0.75 a	0.53 a	1.18 a	0.15 a	0.51 a
$LSD_{(0.05)}$	0.05	0.03	0.05	0.05	0.03
CV (%)	3.89	5.05	2.02	3.49	6.75

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability

Note: Zn_0–0 kg Zn ha^{-1}, Zn_1–2.5 kg Zn ha^{-1} and Zn_2–5.0 kg Zn ha^{-1}.

4.14 Phosphorus content in tomato

The highest phosphorus concentration in tomato (0.58%) was recorded in B_2 (1.5 kg B ha^{-1}). On the other hand, the lowest phosphorus concentration in tomato (0.40 %) was recorded (Table 9) in the B_0 treatment where no B was applied.

The highest phosphorus concentration of 0.53 % was observed in Zn_2 (5.0 kg Zn ha^{-1}) treatment. The lowest phosphorus concentration of 0.44 % was observed (Table 10) in Zn_0 (control condition) treatment.

There was a marked influence of the different doses of K and S on the phosphorus concentration was observed in tomato (Table 11). The highest concentration of phosphorus in tomato (0.67 %) was recorded with the highest dose of B_2Zn_2 (1.5 kg B ha^{-1} + 5.0 kg Zn ha^{-1}) and the lowest (0.34 %) was found in B_0Zn_0(0 kg B ha^{-1}+ 0 kg Zn ha^{-1})treatment.

4.15 Potassium content in tomato

The highest potassium concentration among the different doses of boron (1.40 %) was recorded in B_2 (1.5 kg K ha^{-1}). on the other hand, the lowest potassium concentration (0.81 %) was recorded (Table 9) in the B_0 treatment where no B was applied.

The accumulation of Zn increased in higher level of S application. The highest and statistically superior potassium concentration among the different doses of Zn (1.18 %) was recorded (Table 10) with Zn_2 treatment. The lowest potassium concentration (1.04 %) was observed in the treatmentZn_0 where no Zn was applied.

Significant effect of combined application of different doses of B and Zn on the potassium concentration was observed in tomato (Table 11). The highest concentration of potassium in tomato (1.47 %) was recorded for the treatment B_2Zn_2 (1.5 kg B ha^{-1}+ 5.0 kg Zn ha^{-1}) treatment and it was statistically superior to that of another treatments. The lowest potassium concentration (0.65 %) was found for the treatmentB_0Zn_0 (0 kg B ha^{-1}+ 0 kg Zn ha^{-1}).

4.16 Zinc content in tomato

Among the different doses of B the highest zinc concentration in tomato (0.31 %) was recorded in B_1 (1.0 kg K ha^{-1}) treatment. On the other hand, the lowest Zn concentration (0.10 %) was recorded (Table 9) in the B_0 treatment where no B was applied.

The highest zinc concentration in tomato among different doses of Zn (0.15 %) was recorded with Zn_2 treatment which was statistically identical to the Zn_1 treatment. The lowest zinc concentration (0.09 %) was observed (Table 10) in the treatment Zn_0 where no zinc fertilizer was applied.

Significant effect of combined application of different doses of B and Zn on the zinc concentration was observed in fruit of tomato (Table 11). The highest concentration of zinc in tomato (0.17 %) was recorded with the B_2Zn_2 treatment (1.5 kg B ha^{-1}+ 5.0 kg Zn ha^{-1}). On the other hand, the lowest zinc concentration (0.08 %) was found in B_0Zn_0 (0 kg B ha^{-1}+ 0 kg Zn ha^{-1}) treatment.

4.17 Boron content in tomato

Among the B doses the highest boron concentration in tomato fruit (0.52 %) was recorded in B_2 (1.5 kg K ha^{-1}) treatment that did not differ statistically with the treatment B_1. The lowest sulphur concentration in seed (0.33 %) was obtained from having no potassium recorded (Table 9) in the B_0 treatment where no B was applied.

The highest boron concentration (0.51 %) in seed among different doses of Zn fertilizer was recorded with Zn_2 treatment (5.0 kg Zn ha^{-1}). The lowest boron concentration (0.34%) in seed was observed (Table 10) in the treatment Zn_0 where no zinc fertilizer was applied.

Significant effect of combined application of different doses of B and Zn on the boron concentration was observed in tomato (Table 10). The highest concentration of boron (0.65 %) was recorded with the higher dose of B and Zn which may be due to the higher supply and subsequent assimilation of these elements in the fruit. The lowest boron concentration (0.24 %) in seed was found in B_0Zn_0 treatment combination.

Table 10. Interaction effect of boron and zinc application on N, P, K, Zn and B concentrations in tomato

Treatments	N (%)	P (%)	K(%)	Zn (%)	B (%)
B_0Zn_0	0.53 f	0.34 f	0.65 j	0.08 c	0.24 f
B_0Zn_1	0.60 e	0.42 e	0.86 i	0.11 a-c	0.34 e
B_0Zn_2	0.75 bc	0.44 de	0.91 i	0.14 a-c	0.42 cd
B_1Zn_0	0.64 e	0.47 c-e	1.05 h	0.09 bc	0.39 de
B_1Zn_1	0.76 bc	0.57 b	1.06 gh	0.12 a-c	0.46 c
B_1Zn_2	0.82 a	0.61 b	1.25 d	0.14 ab	0.55 b
B_2Zn_0	0.62 e	0.48 cd	1.34 c	0.09 bc	0.35 e
B_2Zn_1	0.71 cd	0.58 b	1.41b	0.11 a-c	0.56 b
B_2Zn_2	0.80 ab	0.67 a	1.47 a	0.17 a	0.65 a
B_3Zn_0	0.66 de	0.45 de	1.13 ef	0.10 bc	0.39 de
B_3Zn_1	0.73 c	0.51 c	1.18 e	0.11 a-c	0.46 c
B_3Zn_2	0.64 e	0.42 e	1.10 fg	0.13a-c	0.44 cd
$LSD_{(0.05)}$	0.053	0.053	0.055	0.05	0.05
CV (%)	3.89	5.05	2.02	3.49	6.75

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability

Note: B_0– 0 kg B ha^{-1}, B_1–1.0 kg B ha^{-1},B_2– 1.5 kg B ha^{-1}, andB_3– 2.0 kg B ha^{-1}
Zn_0–0 kg Zn ha^{-1}, Zn_1–2.5 kg Zn ha^{-1} and Zn_2–5.0 kg Zn ha^{-1}.

CHAPTER V

SUMMARY AND CONCLUSION

The field experiment was conducted in the experimental farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207 during the period from November 2013 to March 2014 to find out the effect of boron and zinc fertilization the growth, yield and nutrient content of tomato. The experiment consisted of two factors; Factor A: Different levels of boron such as B_0: 0 kg B ha^{-1}, B_1: 1.0 kg B ha^{-1}, B_2: 1.5 kg B ha^{-1} and B_3: 2.0 kg B ha^{-1}; Factor B: Different levels of zinc such as Zn_0: 0 kg Zn ha^{-1}, Zn_1: 2.5 kg Zn ha^{-1} and Zn_2: 5.0 kg Zn ha^{-1}. Data on different growth and yield contributing characters were recorded.

The maximum (117.30 cm) plant height was obtained from B_3 and the minimum (95.67 cm) was recorded from B_0 at 75 DAT. At 75 DAT, the maximum (65.44) number of leaves per plant was counted from B_3 and the minimum (52.33) was recorded from B_0. The maximum (12.22) number of branches per plant was recorded from B_3 and the minimum (8.00) was recorded from B_0. The maximum (9.74) number of clusters per plant was recorded from B_3 and the minimum (8.27) was recorded from B_0. The maximum (133.40) number of flowers per plant was recorded fromB_3 and the minimum (108.20) was recorded from B_0. The maximum (42.07) number of fruits per plant was counted fromB_3 and the minimum (26.83) was recorded from B_0.The maximum (15.65%) dry matter content of leaves was recorded from B_3 and the minimum (8.45%) was recorded from B_0. The maximum (11.85%) dry matter content of fruits was recorded from B_3 and the minimum (6.62%) was recorded from B_0. The maximum (6.18 cm) fruit length was recorded from B_3 and the minimum (5.06 cm) was recorded from B_0. The maximum (12.44 cm) fruit diameter was recorded from B_3 and the minimum (7.84 cm) was obtained from B_0. The maximum (45.08 kg) yield per plot was recorded from B_3 and the minimum (23.68 kg) was recorded from B_0. The maximum (67.36 ton) yield per hectare was recorded from B_3 and the minimum (50.56 ton) was found from B_0.

The maximum (113.60 cm) plant height was recorded from Zn_1 and the minimum (101.30 cm) was recorded from Zn_0 at 75 DAT. At 75 DAT, the maximum (63.08) number of leaves per plant was recorded from Zn_1 and the minimum (58.33) was recorded from Zn_0. The maximum (11.00) number of branches per plant was obtained from Zn_1 and the minimum (8.96) was recorded from Zn_0. The maximum (10.61) number of clusters per plant was recorded from Zn_1 and the minimum (7.49) was recorded from Zn_0. The maximum (129.80) number of flowers per plant was recorded fromZn_1 and the minimum (110.30) was recorded from Zn_0. The maximum (36.65) number of fruits per plant was recorded fromZn_1 and the minimum (31.63) was recorded from Zn_0.The maximum (13.74%) dry matter content of leaves was recorded from Zn_1 and the minimum (9.66%) was recorded from Zn_0. The maximum (11.09%) dry matter content of fruits was recorded from Zn_1 and the minimum (7.04%) was recorded from Zn_0. The maximum (5.78 cm) fruit length was recorded from Zn_1 and the minimum (5.31 cm) was recorded from Zn_0. The maximum (12.18 cm) fruit diameter was recorded from Zn_1 and the minimum (7.83 cm) was recorded from Zn_0. The maximum (43.90 kg) yield per plot was recorded from Zn_1 and the minimum (34.86 kg) was recorded from Zn_0. The maximum (65.85 ton) yield per hectare was recorded from Zn_1 and the minimum (59.48 ton) was obtained from Zn_0.

The maximum (125.00 cm) plant height was recorded from the treatment combination ofB_3Zn_1 and the minimum (82.33 cm) was recorded from B_0Zn_0 at 75 DAT. At 75 DAT, the maximum (68.67) number of leaves per plant was recorded from the treatment combination of B_3Zn_1 and the minimum (50.67) was recorded from B_0Zn_0. The maximum (14.00) number of branches per plant was recorded from the treatment combination of B_3Zn_1 and the minimum (7.33) was recorded from B_0Zn_0. The maximum (15.67) number of clusters per plant was recorded from B_3Zn_1 and the minimum (9.00) was recorded fromB_0Zn_0. The maximum (144.70) number of flowers per plant was recorded from the treatment combination of B_3Zn_1 and the minimum (100.00) was recorded from B_0Zn_0. The maximum (57.67) number of fruits per plant was recorded from B_3Zn_1 and the minimum (38.33) was recorded from the treatment combinationB_0Zn_0.The maximum (14.44%) dry matter content of leaves was recorded from B_3Zn_1 and the minimum (9.02%) was recorded from the treatment combination of B_0Zn_0. The maximum (11.47%) dry matter content of fruits was recorded from the treatment combination of B_3Zn_1 and the minimum (6.83%) was recorded from the treatment combination of B_0Zn_0. The maximum (6.50 cm) fruit length was recorded from the treatment combinationB_3Zn_1 and the minimum (4.93 cm) was recorded from B_0Zn_0. The maximum (5.90 cm) fruit diameter was recorded from the treatment combination of B_3Zn_1 and the minimum (4.37 cm) was recorded from B_0Zn_0. The maximum (49.68 kg) yield per plot was recorded from the treatment combination of B_3Zn_1 and the minimum (18.00 kg) was recorded from B_0Zn_0. The maximum (86.25 ton) yield per hectare was recorded from the treatment combination of B_3Zn_1 and the minimum (31.25 ton) was performed by the treatment combination of B_0Zn_0.

Conclusion:

The result of the present study revealed that different combination of boron and zinc application play an important role on the growth and yield contributing characters of tomato. It is noted that boron exerted marked effect over the control. On the other hand zinc, such as 2.5 kg ha^{-1} helped to increase the yield of tomato. From the experiment, it was found that different levels of boron showed predictable role on yield contributing characters of tomato plant and yield was increased with the increasing levels of boron. The combined effect of 2.0 kg B ha^{-1} and 2.5 kg Zn ha^{-1} contributed the maximum yield. So, further higher levels of boron may be used for obtaining more yields.B_3 (2.0 kg B ha^{-1}) and Zn_1 (2.5 kg Zn ha^{-1}) performed better and combination B_3Zn_1 is better followed by B_2Zn_1.

Recommendation

Considering the situation of the present experiment, further studies in different areas of Bangladesh may be suggested:

1. It may be noted further higher concentration of boron may be used for ensuring the maximum yield in future.
2. Considering the levels of boron and zinc, the plants performed the highest yield further doses such as- 3.0, 3.5 and 4.0 kg ha^{-1} may be study.

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Appendices

Appendix I. Monthly average record of air temperature, rainfall, relative humidity and sunshine of the experimental site during the period from November 2013 to April 2014.

Month	Air temperature (°c)		Relative humidity (%)	Total rainfall (mm)	Sunshine (hr)
	Maximum	Minimum			
November, 2013	29.6	19.2	77	34.4	5.7
December, 2013	26.4	14.1	69	12.8	5.5
January, 2014	25.4	12.7	68	7.7	5.6
February, 2014	28.1	15.5	68	28.9	5.5
March, 2014	32.5	20.4	64	65.8	5.2
April, 2014	33.7	23.6	69	165.3	4.9

Source: Bangladesh Meteorological Department (Climate & Weather Division) Agargoan, Dhaka - 1212

Appendix II. Physical characteristics and chemical composition of soil of the experimental plot

Soil characteristics	Analytical results
Agro-ecological Zone	Madhupur Tract
p^H	6.00 – 6.63
Organic matter	0.84
Total N (%)	0.46
Available phosphorous	21 ppm
Exchangeable K	0.41 meq / 100 g soil

Source: Soil Resource and Development Institute (SRDI), Dhaka

Appendix III. Analysis of variance of the data for different plant characteristics

Sources of variation	Degrees of freedom	Mean square									
		Plant height (cm) at				Leaves/ plant at				Dry matter content (%) in	
		30 DAT	45 DAT	60 DAT	75 DAT	30 DAT	45 DAT	60 DAT	75 DAT	Leaf	Fruit
Replication	2	90.040	32.00	1.750	72.44	0.87	35.19	40.75	43.62	80.424	16.654
Boron (A)	3	101.88**	300.77**	312.70**	712.69**	76.67**	287.00**	57.77**	66.45	46.990**	5.789**
Zinc (B)	2	126.58**	135.31**	337.58**	465.52**	18.87**	74.36**	112.22**	126.56	30.427**	1.334**
Interaction (A X B)	6	4.84	6.70	2.50	3.08	1.10	1.80	10.03	12.22	1.782**	0.039**
Error	22	6.16	8.75	9.144	8.86	1.97	1.83	1.37	1.45	0.089	0.008

*-significant at 5% level and **-significant at 1% level.

Appendix IV. Analysis of variance of the data for different yield contributing characteristics

Sources of variation	Degrees of freedom	Mean square							
		Branches per plant	Clusters per plant	Fruit length (cm)	Fruit diameter (cm)	Flowers per plant	Fruits per plant	Yield per plot (kg)	Yield per ha (ton)
Replication	2	0.896	8.528	0.317	0.081	1722.528	77.583	20.621	158.608
Boron (A)	3	30.118**	24.185**	2.092**	2.130**	1034.546**	193.000**	7.656**	59.081**
Zinc (B)	2	13.271**	19.111**	0.671**	0.462**	1150.778**	210.583**	8.138**	62.746**
Interaction (A X B)	6	1.271*	0.741	0.012	0.034	3.074	0.917	0.042**	0.328**
Error	22	0.472	0.740	0.034	0.020	30.922	5.189	0.222	1.710

*-significant at 5% level and **-significant at 1% level.

Appendix V. Agro-Ecological Zone (AEZ) of Bangladesh