EFFECTS OF ZINC AND BORON FERTILIZATION ON THE YIELD OF BARI TOMATO-14 *(Solanum lycopersicum L.)*

ASRAFI SULTANA

DEPARTMENT OF SOIL SCIENCE

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

DHAKA -1207

JUNE, 2016

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By

ASRAFI SULTANA

REG NO. 10-04120

A Thesis

Submitted to the Faculty of Agriculture,
Sher-e-Bangla Agricultural University, Dhaka
In partial fulfillment of the requirements
For the degree
of

MASTER OF SCIENCE (MS)

IN

SOIL SCIENCE
SEMESTER: JANUARY- JUNE, 2016

Approved by:

Prof. Dr. Md. Asaduzzaman Khan
Department of Soil Science
SAU, Dhaka
Supervisor

Prof. Dr. Alok Kumar Paul
Department of Soil Science
SAU, Dhaka
Co-Supervisor

Dr. Mohammad Mosharraf Hossain
Associate professor & Chairman
Department of Soil Science
SAU, Dhaka

Dedicated

To

My Beloved Parents

DEPARTMENT OF SOIL SCIENCE

Sher-e-Bangla Agricultural University

Sher-e-Bangla Nagar, Dhaka-1207

CERTIFICATE

This is to certify that the thesis entitled **"EFFECTS OF ZINC AND BORON FERTILIZATION ON THE YIELD OF BARI TOMATO-14** ***(Solanum lycopersicum L.)*****"**submitted to the **Faculty of Agriculture,** Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (M.S.) IN SOIL SCIENCE,** embodies the results of a piece of bonafide research work carried out by **ASRAFI SULTANA** Registration.No.10-04120, under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma.

I further certify that such help or source of information as has been availed of during the course of this investigation has duly been acknowledged.

Dated:

Dhaka, Bangladesh

(Prof. Dr. Md. Asaduzzaman Khan)

Supervisor

ACKNOWLEDGEMENTS

At every moment, the author would like to express her profound great fullness to the ***Almighty Allah****, the supreme power of the universe who enables her to complete the present research work and writing up of the thesis for the degree of Master of Science (MS) in Soil Science.*

The author feels a profound privilege to express her heartfelt indebtedness, deepest sense of gratitude and best regards to her Supervisor, ***Prof. Dr. Md. Asaduzzaman Khan****, Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka, for his guidance throughout the period of study including writing up the manuscript of the thesis.*

The author would like to extend her profound respect andthankfulness to her Co-supervisor ***Prof. Dr. Alok Kumar Paul****, Professor Department ofSoil Science, Sher-e-Bangla Agricultural University, Dhaka, for his scholastic supervising, constructive criticism, keen interest, kind advice, guidelines and constant untiring encouragement in conducting this research work.*

The author express her sincere respect to ***Assoc. prof. Dr. Mohammad Mosharraf Hossain;*** *Chairman; Department of Soil Science ; Sher -e- Bangla Agricultural University.*

The author expresses her sincere appreciation and indebtedness to all the teachers of the Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka, for their proficient teaching and cooperation. She extends her thanks and gratefulness to her friends ***Antora Dev, Shanta Rani Das and Sonia Nasrin*** *for their inspiration, close cooperation and good wishes.*

The author oweher boundness gratitude and deepest sense of appreciation to her beloved parents and her Siblings and also thank to her relatives who always inspired and sacrificed their lots of happiness for her higher education.

The author extends her thanks to the staff department of the Soil Science, member of the farm of Sher-e-Bangla Agricultural University, Dhaka, for their help and cooperation during the period of research. Finally, the author would like to thank one and all who are not mentioned here but helped her directly and indirectly during the period of the study.

The Author

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ABSTRACT

A pot experiment was conducted in the net house of Soil Science Department at Sher-e-Bangla Agricultural University, Dhaka during the period from November 2015 to March 2016 to study the effects of zinc and boron on the yield of tomato. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. There were 12 treatment combinations comprising 4 levels of Zn (0, 1.5, 3.0&4.5 kg/ha designated as $Zn_{0,}$ $Zn_{1.5}$, $Zn_{3.0}$ & $Zn_{4.5,}$ respectively) and 3 levels of B (0, 1.5& 3.0 kg/ha designated as B_0, $B_{1.5}$& $B_{3.0,}$ respectively). An amount of 14 kg soil was taken into each of 36 earthen pots. Zinc was added to soil as zinc sulphate (23% Zn) and boron as boric acid (17% B). All the plant parameters were influenced by the different levels of Zn application. The $Zn_{4.5}$ treatment gave the maximum plant height (31.00 cm), maximum number of leaves plant^{-1} (28.22), maximum number of leaf branches (3.66), maximum number of flower clusters plant^{-1} (4.88), maximum number of flowers plant^{-1} (29.88), maximum number of fruits plant^{-1} (25.00) and the maximum fruit yield plant^{-1} was (696.33g). For boron treatment, 3 kg B ha^{-1}also gave the best results in terms of all plant parameters. Thus the $Zn_{4.5}B_{3.0}$ treatment combination produced the maximum plant height (36.66cm),), maximum number of leavesplant^{-1} (37.66),maximum number of leaf branches (4.66) while the $Zn_{4.5}B_{1.5}$ treatment combination the maximum number of flower clusters plant^{-1} (5.66), maximum number of flowers plant^{-1} (37.33),maximum number of fruits plant^{-1} (31.00) and maximum fruit yield plant^{-1} was (798.00gm).This result indicates that the soil was deficient in Zn and B. For achieving satisfactory yield of tomato in this soil (AEZ 28: Madhupur Tract), an application of Zn at 4.5 kg Zn ha^{-1} coupled with 1.5 kg B ha^{-1} is essential.

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Chapter 1

INTRODUCTION

Tomato (*Solanum lycopersicum*L.*)* is a prominent member of Solanaceae family with 2n=24 chromosomes, originated in the premises of Western coastal plains of South America (Harlan, 1992; Ali *et al*., 2012). Tomato is one of the paramount fruit vegetables grown around the globe and in terms of area it ranks next to potato whereas, as a processing crops it ranks first in the world. Tomato has great demand throughout the year. Its production is mainly concentrated during winter season and it covers about 9.8% of the area under total winters vegetables in Bangladesh. Recent statistics showed that tomato was grown in 75602 acre of land and the total production was approximately 4,13,610 metric tons (BBS.2016).The Yield production of tomato is very low compared to many other countries in the world. Food value of tomato is very rich since it has higher contents of Vitamins A, B, and C including calcium and carotene (Bose and Som, 1990).Adequate supply of deficient nutrients can increase the yield, fruit quality, fruit size, keeping quality, color, and taste of tomato (Shukla and Naik, 1993). The low yield record of tomato in Bangladesh, is not an indication of low yield potentiality of this crop. The low yield may be attributed to a number of reasons, viz., unavailability of quality seeds of improved varieties, improper management of fertilizers, irrigation, disease control etc.

Micronutrients can play an important role in tomato production. It is well known that micronutrient deficiencies are one of the major limiting factors for crop production in most tropical woody deep peat soils (Tadano, 1985), including Bangladesh. Among the micro nutrients, boron and zinc play an important role directly and indirectly in improving the growth, yield and quality of tomato in addition to checking various diseases and physiological disorders (Magalhaes*et al.*, 1980).

Zinc mainly functions as the metal component of a series of enzymes. Zinc deficiency is thought to restrict RNA synthesis, which in turn inhibits protein synthesis. Demoranville and Deubert (1987) reported that fruit shape, yield, and shelf life of tomato were affected by boron deficiency Boron has a pronounced positive effect on the production and quality of tomato. Boron is needed by the crop plants for cell division, nucleic acid synthesis, calcium uptake and transport of carbohydrates (Bose and Tripathi, 1996). Boron also plays an important role in flowering and fruiting (Nonnecke, 1989). Boron deficiency affects the growing points of roots and youngest leaves. The leaves become wrinkled and curled with light green color.

Its deficiency affects translocation of sugar, starches, nitrogen and phosphorus, synthesis of amino acids and proteins (Stanley *et al*., 1995). In boron deficient plants the youngest leaves become pale green, losing more color at the base then at the tip. Boron deficiency symptoms will often appear in the form of thickened wilted, or curled leaves, a thickened, cracked, or water soaked condition of petioles and stems, and discoloration, cracking or rotting of fruit, tubers or roots. (Tisdale *et al.,* 1985).To improve the quality of tomato, there should have the technologies which will eventually fulfill the growers as well as consumers' need. Studies on management practices, particularly the management of boron and zinc would help increasing the yield and quality of tomato. Available information in this regard under Bangladesh conditions is inadequate. The present study was, therefore, conducted in order to find out the influence of boron and zinc on the yield of tomato.

Objectives:

1. To know the individual effect of zinc and boron on the yield and yield parameters of tomato (cv. BARI Tomato 14)
2. To examine the interaction effect of zinc and boron on the yield and yield parameters of tomato(cv. BARI Tomato 14)

Chapter 2

Review of Literature

Tomato *(Solanum lycopersicum L.)* is one of the most important and popular vegetable crops in the world. A good volume of research works have been done on various aspects to improve both quality and quantity of tomato**.** It is a rich source of minerals and vitamins. The quality of tomato fruit depends among many others on nutrient supply from soil, especially micronutrients. Available literatures on tomato, which are related to the present study has been cited in the following sections.

2.1 Effects of Zinc on yield attributes

Sommer and Lipman (1926) 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 auxins metabolism, nitrogen metabolism, influence on the activities of enzymes (e.g. dehydrogenase and carbonicanhydrase, proteinases and peptidases), cytochrome C synthesis, stabilization of ribosomal fractions and protection of cells against oxidative stress (Tisdale *et al* 1997; Obata *et at*, 1999).

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 Annanurovaet al.(1992). The treatment was generally beneficial and the number and mean weight of fruits were increased. Application of NPK alone increased yield/plant by 43.4%, compared to the untreated control. Each nutrient had a positive impact on vegetative growth as well as on yield and yield attributes of tomato.

Yadav *et al.*(2001[a]) conducted a field experiment at Hisar, Haryana, India in 1990and 1991 to study the effect of zinc (0, *5,* 10, *15,* and 20 kg Sulphate /(ha) and boron (0, 1, 2, and 4 kg/ha) on the yield and nutrient content and uptake by tomato plants cv. Pusa-120. All the treatments significantly increased tomato yield. Themaximum yield was obtained with 15 kg ZnSO4 and 2 kg B/ha. The highest concentration and uptake of zinc and boron were recorded for 20 kg*ZnSO4*and 4 kg B/ha.

Patnaik *et al* (2001) conducted field experiments during 1997-98 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 12.5and 25 kg $ZnSO_4$/ha, soil application of 12.5 kg $ZnSO_4$/ha + foliar spray of 0.2%$ZnSO_4$ (thrice at weekly intervals), soil application of 12.5 kg $ZnSO_4$Tha + *0.5%*$FeSO_4$ spray (thrice at weekly intervals), 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 39.9 ton/ha with a maximum yield response of 39%. The Zn and Fe contents in index leaves of tomato were in the range of 18.5-273 mg/kg and 116-160 kg, respectively. The nutrients in index leaves 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/ka) compared to leaves (37.2-72.7 mg/kg). The highest uptake of Zn and Fe was recorded with 12.5 kg $ZnS0_4$ soil application along with 0.2% $ZnSO_4$ and 0.5% $PeSO_4$ sprays.

Yadav *et al* (2001[b]) conducted a study during 1990 and 1991, in Hisar, Haryana,India, to evaluate the effect of different concentrations of zinc and boron on the vegetative 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 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 phosphorus (P) and iron (Fe) supplemented in nutrient solution on plant growth at high zinc concentration. Application of supplementary P and Fe resulted a marked increase in both dry weight and chlorophyll concentrations achieving values not significantly different to the control. Application of supplementary P and Fe decreased Zn concentration in the leaves and roots of plants grown at high Zn, but Zn concentrations were still at toxic levels. Phosphorus 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 and Fe concentrations.

Dry matter production uptake of NPK nutrients and the residual soil fertility are favorably influenced by NPK combined with boron and zinc (Balasubramaniam*etal,*1998). Application of soil test based NPK combined with boron (10 kg/ha), Zinc sulphate *(50* kg/ha) ad composed coir pith*(5* t/ha) was reported to give the highest fruit yield of tomato.

The effect of Zn (0.0, 1.0, *2.5.* 5.0 or 10.0 mg/kg soil as zinc sulphate) on the yield and quality of tomato cv. Pusa Ruby was studied in a pot experiment. Application of Zn significantly improved biomass, fruit yield and fruit quality. The highest biomass, fruit yield, total pulp weight, acidity, and lycopene, ascorbic acid, total carotene and water contents were obtained with 5.0 mg Zn/kg soil. Zinc application at 10 mg/kg tended to have an adverse effect on fruit quality. The contents of P. Fe, Mn and Cu generally decreased with and increase in Zn concentration. The Zn content of leaves was highest at the highest rate of Zn (Dube*et al.*2003).

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 bio fertility major staple crops with Zn, Fe, and vitamin A (Welch and Graham, 2004). Biofertilization 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 at.* 2001).Plants emerged from seed with low concentrations of Zn could be highly sensitive to biotic and abiotic stresses (Obata *et* at, 1999). Zinc enriched seeds can perform better with respect to seed germination, seedling health growth and finally yield advantage (Cakmak *et* al. 1996)

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

Zinc concentration is higher in legume crops than in cereals. Its concentrations were found to be on an average 18, 30, 39 and 55 g in grain of corn, rice, drybean and soybean (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 grain yield of the next crop when replanted on Zn deficient soil (Graham*et al*., 1992).

Hossain *et al* (2008) conducted experiments over 3 years to find out an optimum rate of application for the maize-mungbean-rice cropping system in a calcareous soil of Bangladesh. Zinc application was made at 0, 2 and 4 kg/ha for maize (cv. Pacific 984, Thai hybrid) and at 0. 1 and 2kg ha-1 for rice (cv. BRRI dhan-33), with no Zn application for mungbean (cv. BARI mung-5). Effect of Zn was evaluated in terms of yield and mineral nutrient contents (N, P. S and Zn). All the three crops responded significantly to Zn application. The optimum rate of Zn for the maize-mungbean-rice cropping system was found to be 4-0-2 kg ha 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.

2.2 Effects of boron on yield attributes

A greenhouse experiment involving 4 rates of B (0, 5, 10 and 20 mg B/kg) and 3 rates of Zn (0, 10 and 20 mg Zn/kg) was conducted by Gunes et al. (2000) with tomato plants (cv. Lale). Boron toxicity symptoms occurred at B rates of 10 and 20 mg/kg. These symptoms were lower in plants grown with applied Zn. Fresh and dry weights of the plants clearly decreased with applied B. Zn treatments partially depressed the inhibitory effect of B on growth. Increased rates of B increased the concentrations of B in plant tissues; higher concentrations were observed in the absence of applied Zn. The Zn + B treatments increased the concentration of Zn in plants.

Yadav et al (2001[b]) conducted an experiment during 1990 and 1991, in Hisar, Haryana, India, to evaluate the effect of different concentrations of zinc and boron on the vegetative 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.

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 (*Solanum lycopersicum L.*) cultivars to a range of boron levels in field trials at Kadawa (11° 39' N, 8° 2' E) and Samaru (11° 12', 7° 37' E) 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 replicated three times in a randomized complete block 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.

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 *(Solanum* lycopersicum L.)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 of 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.

Smit and Combrink (2004) observed that insufficient fruit set of tomatoes owing to poor pollination in low cost greenhouses is a problem in South Africa, as bumblebee pollinators may not be imported. Since sub-optimum boron (B) levels may also contribute to fruit set problems, this aspect was investigated. Four nutrient solutions 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 and 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.

Pizzeta *et al* (2005) conducted a field experiment to evaluate the effect of boron fertilizer on the yield of broccoli, cauliflower in Sao Paulo, Brazil. Five boron levels (0, 2, 4, 6 and 8kg/ha B as borax were applied. The yield intervals obtained according to the following intervals: 16.9 to20.5 t/ha, 21.6 to 29.6 t/ha and 40.5 to46.3 t /ha, respectively the and the boron effect on yield was quadratic.

Islam (2006) carried out an experiment in BINA farm, Mymensing during 2005 to evaluate the effect of S, Zn and B on the growth and nutrient uptake by BINA-Moog 5.The treatments were as NPK, NPK+S,NPK+Zn, NPK+B,NPK+S+Zn,NPK+Zn+B And NPK+S+Zn+B. Sulphur, zinc and boron were applied@ 20,3 and 1 kg/ha.The highest grain yield(635 kg/ha) was obtained due to the application of NPK+S+Zn+B.

Kamruzzaman (2007) carried out a experiment on tomato in the field laboratory of Crop Botany Department, BAU, Mymensing during 2006-07.The experiment consisted of four levels of boron viz.@ 0,0.4,0.6 and 0.8 kg B/ha as foliar application. Application of standard dose of boron @ 0.4 kg B/ha was found to produce highest fruit yield (2167 kg/ha).

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 weights 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.

A greenhouse 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 in different parts of the tomato plant varied significantly with the treatments. Foliar spray (0.3%) accounted for higher content of B in the shoot. Application of boron 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.

Srivastava et al (1997) reported that application of 0.5 kg B / ha optimally corrected the deficiency of B in the chick pea. They also found in a field experiment that at B-deficient soil, where no fertilizers, complete fertilizer (P, K, S, B, Zn, Mo, Cu, Mn and Fe) or the complete fertilizer minus each of the trace elements were applied flower abortion was the highest and no seed was produced in chickpea (cv. Kalika) in the treatment given no B. Boron had a beneficial effect on morphological characters of crop.

Prasad *et al.* (1997) carried out a field experiments in Rabi [winter] 1991-94 on an acidic red loam soil at Ranchi, India, tomato cv. Pusa Ruby plants were given a soil boron application (0.00, 4.54, 9.09, 13.63 or 18.18 kg borax/ha) at final field preparation or a foliar boron application (0.0, 1.0, 1.5, 2.0 or 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 1991-92, 1992-93 and 1993-94, respectively). Foliar application of borax at 2.5 kg/ha also gave the highest average yield (143.06 q/ha) and the highest net additional income (Rs 7324).

Oyewole and Aduayi (1992) found that a local variety of tomato (Ife plum cv. 51691) was grown in pots for 5 months in soil treated 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 pH and B was negative. Application of B at 2 ppm increased leaf number, stem diameter, flowering and fruit yield, and reduced per cent 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. Calcium when applied singly at higher levels (80 and 160 ppm) increased total chlorophyll content of the leaf. Tomato fruit yield was the greatest (166 g/plant) at B:Ca treatment combination of 2 ppm B (4.48 kg/ha) and 160 ppm Ca (358.4 kg/ha Ca).

Chapter 3

MATERIALS AND METHODS

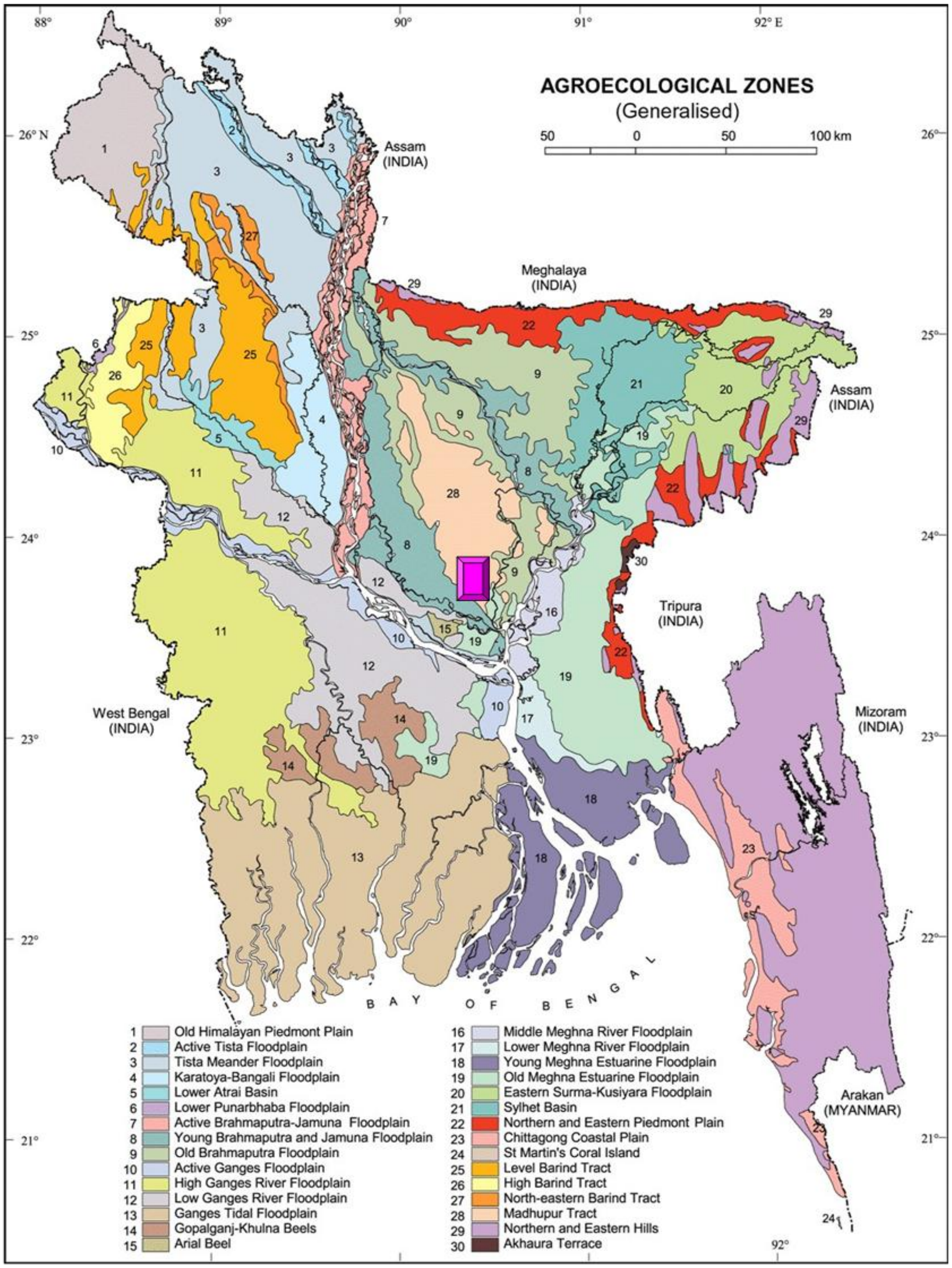
This chapter deals with the materials and methods that were used in carrying out this experiment. It includes a short description of experimental site, soil characteristics, climate, treatments, pot culture and statistical analysis. Such description is given below:

3.1 Experimental site

The experiment was conducted in a net house of Soil Science Department at Sher-e-Bangla Agricultural University, Dhaka. The location of the site was 23°74 N latitude and 90° 35 longitudes with an elevation of 8.2 meter from sea level.

3.2 Soil characteristics

The soil of the experimental site belongs to Tejgaon series under the Agro-ecological zone, Madhupur Tract (AEZ-28), which falls into Shallow Red Brown Terrace Soils. Soil samples were collected from the experimental plots to a depth of 0-15 cm from the surface before initiation of the experiment and analyzed in the laboratory. The soil was having a texture of Silty clay with pH 5.6. The physical and chemical properties of initial soil and morphological characteristics of the experimental field are given in Tables 1 and 2.



Location of the Experiment Site

Figure 1: Map showing the experimental site under study.

Table 1.Physical and chemical properties of the initial soil.

Soil Properties	Value
A. Physical properties	
Partical Size Analysis	
% Sand	28
% Silt	41.0
% Clay	30.5
B. Chemical Properties	
Soil PH	5.6
Organic matter (%)	1.16
Organic carbon (%)	0.69
C:N ratio	9.8 :1
Total N (%)	0.09
Available P (ppm)	12.8
Available K (meq/100 soil)	0.10
Available S (ppm)	23.1
Available Zn (ppm)	3.10

Table 2: Morphological characteristics of the experiment field.

Morphological Features	Characteristics
Location	Sher –e-Bangla agricultural University
AEZ no. and name	AEZ 28 Madhupur Tract
Soil Series	Tejgaon
General Soil Types	Deep Red Brown Terrace Soil
Topography	Fairy leveled
Depth of inundaton	Above flood level
Drainage Condition	Well drained
Land type	High land

3.3 Climate

The experimental area has sub-tropical humid climate characterized by heavy rainfall during May to September and scanty rainfall during rest of the year. The annual precipitation of the site is 2152 mm and potential evapotranspiration is 1297 mm. The average maximum temperature is 30.3^0 c and average minimum temperature is 21.2^0 c. The experiment was done during rabi season. Temperature during the cropping period was ranged between 12.2^0 c to 29.2^0 c. The humidity varies from 71.5 % to 81.3%. The day length was 10.5 – 11.0 hours and there was a very little rainfall during of the experimental period.

3.4 Seeds and variety

BARI tomato-14, a high yielding variety of tomato (*Solanum lycopersicum* L.) developed by Bangladesh Agricultural Research Institute (BARI), Gazipur was used as a test crop. Seeds were collected from BARI , Gazipur.

3.5 Raising of seedlings

Tomato seedlings were raised in two seed beds of 2m x 1m size. The soil was well prepared and converted into loose friable condition in obtaining good tilth. All weeds, stubbles and dead roots were removed. An amount of 15 g seeds was sown in each seedbed and it was covered with light soil, Shading was provided by bamboo mat (chatai) to protect young seedlings from scorching sunshine and rainfall. Light watering, weeding and mulching were done as and when necessary to provide seedlings with a good condition for growth.

3.6 Treatments

There were 12 treatment combinations consisting of four rates of each of zinc (0, 1.5, 3.0 and 4.5 kg zn/ha) and boron (0, 1.5 and 3.0 kg B/ha). The treatments are as follows:

A. Zn level

i. Control
ii. 1.5 kg/ha
iii. 3.0 kg/ha
iv. 4.5 kg/ha

B. B level

i. Control
ii. 1.5 kg/ha
iii. 3.0 kg/ha

The experiment consists of 12 treatment combinations. The treatment combinations are as follows:

i. Zn_0B_0
ii. $Zn_0B_{1.5}$
iii. $Zn_0B_{3.0}$
iv. $Zn_{1.5}B_0$
v. $Zn_{1.5}B_{1.5}$
vi. $Zn_{1.5}B_{3.0}$
vii. $Zn_{3.0}B_0$
viii. $Zn_{3.0}B_{1.5}$
ix. $Zn_{3.0}B_{3.0}$
x. $Zn_{4.5}B_0$
xi. $Zn_{4.5}B_{1.5}$
xii. $Zn_{4.5}B_{3.0}$

Every treatment received nitrogen, phosphorus, potassium, and sulphuras basal doses. The doses and sources of different nutrients used in the experiments are given in the Table no 3.

Table 3: Rates and sources of fertilizers used in the experiment.

Nutrient element	Source	Rate/ha
Nitrogen	Urea	160 kg/ha
Phosphorus	TSP	50 kg/ha
Potassium	MoP	90 kg/ha
Sulphur	Gypsum	20 kg/ha

3.7 Experimental design and layout:

The experimental design was a Completely randomized Design (CRD) with two factors and three replications for each treatment. The distance between pot to pot and that between row to row were 40 cm and 1m, respectively.

R_1	R_2	R_3
Zn_0B_0	Zn_0B_0	Zn_0B_0
$Zn_0B_{1.5}$	$Zn_0B_{1.5}$	$Zn_0B_{1.5}$
$Zn_0B_{3.0}$	$Zn_0B_{3.0}$	$Zn_0B_{3.0}$
$Zn_{1.5}B_0$	$Zn_{1.5}B_0$	$Zn_{1.5}B_0$
$Zn_{1.5}$ $B_{1.5}$	$Zn_{1.5}$ $B_{1.5}$	$Zn_{1.5}$ $B_{1.5}$
$Zn_{1.5}B_{3.0}$	$Zn_{1.5}B_{3.0}$	$Zn_{1.5}B_{3.0}$
$Zn_{3.0}B_0$	$Zn_{3.0}B_0$	$Zn_{3.0}B_0$
$Zn_{3.0}B_{1.5}$	$Zn_{3.0}B_{1.5}$	$Zn_{3.0}B_{1.5}$
$Zn_{3.0}B_{3.0}$	$Zn_{3.0}B_{3.0}$	$Zn_{3.0}B_{3.0}$
$Zn_{4.5}B_0$	$Zn_{4.5}B_0$	$Zn_{4.5}B_0$
$Zn_{4.5}B_{1.5}$	$Zn_{4.5}B_{1.5}$	$Zn_{4.5}B_{1.5}$
$Zn_{4.5}B_{3.0}$	$Zn_{4.5}$ $B_{3.0}$	$Zn_{4.5}$ $B_{3.0}$

Figure2: Layout of the experiment

3.8 Pot preparation

Treatment wise fertilizers were mixed in the pot soil (14 kg). Pots were placed into the net house. The moisture level in the pot soil was maintained at field capacity level.

3.9 Application of manure and fertilizers

As sources of N, P, K, S, Zn and B as urea, TSP, MoP, Gypsum, Zinc Sulphate and boric acid were applied, respectively. The total amounts of TSP, MoP and Gypsum was applied during the final pot preparation. Treatment wise required amounts of fertilizers were calculated by using the rate of nutrient application and amount of used soil in the earthen pot. Treatment wise zinc sulphate and boric acid were incorporated into soil during final pot preparation.

3.10 Transplanting of seedlings

Healthy and uniform 30 days, old seedlings were uprooted separately from the seed bed and were transplanted in the experimental pot in the afternoon of November 2015. Each pot contains one healthy plant. The seedbed was watered before uprooting the seedlings so as to minimize damage of the roots.

3.11 Intercultural operation

After transplanting of seedlings, various intercultural operations such as irrigation, weeding, staking and top dressing of urea. were accomplished for better growth and development of the tomato seedlings. Over-head irrigation was provided with a watering cane to the pots once immediately after transplanting of seedlings in every alternate day in the evening up to seedling establishment. Further irrigation was provided when needed.

3.11.1 Staking When the plants were well established, staking was given to each plant by dhaincha *(Sesbania sp.)* sticks to avoid lodging of the plant. Within a few days of staking, as the plants grew up, the plants were monitored and intercultural management practices according to necessity.

3.11.2 Weeding

Weeding was done to keep the pots clean and maintaining easy aeration of soil which ultimately facilitated better crop growth and development of plant. The newly emerged weeds were uprooted carefully. Mulching for breaking the crust of the soil was done when needed.

3.11.3Top dressing of urea fertilizer

After basal dose, the remaining doses of urea were used as top-dressed in 3 equal installments at 20, 30 and 40 DAT. The fertilizers were applied on the top soil and mixed well with the soil. Mixing up operation was done immediately after adding the nitrogenous fertilizer.

3.11.4 Control of pest and disease

Malathion57 EC was applied @ 2 ml/L against the insect pests like cut worm, leaf hopper and fruit borer .The insecticide application was made fortnightly from one week of after transplanting to a week before first harvesting. During foggy weather precautionary measured against disease infection of tomato was taken by spraying DithaneM-45 fortnightly @ 2 g/L. Ridomil gold was also applied @ 2 g/L against blight disease of tomato.

3.12 Harvesting

Fruits were harvested at 3 day intervals from early ripe stage when they attained slightly red color. Harvesting was started from 26 February 2016 and was continued up to 25 March, 2016.

3.13 Collection of data

Plant from each pot was selected and tagged for data collection. Some data were collected from sowing to harvesting with 10-days intervals and some data were collected at harvesting stage. Data were collected on the following parameters:

1. Plant height (cm)
2. No. of leaves /plant.
3. No. of branches /plant
4. No. of flower cluster/ plant
5. No. of flower/plant
6. No. of fruits/plant
7. Individual fruit weight (g)
8. Total yield/plant (g)

3.13.1 Plant height

Plant height was measured from the sample plants in centimeter from the ground level to the tip of the longest stem and mean value was calculated.

3.13.2 Number of leaves /plant

The number of leaves/plant was counted from the ground level to the tip of the longest stem and mean value was calculated.

3.13.3 Number of branch /plant

The number of Branches/plant was counted from the ground level to the tip of the longest stem and mean value was calculated.

3.13.4 Number of flower clusters/ plant

The number of flower clusters was counted from the sample plants and the average number of flower clusters produced per plant was calculated.

3.13.5 Number of flowers per plant

The numbers of flowers per cluster was counted and mean value was calculated

3.13.6 Number of fruits in clusters per plant

The number of fruits was recorded from each plant, and the total number of fruit per plant was recorded.

3.13.7 Single fruit weight

The weight of fruit was recorded with an electric balance from each plant and their average was calculated in gram (g).

3.13.8 Fruit yield per plant

An electric balance was used to take the weight or fruits per plant. It was measured by totaling of fruit yield from each unit pot during the period from the first to the final harvest and was recorded in gram (g).

3.14 Statistical analysis

The data of different parameters were statistically analyzed to find out the significant difference due to different treatments on yield and yield contributing characters of tomato. The mean values of all the characters were calculated and analysis of variance was performed by the ‘F’ (variance ratio) test. The significance of the difference among the treatment means was estimated by the Duncan’s Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984)

Chapter 4

RESULTS AND DISCUSSIONS

This Chapter includes the experimental results along with discussions. Individual and combined effects of Zn and B on plant height, number of branches per plant, number of leaf per plant, number of clusters per plant, number of flowers per cluster, number of fruits per plant, weight of fruit per plant, and fruit yield per pot. The data are presented in tables and are discussed character wise under the following heads.

4.1 Plant height

Plant height of tomato significantly increased due different levels of zinc application (Table 4)..With increasing the levels of zinc, plant height increased significantly up to $Zn_{4.5}$ treatment and the maximum plant height was (31.0 cm) and the lowest(18.6)was obtained from the control (Zn_0) treatment. Mondal *et al. (*1992) found that plant height of tomato was increased up to the highest level of zinc.

Different levels of boron showed statistically significant differences for plant height (Table 4). With increasing the doses of boron, the plant height increased significantly up to $B_{3.0}$treatment. Thus the maximum plant height was obtained from $B_{3.0}$(31.0cm) and the lowest from the B_0 (21.9 cm).

Combined effect was also recorded between zinc and boron in consideration of plant height and it found the significant variation (Table 5). The maximum plant height (36.7 cm) was recorded from treatment combination $Zn_{4.5}B_{3.0}$which is statistically similar to $Zn_{4.5}B_{1.5}$ treatment. The minimum plant height (11.0cm) was recorded from treatment combination Zn_0B_0. These results showed that higher dose of zinc and boron increased the plant height.

4.2 Number of leaves/plant

A statistically significant variation was recorded for the effect of zinc in terms of number of leaves per plant (Table 4). The highest number of leaves (28.2) was observed with from $Zn_{4.5}$ treatment which was statistically identical (26.2) with $Zn_{1.5}$ treatment and the lowest number of leaf (19.0) was recorded from Zn_0 treatment (zn control) .

In case of different levels of boron, statistically significant variation was found for the number of leaves per plant (Table 4). The highest number of leaves (29.3) was recorded from $B_{3.0}$treatment comprising 3.0 kg B/ha .The lowest number of leaves (17.3) was due to B_0 treatment (control) condition under the present trial. With increasing levels of boron, the number of leaves also increases and the differences were significant between the treatments.

Combined application of different doses of zinc and boron on the number of leaves per plant showed a statistically significant variation (Table 5). The highest number of leaves (37.6) was recorded from treatment combination $Zn_{4.5}$ $B_{3.0}$, while the lowest number of leaves (12.0) was recorded from treatment combination Zn_0B_0 (control) treatment. These results revealed that higher dose of zinc and boron increased the number of leaf.

4.3 Number of branches/plant

A statistically significant variation was recorded for the effect of zinc on the number of branches/plant (Table 4). The maximum number of branches (3.66) was recorded from $Zn_{4.5}$ treatment which was statistically similar with treatment $Zn_{1.5}$ and $Zn_{3.0}$ .The minimum number of branches (2.00) was recorded from Zn_0 treatment (control) condition. Similar result was reported by Yadav *et al* (2001[b]).

Different levels of boron showed statistically significant differences for number of branches/plant (Table 4). The maximum number of branches (3.50) was recorded from $B_{3.0}$ treatment which was statistically similar (2.91) with $B_{1.5}$ treatment, while the minimum number of branches (2.00) was recorded from B_0treatment (control) which was also statistically similar (2.91) with $B_{1.5}$treatment .With increasing levels of boron number of branches also increases.

The effect of integrated use of zinc and boron on number of branches of tomato is presented in (Table 5) .The maximum number of branch (4.66) was recorded from treatment combination Zn B 4.5kg Zn/ha + 3.0 kg B/ha, while the minimum number of branch (1.66) was recorded from treatment combination Zn_0B_0 i.e without any zinc and boron. These results revealed that higher dose of zinc and boron increased the number of branch.

4.4 Number of flower clusters/ plant

The effect of zinc on number of flower clusters per plant was influenced significantly (Table 4). The highest number of flower cluster per plant (4.88) was demonstrated by the from treatment which was statistically significant from the treatments $Zn_{1.5}$ and $Zn_{3.0}$. Plants in control (Zn_0) treatment the lowest number of flower clusters per plant (2.11), which was statistically similar with $Zn_{1.5}$ and $Zn_{3.0}$ treatments. It is evident from the results that the increasing application of Zn increased the number of flower cluster per plant.

Boron fertilizer had significant effect on the number of flower clusters per plant (Table 4). The highest number of flower cluster per plant (3.83) was resulted from the treatment $B_{3.0}$, which was statistically similar with $B_{1.5}$treatment and the minimum number of flower cluster per plant (2.91) was produced by the B_0 (control) treatment which was statistically similar with $B_{1.5}$treatment. The number of flower clusters per plant increased with increasing level of B.

Integrated effect of zinc and boron on the number of flower clusters per plant was found significantly different (Table 5). The $Zn_{4.5}B_{1.5}$treatment produced the maximum number of flower clusters per plant (5.66), which was statistically similar with $Zn_{1.5}B_{3.0}$, $Zn_{4.5}B_0$ and $Zn_{4.5}B_{3.0}$treatments. The lowest number of flower cluster per plant (1.66) was obtained from Zn_0B_0, which was similar with $Zn_0B_{1.5}$, $Zn_0B_{3.0}$, $Zn_{1.5}B_0$, $Zn_{1.5}B_{1.5}$, $Zn_{3.0}B_0$ and $Zn_{3.0}B_{1.5}$ treatments. It was further observed that the second highest number of flower cluster per plant was found (4.66) in treatment $Zn_{4.5}B_{3.0}$.

Table no 4: Single effects of zinc and boron on Plant height, number of leaves, number of branches and number of flower clusters per plant in tomato.

Treatment	Plant height (cm)	Number of leaves/plant	Number of Branches/Plant	Number of flower cluster/plant
Zinc				
Zn_0	18.6 b	19.0 b	2.00 b	2.11 b
$Zn_{1.5}$	30.2 a	26.2 a	2.77 ab	3.44 b
$Zn_{3.0}$	30.0 a	21.2 b	2.77 ab	3.11 b
$Zn_{4.5}$	31.0 a	28.2 a	3.66 a	4.88 a
$SE_{(+,-)}$	0.913	0.621	0.195	0.215
CV (%)	4.54 %	9.80%	27.6%	27.4%
Boron				
B_0	21.9 c	17.3 c	2.00 b	2.91 b
$B_{1.5}$	29.0 b	24.4 b	2.91 a b	3.41 a b
$B_{3.0}$	31.0 a	29.3a	3.50 a	3.83 a
$SE_{(+,-)}$	0.360	0.669	0.223	0.267
CV (%)	4.54%	9.80%	27.55%	27.4%

In a column the figures having similar letters(s) do not differ significantly at 5% level of significance as per DMRT.

Table no 5:Combinedeffects of zinc and boron on Plant height, number of leaf, number of branches and number of flower clusters per plant in tomato.

Treatment Combination	Plant height (cm)	Number of leaves/plant	Number of Branches/Plant	Number of flower clusters/plant
Zn_0B_0	11.0 g	12.0 f	1.66 e	1.66 e
$Zn_0B_{1.5}$	18.0 f	22.7 c d	2.00 d e	2.00 d e
$Zn_0B_{3.0}$	26.7 d	22.3 c d	2.33 c d e	2.66 c d e
$Zn_{1.5}B_0$	27.3 d	22.7 c d	2.00 d e	3.33 b c d e
$Zn_{1.5}B_{1.5}$	31.3 c	29.3 b	3.00 b c d e	2.66 c d e
$Zn_{1.5}B_{3.0}$	32.0bc	32.7 b	3.33 a b c d	4.33 a b c
$Zn_{3.0}$ B_0	37.3 d	16.3 e f	2.00 d c	2.33 d e
$Zn_{3.0}$ $B_{1.5}$	32.3 b c	22.7 c d	2.66 b c d c	3.33 b c d e
$Zn_{3.0}$ $B_{3.0}$	30.3 c	24.7 c	3.66 a b c	3.66 b c d
$Zn_{4.5}$ B_0	22.0 e	18.0 d e	2.33 c d e	4.33 a b c
$Zn_{4.5}$ $B_{1.5}$	34.3 a b	23.0 c	4.00 a b	5.66 a
$Zn_{4.5}B_{3.0}$	36.66 a	37.7 a	4.66 a	4.66 a b
SE (0.05)	0.720	1.338	0.446	0.5358
CV %	4.54%	9.80%	27.6%	27.4%

In a column the figures having similar letters(s) do not differ significantly at 5% level of significance as per DMRT.

4.5 Number of flowers/ plant

The number of flowers per plant varied significantly with the application of different levels of zinc (Table 6). The maximum number of flowers (29.9) per plant was recorded from $Zn_{4.5}$ treatment which was not statistically similar with other treatments and the minimum number of flower (12.4) per plant was recorded from Zn_0 treatment which was significantly lower than that obtained from other treatments. The $Zn_{1.5}$ and $Zn_{3.0}$ treatments save number of leaves /plant.

Application of B fertilizers at different doses showed a significant variation in the number of flowers per plant (Table 6). The maximum number of flowers (23.8) per plant was recorded from $B_{3\cdot0}$ which was closely (23.6) followed by the $B_{1.5}$ treatment. On the other hand the minimum number of flowers (14.5) per plant was recorded from B_0 treatment which was not statistically similar with other treatments. With increasing the levels of boron, the number of flowers per plant increased and the variations due to different levels of boron were statistically significant.

Combined application of different doses of zinc and boron on number of flowers showed a statistically significant variation. The highest number of flowers (37.3) per plant was recorded from treatment combination $Zn_{4.5}B_{1.5}$which was statistically similar with $Zn_{4.5}B_{3.0}$treatment.On the other hand, the lowest number of flowers (10.0) per plant was observed with Zn_0B_0 (Table 7). The second highest number of flowers (32.3) was noted in $Zn_{4.5}B_{3.0}$ treatment. This result reveals that higher dose of zinc and boron influenced the plant growth and ultimately number of flowers per plant.

4.6 Number of fruits/ plant

The effect of different levels of Zn application on the number of fruits per plant was significant (Table 6). The number of fruits per plant increased with increasing levels of zinc up to $Zn_{4.5}$ treatment. The highest number of fruit per plant (25.2) was obtained from $Zn_{4.5}$ treatment, which was statistically different from the other zn treatments. The lowest number of fruits per plant (8.66) was produced by control (Zn_0) treatment, which was statistically similar with $Zn_{1.5}$ treatment. It was observed that the higher application of Zn increased the number of fruits per plant. Similar result was reported by Yadav *et al*, (2001[b])

Like zinc effects, the effect of different levels of boron on the number of fruits per plant was found positive and significant (Table 6). The number of fruits per plant increased with increasing levels of boron application. The highest number of fruits per plant (19.3) was obtained from the $B_{3.0}$ treatment, which was statistically similar with $B_{1.5}$ treatment. The lowest number of fruits per plant (11.3) was found in control (B_0) treatment.

The interaction effect of different Zn-B treatment combinations on the number of fruit per plant was significant (Table 7). The highest number of fruits per plant (31.0) was found in $Zn_{4.5}B_{1.5}$ treatment, which was statistically similar with the second highest (27.3) number of fruits due to $Zn_{4.5}$ $B_{3.0}$. The lowest number of fruit per plant (7.00) was produced by the control (Zn_0B_0) treatment, which was not statistically different from the effect of treatment combinations of $Zn_0B_{1.5}$, $Zn_0B_{3.0}$, $Zn_{1.5}B_0$, $Zn_{1.5}B_{1.5}$ and $Zn_{3.0}B_0$.

4.7 Yield of fruits /plant

The yield of fruits per plant varied significantly with the application of Zinc in tomato (Table 6). The highest Yield of fruit (696g) per plant was recorded from $Zn_{4.5}$ treatment which was statistically similar (653g) with $Zn_{1.5}$ treatment and (660 g) with $Zn_{3.0}$ treatment. The lowest yield of fruit (528 g) per plant was obtained from Zn_0 treatment which differed statistically with other treatments.

Different levels of boron application showed statistically significant differences in fruit yield per plant. The highest fruit yield (671g) per plant was observed with $B_{1.5}$treatment which was statistically similar (667 g) with $B_{3.0}$ treatment (Table 6). On the other hand the lowest fruit yield (592 g) per plant was noted with B_0treatment. With increasing levels of boron application plant growth increased which impacted on the number of flowers and fruits per cluster as well as the fruit yield per plan

Combined effect of different doses of zinc and boron on the yield of fruit per plant was significant (Table 7). The highest yield of fruits (798 g) per plant was due to $Zn_{4.5}B_{1.5}$ treatment combination which was statistically similar with the treatments $Zn_{3.0}B_{3.0}$. On the other hand, the lowest yield of fruit (446 g) per plant was obtained from the Zn_0B_0treatment combination. This result indicates that higher dose of zinc and boron positively influential on thegrowth , flowering and yield of fruit per plant.

Table no 6: Single effects of zinc and boron on the number of flowers, number of fruits and yield of fruit/plant.

Treatments	Number of flowers/plant	Number of fruits/plant	Yield of fruit/plant (g)
Zinc			
Zn_0	12.4 c	8.7 c	528 b
$Zn_{1.5}$	18.0 b	12.6 c	653 a
$Zn_{3.0}$	22.1 b	18.1 b	660 a
$Zn_{4.5}$	29.9 a	25.2 a	696 a
SE(+-)	1.125	1.028	16.117
CV (%)	16.2%	17.3%	6.07%
Boron			
B_0	14.5 b	11.3 b	592 b
$B_{1.5}$	23.6 a	17.9 a	672 a
$B_{3.0}$	23.8 a	19.3 a	667 a
SE(+-)	0.961	0.803	11.284
CV (%)	16.15%	17.3%	6.0%

In a column figures having similar letters(s) do not differ significantly at 5% level of probability as per DMRT.

Table no 7: Combined effects of zinc and boron on the number of flowers, number of fruits and yield of fruit/plant

Treatment	Number of flowers/plant	Number of fruits/plant	Yield of fruits/plant (g)
Zn_0B_0	10.00 h	7.0 g	446 e
$Zn_0B_{1.5}$	12.7 g h	8.7 g	575 c d
$Zn_0B_{3.0}$	14.7 e f g h	10.33 f g	564 d
$Zn_{1.5}B_0$	14.3 e f g h	9.7 g	650 b c
$Zn_{1.5}B_{1.5}$	18.7 d e f g	12.0 e f g	644 b c d
$Zn_{1.5}B_{3.0}$	21.0 c d e	16.0 d e f	667 b
$Zn_{3.0}$ B_0	13.7 b c d	11.0 f g	653 b c
$Zn_{3.0}$ $B_{1.5}$	25.7 b c d	20.0 c d	670 b
$Zn_{3.0}$ $B_{3.0}$	27.0 b c	23.3 b c	764 a
$Zn_{4.5}$ B_0	20.0 c d e f	17.3 d e	619 b c d
$Zn_{4.5}$ $B_{1.5}$	37.3 a	31.0 a	798 a
$Zn_{4.5}B_{3.0}$	32.3 a b	27.3 a b	672 b
SE(+-)	1.922	1.607	22.568
CV (%)	16.15%	17.25%	6.07%

In a column figures having similar letters(s) do not differ significantly at 5% level of probability as per DMRT.

Chapter 5

Summary and Conclusion

A pot experiment was conducted in the net house of Soil Science Department at Sher-e-Bangla Agricultural University, Dhaka, during the period from November 2015 to March 2016 to study the effects of zinc and boron on the growth and yield of tomato. The experiment was designed in a Completely Randomized Design (CRD) with three replications. There were 36 earthen pots altogether and 14 kg soil was taken in each earthen pot. There were 12 treatment combinations comprising 4 levels of Zn (0, 1.5, 3.0& 4.5 kg/ha designated as $Zn_{0,}$ $Zn_{1.5}$, $Zn_{3.0}$ & $Zn_{4.5}$ respectively) and 3 levels of B (0, 1.5 & 3.0 kg/ha designated as B_0, $B_{1.5}$& $B_{3.0}$respectively). The individual and combined effects of zinc (Zn) and boron (B) on tomato were studied.

Plant height of tomato was significantly increased by different levels of zinc application. The tallest plant (31.0 cm) was produced by the $Zn_{4.5}$ treatment and shortest plant (18.6 cm) was found in control (Zn_0) treatment. Plant height increased with increasing levels of boron. The tallest plant (31.0 cm) was resulted from $B_{3.0}$ treatment and the shortest plant (21.9cm) was found in control (B_0) treatment. The treatment combination of zinc and boron had significant effect on plant height. The tallest plant (36.7 cm) was found in $Zn_{4.5}B_{3.0}$ treatment and the shortest plant (11.0 cm) was observed in the control (Zn_0B_0) treatment. The second highest plant (34.3cm) was observed in the treatment $Zn_{4.5}B_{1.5}$.

The effect of Zn on the number of leaves/plant was influenced significantly. The highest number of leaf (28.2) was observed with the treatment $Zn_{4.5}$ and the lowest number of leaves per plant (19.0) was noted in zn_0 treatment. Boron fertilizer had also significant effect on number of leaves per plant. The maximum number of leaves per plant (29.3) was recorded with the $B_{3.0}$ treatment and the minimum number of leaves per plant (17.3) was produced in control (B_0).The treatment$Zn_{4.5}B_{3.0}$ produced the maximum number of leaves per plant (36.7) and the lowest number of leaves per plant (11.0) was obtained from the treatment Zn_0B_0.

The number of leaf branches/plant increased with levels of Zn. The maximum number of branches (3.66) was recorded from $Zn_{4.5}$treatment. The minimum number of branches (2.00) was observed in Zn_0 treatment (control). Different levels of boron showed statistically significant differences for the number of branches/plant. The maximum number of branches (3.50) was observed from $B_{3.0}$ treatment while the minimum number of branches (2.00) was observed in B_0 treatment. The treatment$Zn_{4.5}B_{3.0}$ produced the maximum number of leaf branches per plant (4.66) and the lowest number of branch per plant (1.66) was obtained from the treatment Zn_0B_0.

The effect of Zn on the number of flower clusters was influenced significantly. The highest number of cluster (4.88) was recorded from the $Zn_{4.5}$ treatment and the lowest number of flower clusters per plant (2.11) was noted in Zn_0 treatment. Boron fertilizer had also significant effect on the number of clusters per plant. The maximum number of clusters per plant (3.83) was recorded from the treatment $B_{3.0}$ and the minimum number of clusters per plant (2.91) was produced in control (B0) treatment. The treatment combination $Zn_{4.5}B_{1.5}$ produced the maximum number of clusters per plant (5.66) and the Zn_0B_0 (control) treatment had the lowest number of leaves per plant (1.66).

The number of flowers per cluster progressively increased with increasing levels of Zn. The maximum number of flowers per cluster (29.9) was produced by $Zn_{4.5}$ treatment and the minimum number of flowers per cluster (12.4) was observed in control (Zn_0). Again, the maximum number of flowers per cluster (23.8) was found in $B_{1.5}$ treatment and the minimum number (14.5) was observed in B_0 control treatment. Integrated effect of Zn and B on the number of flowers per cluster was significant. The highest number of flowers per cluster (37.3) was found in $Zn_{4.5}B_{1.5}$ treatment and the treatment combination Zn_0B_0 gave the lowest number of flowers per cluster (10.0).

The effect of Zn-B treatments on the number of fruits per cluster was significant. There were significant differences between the different levels of zinc in respect of the number of fruits per plant. The highest number of fruits per plant (25.2) was obtained from $Zn_{4.5}$treatment and the minimum number of fruits per plant (8.66) was found from control (Zn_0) treatment. The number of fruits per plant increased with increasing level of boron application up to the highest level. The maximum number of fruits per plant (19.3) was obtained from B_3 treatment and the minimum number of fruits per plant (11.3) was found in control (B_0) treatment. The combined effect of zinc and boron on the number of fruits per plant was significant. The maximum fruits per plant (31.0) was obtained from $Zn_{4.5}B_{1.5}$ treatment and the minimum number of fruits per plant (7.0) was produced by the control (Zn_0B_0) treatment.

There was a significant positive effect on the yield of tomato. The maximum weight of fruit (696 g) was produced by $Zn_{4.5}$ treatment and the minimum weight of fruit (528) was found in control (Zn_0) treatment. Fruit weight increased with increasing levels of boron. The maximum weight (666.9 g) was obtained from $B_{3.0}$ treatment and minimum (591.8 g) was found in control (B_0) treatment. The treatment combinations of Zn and B had significant effect on the yield of fruit. The maximum weight (798 g) was found in $Zn_{4.5}B_{1.5}$treatment and the minimum (446 g) was observed in the control (Zn_0B_0) treatment. The second highest fruit (672 g) was observed in the treatment of $Zn_{4.5}B_{1.5}$. These results showed that higher dose of zinc and boron application significantly increasing the yield of fruit.

From the present study, the following conclusion has been undertaken.

• The Individual effect of Zn and B on the yield of tomato was found positive and significant.

• The combined effect of Zn and B enhanced the yield and yield attributes of tomato.

• Application of Zn @ 4.5 kg/ha and B @ 1.5 kg/ha was the most suitable combination to give the highest yield of tomato.

Further research works at different regions of the country are needed for confirmation of the present findings.

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Appendix 1: Analysis of variance of the data on plant height, number of leaves, number of branches and number of flower clusters of tomato as influenced by Zinc and Boron.

Source of variance	Degree of freedom	Mean Square			
		Plant height	**Number of leaves**	**Number of branches**	**Number of Flowers cluster**
Block	2	1.694	3.583	0.528	0.528
Zinc (A)	3	317.704*	165.111*	4.176*	11.889*
Boron(B)	2	292.528*	443.083*	6.861*	2.528*
Interaction (A×B)	6	38.898	38.417	2.722	1.083
Error	13	1.556	5.375	9.556	0.861

Appendix 2: Analysis of variance of the data on Number of Flowers, number of fruits and yield of tomato fruit as influenced by Zinc and Boron

Source of variance	Degree of freedom	Mean Square		
		Number of Flowers	**Number of Fruits**	**Yield of Fruits**
Block	2	1.778	3.444	770.250
Zinc(A)	3	485.519*	465.213*	56611.296*
Boron(B)	2	336.194*	220.444*	24095.083*
Interaction(A x B)	6	38.380	30.296	9297.602
Error	13	11.083	7.750	1527.972

Appendix Fig 1: Tomato experiment in the net-house

Appendix Fig 2: Flowering of tomato Plant

Appendix Fig 3 : Fruiting of tomato plant

Appendix Fig 4: Harvesting of tomato