PRODUCTIVITY AND PROFITABILITY OF TOMATO AS INFLUENCED BY MICRONUTRIENTS

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JUNE, 2016

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Reg. No.: 10-04095

A Thesis
Submitted to the Department of Horticulture,
Sher-e-Bangla Agricultural University, Dhaka
In partial fulfillment of the requirements
for the degree
of

MASTER OF SCIENCE (MS)
IN
HORTICULTURE

SEMESTER: JANUARY - JUNE, 2016

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CERTIFICATE

This is to certify that the thesis entitled **"PRODUCTIVITY AND PROFITABILITY OF TOMATO AS INFLUENCED BY MICRONUTRIENTS"** submitted to the Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE** in **HORTICULTURE**, embodies the result of a piece of *bona fide* research work carried out by **ISHRAT JAHAN BANNY**, Registration No. **10-04095** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

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ACKNOWLEDGEMENT

The author deems it a much privilege to express her enormous sense of gratitude to the almighty creator for there ever ending blessings for the successful completion of the research work.

The author feels proud to express her deep sense of gratitude, sincere appreciation and immense indebtedness to her supervisor **Dr. Tahmina Mostarin,** Professor, Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka, for her continuous guidance, cooperation, constructive criticism and helpful suggestions, valuable opinion in carrying out the research work and preparation of this thesis, without her intense co-operation this work would not have been possible.

The author feels proud to express her deepest respect, sincere appreciation and immense indebtedness to her co-supervisor **Dr. Mohammad Humayun Kabir**, Associate Professor, Department of Horticulture, SAU, Dhaka, for her scholastic and continuous guidance during the entire period of course, research work and preparation of this thesis.

The author expresses her sincere respected Chairman, Department of Horticulture, SAU, Dhaka, for valuable suggestions and cooperation during the study period and also expresses her heartfelt thanks to all the teachers of the Department of Horticulture, SAU, for their valuable teaching, suggestions and encouragement during the period of the study.

The author expresses her sincere appreciation to her father Md. Abdur Rashid Akando, beloved mother Most. Monowara Begum, friends, relatives and well-wishers.

The Author

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ABSTRACT

The experiment was conducted in the Horticultural Farm of Sher-e-Bangla Agricultural University, Dhaka during the period from October 2015 to March 2016 to find out the productivity and profitability of tomato as influenced by micronutrients. This is a single factor experiment and consisted of 11 treatments. The treatments are the combination of different doses of micronutrients according to North Caroline University law, USA. The treatments are **T_0:** Zn_0 B_0 Cu_0 kg ha^{-1}, **T_1:** Zn_0 B_4 Cu_2 kg ha^{-1}, **T_2:** Zn_4 B_4 Cu_2 kg ha^{-1}, **T_3:** Zn_6 B_4 Cu_2 kg ha^{-1}, **T_4:** Zn_8 B_4 Cu_2 kg ha^{-1}, **T_5:** Zn_8 B_0 Cu_2 kg ha^{-1}, **T_6:** Zn_6 B_2 Cu_0 kg ha^{-1}, **T_7:** Zn_6 B_6 Cu_2 kg ha^{-1}, **T_8:** Zn_6 B_4 Cu_0 kg ha^{-1}, **T_9:** Zn_6 B_4 Cu_1 kg ha^{-1} and **T_{10}:** Zn_6 B_4 Cu_3 kg ha^{-1}. Recommended doses of cowdung, Urea, TSP and MP were also used as basal dose. The experiment was laid out in Randomized Complete Block Design with 3 replications. Maximum number of clusters $plant^{-1}$ (9.35), number of flowers $cluster^{-1}$ (7.75), number of fruits $cluster^{-1}$ (4.25), individual fruit weight (92.50 g), dry matter content of fruit (15.37 %), TSS (8.76 %), yield of fruit $plant^{-1}$ (2.88 kg), and the maximum yield $hectare^{-1}$ (96.00 t/ha), were recorded from the T_3 treatment while the minimum results were observed from the T_0. From economic point of view, the treatment **T_3** gave the highest economic return (Tk. 674944 ha^{-1}) with 2.37 BCR. So, economic analysis revealed that the treatment combination of T_3 appeared to be the best for achieving higher productivity and profitability of tomato.

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LIST OF ACRONYMS

ABBREVIATIONS	ELABORATIONS
AEZ	Agro-Ecological Zone
Anon.	Anonymous
ANOVA	Analysis of Variance
@	at the rate of
a.i	Active ingredient
Adv.	Advanced
Agron .	Agronomy
Agric.	Agriculture Agricultural
Agril.	Agricultural
BRRI	Bangladesh Rice Research Institute
BARI	Bangladesh Agricultural Research Institute
SAU	Sher-e-Bangla Agricultural University
BAU	Bangladesh Agricultural University
BBS	Bangladesh Bureau of Statistics
RCBD	Randomized Complete Block Design
CV	Coefficient of Variation
cv.	Cultivar
EC	Emulsifiable Concentrate
cm	Centimeter
df	Degrees of Freedom
DAS	Days After Sowing
LSD	Least significance difference
et al.	and others
etc.	etcetera
FAO	Food and Agricultural Organization
Fig	Figure
ns	Non Significant

ABBREVIATIONS	ELABORATIONS
J.	Journal
PP.	Pages
g	Gram
ha^{-1}	Per hectare
t	Ton
%	Percent
m^2	Square meter
pod^{-1}	Per pod
J.	Journal
kg	Kilogram
No.	Number
NS	Non Significant
NOS	Number of species
^0C	Degree Celsius
Res.	Research
RH	Relative humidity
WCE	Weed control efficiency
SRDI	Soil Resource Development Institute
Sci.	Science 's
HI	Harvest Index
Vol.	Volume

CHAPTER I

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) is one of the most important and popular vegetables in Bangladesh. It is a member of the Solanaceae family which possesses versatile use. Due to the excellent adaptability to wider range of soil and climatic conditions it is widely grown in winter in any parts of the world (Ahmed, 1976). The climatic condition of Bangladesh favours tomato to grow in winter season and it can be cultivated in all parts of the country (Haque *et al.,* 1999). It originated in tropical America (Salunkhe *et al.,* 1987), mainly in the region of the Andes Mountain in Peru and Bolivia. It ranks third, next to potato and sweet potato, in terms of world vegetable production (FAO, 2003) and as a processing crop ranks first among the vegetables (Choudury, 1979 and Shanmugavelu, 1989). The present leading tomato producing countries of the world are China, USA, India, Egypt, Turkey, Iran, Italy, Mexico and Brazil (FAO, 2003).

Tomato is very popular because of its high nutritive value and diversified use. Its food value is very high as it contains vitamins A, B, C, calcium and minerals (Bose and Som, 1990) and it keeps eye sight good. Tomato contains lycopene pigment which is a vital anti-oxidant that helps to fight against cancerous cell formation as well as other kind of health complications and diseases (Kumavat and Chaudhari, 2013). It is also used as vegetable, raw salad or as processed food items such as sauce, soup, juice, ketchup, pickles, paste, puree, powder, jam, and jelly. Nutritional value of red tomatoes (raw) per 100 g contains 18 kcal energy, 4.0 g carbohydrates, and 2.6 g sugars, 1.0 g dietary fiber, 0.2 g fat, 1.0 g protein, 95 g water, 13 mg vitamin C (Zhang *et al.,* 2009). Food value of tomato is generally dependent on its chemical composition such as dry matter, titratablc acidity, total sugar, total soluble solids and ascorbic acids etc. Excellent nutritional and processing qualities have made tomato demandful in both domestic and foreign markets.

According to BBS (2015), tomato covered 75602 acres of land and the total production was approximately 413610 metric tons. Thus, the average yield of 5471kg/acre which is quite low as compared to that of other tomato producing countries. The low yield of tomato in Bangladesh, however, is not an indication of low potentiality of this crop, but it may be due to a number of reasons, *viz.* unavailability of quality seeds of improved varieties, nonjudicious use of micronutrient fertilizers and improper management. Fertilizer management practices are one of the most important cultural practices particularly in tomato due to the intensive cropping and gradual decline in soil nutrients. This situation can be alleviated by proper fertilizer management practices (Tindall, 1983).

Micronutrients have an important role on plant growth specially in the physiology of tomato crop and are required for plant activities such as aspiration, meristamatic development, chlorophyll formation, photosynthesis, gossypol, tannin and phenolic compounds development (Anon., 1995) in nutrient deficient soil. Adequate supply of nutrient can increase the yield, fruit quality, fruit size, keeping quality, colour and taste of tomato (Shukla and Naik, 1993). The micronutrients required for plants are iron, boron, manganese, copper, zinc and molybdenum. These are required in very small amounts and expressed as parts per million (ppm) in plant tissue.In Bangladesh, most of the soils have micronutrient deficiency. Moreover, these important components of soils are declining with time due to intensive cropping and use of higher doses of nitrogenous fertilizers with little or no addition of micronutrient fertilizer or organic manure. Unless due attention is paid to the maintenance of soil macro and micro nutrients, it may not be possible to achieve the goal of increased and sustained productivity. Efforts are needed to build-up and maintain a moderate level of soil nutrient status.

Micronutrient deficiencies is one of the major limiting factors for crop production in Bangladesh .Among micronutrients, Zinc, boron and copper are the most important nutrient elements for tomato production. Zinc is essential for normal plant growth and development as well as carbohydrates, protein metabolism and sexual fertilization of plant (Imtiaz *et al.*, 2003; Vasconcelos *et al.,* 2011). Zinc plays an important role directly and indirectly in improving the yield and quality of tomato in addition to checking various diseases and physiological disorders. Crops differ in their sensitivity to zinc deficiency. It gives a rosette appearance and yellowing between veins of new growing leaves occur in plant (Marchner, 1995), while B deficiency reduced yield and quality in tomatoes (Davis *et al.,* 2003).Boron is another important element for tomato as fruit vegetable. A positive correlation was observed between boron and flower bud, number of flowers and weight of fruit in tomato (Bose *et al.,* 2002), while other scientist observed significant positive interaction between fertilizer treatments and physiological stages of crop growth. Copper nutrient plays a pivotal role in the growth and development of plants and a necessary redox element taking part in a wide variety of processes, comprising of respiration and photosynthesis or the detoxification of superoxide radicals(Fox and Guerinot, 1998).(Atta-Aly *et al*.,1991) pointed that supplementing nutrient solution with a low level of cobalt (0.25 ppm) improved growth of tomato plants and enhanced both flowering and fruiting. (Basavarajeshwari *et al*., 2008) showed that best treatment was the mixture of micronutrients (Bo and Zn @ 100ppm) recording fruit yield of 27.98 t/ha and differed significantly from the control as well as other treatments.

Numerous research works have been carried out on fertilizer requirements and the effect of fertilizers on growth and yield of tomato in developed countries but information on systematic research in this context in Bangladesh is limited. Therefore, the present study was undertaken with the following objectives:

- To study the effect of Zinc, boron and copper on the productivity of tomato.
- To findout the profitability by using these micronutrients on tomato production.

CHAPTER-II

REVIEW OF LITERATURE

Tomato is one of the most popular and quality vegetables grown in Bangladesh which received much attention to the researchers throughout the world. Numerous investigators in various parts of the world have investigated the response of tomato to different levels of micronutrients for its successful cultivation. Micronutrients play an important role for proper growth, development, flowering, fruiting and different metabolic processes of plants. However, available literature on tomato and some other related crops which are relevant to the present study have been reviewed in this chapter.

2.1 Effect of zinc on tomato

Zinc plays a fundamental role in several critical functions in the cell such as protein metabolism, gene expression, structural and functional integrity of biomembranes and photosynthetic carbon metabolis. Some of metabolic changes brought about by Zn deficiency could be well explained by the function of Zn as a structural component of a special enzyme or involvement in specific steps in particular metabolic pathways. However, there are changes in the synthesis and metabolism of Zn-deficient plants that could not be explained directly by the presence of Zn in the metabolic pathway or enzyme structure. Such responses are regarded to be rather indirect effects of Zn deficiency. Concerning the central role of Zn in stability of biomembranes and proteins. Zn deficiency can affect the photochemical processes in the thylakoids, and thus inhibits biophysical processes of photosynthesis. The flow of electrons through PSII is indicative of the overall rate of photosynthesis and is an estimation of photosynthetic performance.

Sultana *et al.* (2016) found that the tomato yield and its contributing yield traits were significantly affected by foliar fertilizer treatments as against soil application of B and Zn fertilizers. Among various treatments, foliar application of Zn (0.05 %) + B (0.03%) produced maximum fruit yield (85.5 and 81.7 t ha^{-1} in 2013 and 2014, respectively) while the control no application of Zn (0.0) and B (0.0) produced 66.8 and 60.7 t ha^{-1} in 2013 and 2014, respectively and it was statistically identical with soil application of B and Zn @ 2 and 6 kg ha^{-1} (T5), respectively. The increment of yield was 19.2 to 31.1% and 7.57 to 18.3%, respectively, over control and soil application. The integrated use of foliar application of micronutrients and soil application of macronutrients are recommended to enhance tomato yield.

Harris and Mathuma (2015) conductd an experiment on effects of foliar application of boron, zinc and their combinations on growth and yield of tomato cv. Thilina. Treatments; T1-B (150 ppm), T2-B (250 ppm), T3-B (350 ppm), T4-Zn (150 ppm), T5-Zn (250 ppm), T6-Zn (350 ppm), T7-B (150 ppm)+Zn (150 ppm), T8-B (250 ppm)+Zn (250 ppm), T9-B (350 ppm)+Zn (350 ppm) and T10- Control. The results revealed that foliar application of Zn alone at 250 ppm resulted in the maximum plant height, total dry weight, number and fresh weight of fruits/ plant. Foliar application of B at 250 ppm increased dry weight of leaves/ plant and dry weight of stem/ plant, and dry weight of roots/plant were high in both B at 250 ppm and Zn at 150 ppm. In all parameters, the lowest performance was recorded in the control treatment. The results also revealed that under the conditions in the experiment, yield could be increased by the application of Zn at the rate of 250 ppm at flowering stage.

Ali *et al.* (2015) conducted an experiment to increase the yield of BARI hybrid tomato 4, cultivated in summer season of Bangladesh, foliar application of zinc and boron [T0: control; T1: 25-ppm ZnSO4 (Zinc Sulphate); T2: 25-ppm H_3BO_3 (Boric Acid) and T3: 12.5-ppm $ZnSO_4$ + 12.5-ppm H_3BO_3] was done. Maximum plant height (106.9 cm), number of leaves (68.9/plant), leaf area (48.2 cm^2), number of branches (11.9/plant), number of clusters (21.6/plant), number of fruits (1.8/clusters and 33.6/plant), fruit length (5.3 cm), fruit diameter (5.1 cm), single fruit weight (60.4 g) and yield (1.9 kg/plant, 25.7 kg/plot and 58.3 t/ha) were found from foliar application of 12.5-ppm $ZnSO_4$ + 12.5-ppm H3BO3 while minimum from control. Early flowering (49.3 days) and minimum diseased infested plant (9.4%) were also found from foliar application of 12.5-ppm $ZnSO_4$ + 12.5-ppm H_3BO_3.Combined foliar application of zinc and boron was more effective than the individual application of zinc or boron on growth and yield for summer season tomato (BARI hybrid tomato 4).

Ullah *et al.* (2015) found that among different levels of Zn 0.4% showed significant increased in number of flowers cluster plant^{-1} (27.45), number of flowers cluster^{-1}(5.66), number of fruits cluster 1(4.57), number of branches plant^{-1} (7.36) and yield (t ha^{-1}) (23.40). Boron also significantly affected growth and yield components. Among different levels of boron 0.15% showed significant increased in number of flowers cluster plant^{-1}(27.55), number of fruits cluster^{-1}(4.40) and yield (t ha^{-1}) (23.33). Based on the above results it can be recommended that Zn @ 0.4% and B @ 0.15% should be combinely applied to tomato for better growth and yield under the agro climatic conditions of Peshawar.

Shnain *et al.* (2014) conducted an experiment with nine treatments with following combination of which was T1 (control),T2(Zn 1.25 g/L), T3 (Zn 2.0 g/L), T4 (B 1.25g/L),T5 (B 1.25g/L + Zn 1.25 g/L),T6 (B 1.25 g/L),T7 (B 2.0g/L),T8 (B 2.0g/L + Zn 1.25g/L) and T9 (B 2.0 g/L + Zn 2.0 g/L). The cultivar of tomato was "heem shona" Syngenta Company. The highest fruit weight (72.67 g) was recorded in T6 and the highest plant height (2.93) m, No. leaves per plant (39.33) leaves, No. clusters per plant (12.33), No. fruits per cluster (7.17), No. fruit per plant (88.33), yield per plant (6.33 kg), total yield (113.628 t /ha) shelf life (26.33 days) Total soluble solid (0Brix) (5.67) Vitamin C (32.57 mg / 100 g) and benefit: cost ratio (4.05 was obtained in T5 treatment under Allahabad agro climatic conditions.

Kazemi (2013) showed that high Zn (100 mg/L) and Fe (200 mg/L) and their combination significantly promoted vegetative and reproductive growth. Foliar application of Zn (100 mg/L) + Fe (200 mg/L) resulted in the maximum plant height (124.14 cm), branches per plant (8.36), flowers per cluster (18.14), fruits per cluster (8), fruits per plant (90.14), fruit weight (95.14 g), chlorophyll content (22.14 SPAD) and yield (25.14 t ha^{-1}). Fe and Zn alone or in combination had significant effect on leaves-NK content and nitrate reductase activity. The highest TSS (5.87 °Brix), TA (4 %), pH (2.61 %), fruit firmness (3.66 kg cm^{-2}) and fruit lycopene content (2.25 mg/100 g) were observed when tomato plants treated with 100 mg/L Zn+200 mg/L Fe, thus it was recommended to apply foliar application of Zn and Fe in order to improve growth, flower yield, quality and chemical constituents in tomato plants.

Sivaiah *et al*. (2013) found in tomato cv. UtkalKumari, maximum growth rate (85.7%) was observed with application of zinc, followed by application of micronutrients mixture (78.2%) and boron (77.5%). Tomato cv. Utkal Raja, maximum increase in branches per plant was observed with the application of manganese (148.7%) followed by micronutrient combination (144.1%). In UtkalKumari, the fruit yield per plant ranged from 1.336 kg to1.867 and in Utkal Raja, it ranged from 1.500 kg to 1.967 kg. In both the varieties, combined application of micronutrients produced the maximum fruit yield followed by application of boron and zinc.

Gurmani *et al.* (2012) conducted a glasshouse pot experiment to study the effect of soil applied zinc (@ 0, 5, 10 & 15 mg kg^{-1}) on the growth, yield and biochemical attributes in two tomato cultivars; VCT-1 and Riogrande. The result showed that zinc application increased the plant growth and fruit yield in both cultivars. Maximum plant growth and fruit yield in both cultivars were achieved by the Zn application at 10 mg kg^{-1} soil. Application of 5 mg Zn kg^{-1} had lower dry matter production as well as fruit yield when compared with Zn 10 and 15 mg kg^{-1}. The percent increase of fruit yield at 5 mg Zn kg^{-1} was 14 and 30%, in VCT-1 and Riogrande, respectively. In the same cultivars, Zn application @ 10 mg Zn kg^{-1} caused the fruit yield by 39 and 54%, while 15 mg Zn kg^{-1} enhanced by 34 and 48%, respectively. Zinc concentration in leaf, fruit and root increased with the increasing level of Zn. Zinc application at 10 and 15 mg kg^{-1} significantly increased chlorophyll, sugar, soluble protein, superoxide dismutase and catalase activity in leaf of both cultivars. The results of the study suggested that soil application of 10 mg Zn kg^{-1} soil have a positive effect on yield, biochemical attributes and enzymatic activities of both the tomato cultivars.

Sbartai *et al.* (2011) conducted an experiment to evaluate the response of tomato plants (*Lycopersicon esculentum* L. var. Rio Grande) to treatment with zinc and accumulation (trace element) in the roots and leaves of young plants. This is done by analyzing the effects of zinc on the rate of chlorophyll and enzyme activity involved in the antioxidant system (CAT, GSH, APX). Plants previously grown on a basic nutrient solution is treated by increasing concentrations of $ZnSO_4$ (0, 50, 100, 250, 500 microM) for 07 days. The results showed that Zn does not affect the amount of chlorophyll at 50 and 100 microns, while it seems to inhibit the higher concentrations (250 and 500 microns). On the other hand, treatment with zinc induced the activity of enzymes studied, namely (CAT, APX, GSH) especially for higher concentrations. Finally, the determination of zinc in the roots and leaves of tomato shows a greater accumulation in the roots compared to leaves.

Ejaz *et al.* (2011) found that individual application of nutrient provide better results as compared to control but their combined effect (Zn = 6%, B = 5%, N = 2%) provided substantial results in plant heights, no. of leaves, no of flowers, no of fruits, average fruit weight and yield per plant. It is confirmed from the results that combination of macro-nutrients and micro-nutrients as foliar application has the ability to enhance the growth and yield of tomato positively.

Patil *et al*. (2010) was conducted an experiment to evaluate the effect of foliar application of micronutrients on flowering and fruit-set of tomato. They have showed the flowering parameters like days required for initiation and 50 percent flowering, number of clusters, number of flowers, total number of flowers and fruit setting percentage per plant were influenced significantly due to different treatments. The minimum number of days (30.00) for initiation of flowering and 50% flowering (38.86) were recorded with Boron 50ppm and 100ppm while the maximum number of days were recorded in control. The treatment Boron 100ppm + Iron 200ppm + Zinc 200ppm was most effective in increasing number of clusters (13.85) and number of flowers (51.24) per plant. Maximum number of flowers per cluster and percent fruit setting (47.76%) was recorded with Boron 50ppm + Iron 100ppm+ Zinc 100ppm, while minimum was recorded in control.

Tavassoli *et al*. (2010) performed an experiment to investigate zinc (Zn) and manganese (Mn) nutrition effects on greenhouse tomato in a perlite-containing media. Experimental treatments were: (1) control (Mn and Zn – free nutrition solution), (2) Application of Mn in a concentration equal to the full Hoagland's nutrient solution (4.06 mg/L), (3) application of Zn in a concentration equal to the full Hoagland's nutrient solution (4.42 mg/L), (4) application of Mn and Zn in concentrations equal to the 50% Hoagland's nutrient solution (2.03 mg/L Mn + 2.21 mg/L Zn), and (5) application of Mn and Zn in a concentration equal to the full Hoagland's nutrient solution (4.06 mg/L Mn + 4.42 mg/L Zn). Results showed that the highest fresh-fruit yield and leaf dry matter and content of Mn and Zn in fruit were obtained from single or combined application of Mn and Zn in concentrations equal to the full Hoagland's nutrient solution. In addition, Zn and Mn nutrition significantly affected the fruit concentrations of crude protein, nitrogen and phosphorus, while the effect of these treatments on fruit size of tomato was not significant.

Salam *et al.* (2010) found the highest pulp weight (88.14%), dry matter content (5.34%), TSS (4.50%), acidity (0.47%), ascorbic acid (10.95 mg/100g), lycopene content (112.00 µg/100g), chlorophyll-a (41.00µg/100g), chlorophyll-b (56.00 µg/100g), marketable fruits at 30 days after storage (67.48%) and shelf life (16 days) were recorded with the combination of 2.5 kg B+ 6 kg Zn/ha and recommended dose of NPK fertilizers (N= 253, P= 90, and K= 125 kg/ha).

Patnaik *et al.* (2001) reported in tomato the application of ZnSO4 @ 12.5 kg ha^{-1} to soil followed by foliar sprays of 0.2% ZnSO4 and 0.5% FeSO4 thrice at weekly intervals has resulted in higher fruit yield of 39.88 t ha^{-1} with a maximum yield response of 39 per cent.

Makhan *et al*. (2000) was conducted a field experiment for the response of foliar application of micronutrients on tomato variety at Vegetable Research Farm and Laboratory of CCS Haryana Agricultural University. The experiment was laid out randomized block design with three replications consisting of eight treatments of micronutrients and control making a total nine treatments. The treatments were ammonium molybdate, borax, copper sulphate, ferrous sulphate, manganese sulphate, zinc sulphate, mixture of all micronutrients and control. The micronutrients were applied as foliar spray @5 g per liter (0.5%) at the interval of ten days i.e. 40, 50, 60 days after transplanting. Mixture was made by taking all the micronutrients in equal proportion i.e. 0.83 g and mixed thoroughly. Five weeks old seedlings were transplanted for the experimentation. The result indicates that application of all the micronutrients, significantly enhanced plant height over control. Highest increase in plant height (54.80 cm) was recorded with application of Zinc sulphate. They have concluded that Zinc may serve as source of energy for synthesis of auxin which helps in elongation of stem.

Cakmak *et al.* (1999) reported that zinc also helps in various metabolic processes; its deficiency inhibits growth and development of plants.

Singh and Verma (1991) observed highest yield and optimum plant growth in cultivar Pusa Ruby of tomato cultivar by soil application of K at 120 kg ha^{-1}, Zn at 10 kg ha^{-1} and B at 2 kg ha^{-1} alone or in combination.

Das and Patro (1989) reported in marglobe cultivar of tomato, highest yield (298 q ha^{-1}) were obtained by spaying urea at 2% alone or combination with micronutrients. 0.075% Mo, 0.10% Zn, 0.25% B and 0.04% Cu and also reduced the wilt infection by 23.6% compared with 35.46% in the control.

2.2 Effect of boron on tomato

Boron is an essential micronutrient required for normal plant growth and development. It performs a wide range of functions in tomato plants. It is a very sensitive element and plants differ widely in their requirements but the ranges of deficiency and toxicity are narrow. It maintains a balance between sugar and starch in plant body. It translocates sugar and carbohydrates in different parts of the plant body. It is important in pollination and seed production. It is necessary for normal cell division, nitrogen metabolism and protein formation. It is essential for proper cell wall formation. Boron plays an important role in the proper function of cell membranes and the transport of K to guard cells for the proper control of internal water balance. The requirements of B in vegetables generally more than other corps.

Sakamoto (2012) conducted a study to demonstrate the only role of B in plants as the structural maintenance of cell wall. The author stated that soil B, as boric acid, is acquired through roots and then distributed around the plant via the passive and active transport pathway. To adapt variations in the environmental B status, the active B transport system is tightly regulated at the molecular level in plants. In agriculture, both deficient and excess levels of soil B impair plant growth, resulting in the reduction of quantity and quality of crops. The major causes of B toxicity in plants contain oxidative stress, metabolism alteration and deoxyribonucleic acid damage.

Naz *et al.* (2012a) conducted a study to observe the effect of Boron (B) on the growth and yield of Rio Grand and Rio Figue cultivar of tomato at Horticultural Research Farm, NWFP Agricultural University, Peshawar during 2008- 2009. Different doses of B (0, 0.5, 1.0, 2.0, 3.0 and 5.0kg ha^{-1}) with constant doses of nitrogen, phosphorus and potash was incorporated at the rate of 150, 100, 60 kg ha^{-1}. The experiment was laid out in Randomized Complete

Block Design with 2 factors. Boron showed a significant effect on the growth and yield of tomato. However, 2 kg B ha^{-1} resulted in maximum number of flower clusters per plant, fruit set percentage, total yield, fruit weight loss and total soluble solid. Rio Grand cultivar of tomato showed significant effect on all parameters. Maximum number of flower clusters per plant, fruit set percentage and total yield were recorded with Rio Grand cultivar of tomato. Finally, authors concluded that 2 kg B ha^{-1} significantly affected flowering and fruiting of Rio Grand cultivar.

Luis *et al.* (2012) conducted a study to evaluate the effect of boron on two variety of tomato. The objective of this research was to study the how B toxicity (0.5 and 2 mM B) affects the time course of different indicators of abiotic stress in leaves of two tomato genotypes having different sensitivity to B toxicity (cv. Kosaco and cv. Josefina). Under the treatments of 0.5 and 2 mM B, the tomato plants showed a loss of biomass and foliar area. At the same time, in the leaves of both cultivars, the B concentration increased rapidly from the first day of the experiment. These results were more pronounced in the cv. Josefina, indicating greater sensitivity than in cv. Kosaco with respect to excessive B in the environment. The levels of (O_2 and anthocyanins presented a higher correlation coefficient ($r>0.9$) than did the levels of B in the leaf, followed by other indicators of stress, such as GPX, chlorophyll b and proline ($r>0.8$). Their results indicate that these parameters could be used to evaluate the stress level as well as to develop models that could help to prevent the damage inflicted by B toxicity in tomato plants.

Kumari (2012) Foliar application of boron was found to be the best treatment for enhancing germination percentage whereas multiplex treatment was best for increasing seedling length.

Gurmani *et al*. (2012) designed a glasshouse pot experiment, with two tomato cultivars VCT-1 and Riogrande, to assess the effects of four levels of soil application of B (0, 0.5, 1.0 and 1.5 mg kg^{-1}) in the form of borax on plant growth, biochemical content, antioxidant activity and fruit yield. Higher plant growth and fruit yield in both cultivars were achieved by the B 1.0 and 1.5 mg kg^{-1} soil application respectively. Application of 0.5 mg B kg^{-1} had lower dry matter production as well as fruit yield when compared with B 1.0 and 1.5 mg kg^{-1}. The percent increase of fruit yield at 0.5 mg B kg^{-1} was 12 and 10, in VCT-1 and Riogrande respectively. In the same cultivars, B application @ 1.0 mg B kg^{-1} caused the fruit yield by 23 and 21% while 1.5 mg B kg^{-1} enhanced by 22 and 20% respectively. Boron concentration in leaf, fruit and root increased with the increasing level of B. Boron application at 1.0 and 1.5 mg kg^{-1} significantly increased chlorophyll, sugar and protein content in both cultivars. Superoxide dismutase and catalase activity was significantly increased by the soil application of 1.5 mg B kg^{-1} in both cultivars of tomato. The study results showed that soil application of 1.0 mg B kg^{-1} soil have positive effect on plant growth, yield and biochemical.

Naz *et al*. (2012b) conducted a study to observe the effect of Boron on physiological growth on tomato. Tomato crop requires heavy manure and sufficient amount of fertilizers for higher yield. For improving plant growth and development, use of organic and inorganic manure or fertilizers is essential. It is well established that chemical fertilizers improve plant growth directly by providing nutrients. Like the other nutrients, Boron also plays an important role in production of any crop in terms of yield, quality and control of some diseases. Boron plays an essential role in the development and growth of new cells in the meristem, proper pollination and fruit or seed set, translocation of sugar, starches, nitrogen and phosphorus, synthesis of amino acids and proteins, regulation of carbohydrate metabolism and stabilize the oxidative system in plants.

Farzaneh *et al.* (2011) conducted a completely randomized factorial experiment with 16 treatments and three replicates to study the effect of nitrogen and boron on yield, shoot and root dry weights and leaf concentration of nutrient elements in hydroponically grown tomato in greenhouse of Agricultural College of Zanjan University in 2000. In this experiment, tomato seed of Rio Grande Ug was selected and simple and interaction effect of four levels of N (100, 200, 300 and 400 mgL^{-1}) and four levels of B (0.5, 1.0, 1.5 and 2.0 mg L^{-1}) on tomato yield, shoot and root dry weights and leaf concentration of nutrient elements was investigated. The results indicated that the simple and interaction effect of nitrogen and boron on yield and tomato shoot and root dry weights were significant. Te highest yield and root dry weights were obtained in N200B1.0 treatment and the highest shoot dry weight was obtained in N300B1.0 treatment. By increasing the nitrogen level in the nutrient solution, leaf N and Mn concentration increased while B, Fe and Zn concentration of leaves decreased significantly. In contrast, by increasing the boron levels, leaf N, B and Zn concentration increased and Fe and Mn concentration of leaves decreased significantly. With respect to the results of this study, applications of 200 mgL^{-1} N and 1.0 mgL^{-1} B of nutrient solution are recommended to obtain higher yield and better quality for tomato in hydroponic culture.

Nada *et al*. (2010) conducted a study to clarify a critical concentration of excess boron (B) in nutrient solution for hydroponically cultured tomato. The study also investigated the influences of excess B on growth, photosynthesis and fruit maturity. In tomato topped at the first truss, B concentrations higher than 2 ppm in nutrient solution resulted in a significant increase in leaf B concentration. At the fruit developmental stage, fresh weights of leaf and fruit were suppressed at 8 ppm and 4 ppm B in nutrient solution, respectively. Photosynthetic rate, respiration rate and stomatal conductance decreased with excess B at 4 ppm or higher concentration from the first truss flowering stage to fruit developmental stage. When tomato was topped at the second truss and limited to two fruits in each truss, excess B did not affect fruit growth or maturation in the first truss. However, fruit size and Brix were reduced in the second truss. These may be caused by decrease in the photosynthate distribution to fruit in the second truss because of the decrease in photosynthetic activity. Furthermore, excess B could promote fruit maturity in the second truss because of production of ethylene with increase in injured leaves. Based on these results, the authors suggest that the critical concentration of B in nutrient solution is 4 ppm for long-term hydroponic cultivation of tomatoes.

A field experiment was conducted by Huang and Snapp (2009) in 2002 and 2003 to evaluate the effects of K and B on yield and quality of fresh market tomatoes cv. 'Mountain Spring' at southwest Michigan with well-drained soil (Alfisol Hapludalf, Oakville fine sand). Treatments applied during fruit development included three fertigation regimes (1N:0.8K, 1N:1.7K, and 1N:2.5K) in the presence and absence of a weekly foliar spray of B (300 mg). Increasing K concentration in the fertilizer increased K content in leaf tissue, but in some cases reduced tissue calcium (Ca) and B. Fruit quality was influenced by nutrition, as the greatest rate of K was associated with increased crack susceptibility as indicated by a fruit bioassay and a 14% increase in incidence of the defect ''shoulder check'' in field-grown fruit compared to less rates of K nutrition. Boron foliar spray increased tomato marketable yield and fruit quality, reducing shoulder check incidence by 50% compared to zero-B treated plants in 2003. Because of yield and quality improvements, B was a cost effective treatment as shown by partial budget analysis, whereas increasing K nutrition did not provide consistent economic benefits. Moderate K rates were associated with the greatest marketable yield, and the 1N:1.7 K plus foliar B nutrient regime produced the greatest quality fruit. Overall data were consistent with the need to carefully evaluate K and B nutrition in tomatoes, in the context of soil type, yield potential, fruit quality, and nutrition regime.

Patil *et al.* (2008) conducted a field experiment to study the effect of foliar application of micronutrients on growth and yield of tomato (Megha) during 2005-06 and 2006-07 at the All India Co-Ordinated Vegetable Improvement Project (AICVIP) in the University of Agricultural Sciences, Dharwad. The results based on two years mean revealed that out of nine different treatments, the application of boric acid @ of 100ppm resulted in maximum number of primary branches (18.30), yield per plant (2.07 kg) and fruit yield (30.50 t/ha).

Followed by best treatment was the mixture of micronutrients (Bo, Zn, Mn and Fe @ 100ppm and Mo @ 50ppm) recording fruit yield of 27.98 t/ha and differed significantly from the control as well as other treatments.

Jyolsna and Mathew (2008) conducted a pot culture experiment to study the effects of 0, 0.5, 1.0, and 1.5 kg B ha^{-1} with recommended doses of chemical fertilizers (75:40:25 N, P_2O_5 and K_2O kg ha^{-1}; RDF) and RDF + farmyard manure (FYM; 25 tons ha^{-1}) on growth, yield, and quality of tomato as well as the B status of a lateritic soil in southern Kerala. Boron significantly increased plant height and number of primary branches. It also reduced the days to flowering and increased fruit set (12.5 to 20% more at the highest level) both with and without FYM. Benefit–cost ratio was 40% greater for the highest level of B when applied in conjunction with RDF compared with RDF alone (no B). Quality parameters like reducing sugars, total sugars, vitamin C, and lycopene concentrations also improved following B application. Nevertheless, B availability in these soils attained sufficiency levels (2 mg kg^{-1}) at 0.5 kg ha^{-1} of applied B, implying the need to exercise caution especially when applying higher doses

Hossein (2008) conducted a field experiment at Horticultural farm, BAU, Mymensingh during 2007-2008 to evaluate the effect of Zn and B on the growth and yield of Tomato. The treatments were four levels of Zn (0, 0.5, 1.0 and 1.8 kg ha^{-1}) and four levels of B (0, 0.1, 0.3 and 0.6 kg ha^{-1}). The highest fruit yield (74.88 t ha^{-1}) was obtained due to the application of 1.8 kg Zn and 0.1kg B ha^{-1}.

Kamruzzaman (2007) conducted a field experiment on tomato at the field laboratory of Crop Botany Department, BAU, Mymensingh during 2006-07. The experiment comprised of four levels of boron viz. @ 0, 0.4, 0.6 and 0.8 kg B ha $^{-1}$ as foliar application. Application of standard dose of boron Ca. 0.4 kg B ha^{-1} was found to produce highest fruit yield (2166.6 kg ha^{-1}).

Kumari and Sharma (2006) carried out an experiment in summer season of 2004 to study the effect of boron, zinc, molybdenum, copper, iron, manganese, mixture of all and multiplex through foliar sprays on plant growth, fruit and seed yield of tomato. All the treatments were given at a concentration of 100 ppm starting from 30 days after transplanting and repeated twice at 10 days interval. The recommended dose of NPK. i.e. 100 kg N, 75 kg P_20_5 and 55 kg K_2O/ha were uniformly applied in all the treatments including control where no spray of micronutrients was done. All the characters viz plant height (cm), days taken to first flowering, number of branch/ plant, fruit/plant, fruit yield/plant, yield/ha except seed vigour index showed significant variations. Foliar application of boron @ 100 ppm concentration at 30 days after transplanting and repeated at 10 days interval twice was found most effective for growth and seed yield with net return of Rs. 150811/ha with cost: benefit ratio of 1: 2.13.

Shah (2006) conducted a field experiment at the Horticulture farm, BAU, Mymensingh during the rabi season, 2005-06. There were 5 levels of NPKS and B fertilizers *viz*. i) N (0, 190, 253 and 317 kg ha^{-1}); ii) P (0, 66, 88 and 110 kg ha^{-1}); iii) K (0, 94, 125 and 154 kg ha^{-1}); iv) S (0, 15, 20 and 25 kg ha^{-1}) and v) B (0, 1.5, 2 and 2.5 kg ha^{-1}) in the 17 selected treatments. The different combinations of NPKS and B exhibited significant variation in respect of all the characters. The maximum number of flowers and matured fruits per plant were obtained from the treatment (N253 P88 K125 S20 B2 kg ha^{-1}). Importantly the plants fertilized with the same treatment gave the maximum fruit yield (62.69 ton ha^{-1}).

Yadav *et al.* (2006) evaluated the effects of boron (0.0, 0.10, 0.15, 0.02, 0.25, 0.30 or 0.35%), applied to foliage after transplanting, on the yield of tomato cv. DVRT-1 in Allahabad, Uttar Pradesh, India, during 2003-04. The highest number of fruits per plant (44.0), number of fruits per plot (704.0), yield per plant (0.79kg), yield per plot (12.78kg) and yield ha^{-1} (319.50 quintal) were obtained with 0.20% boron, whereas the greatest fruit weight (27.27g) was recorded for 0.10% boron.

Sathya (2006) conducted an experiment to evaluate the various levels of B on yield of PKM1 tomato. The results revealed that the highest fruit yield of 33 t ha^{-1} was recorded in treatment that received borax @ 20 kg ha^{-1} and was found to be significantly superior to rest of the treatments (0, 5, 10, 15 and 25 kg ha^{-1}). The yield increase was about 33.6 per cent over control.

Bhatt and Srivastava (2005) investigated the effects of the foliar applications of boron (boric acid), zinc (zinc sulfate), molybdenum (ammonium molybdate), copper (copper sulfate), iron (ferrous sulfate), manganese (sulfate), mixture of these nutrients, and Multiplex (a commercial micronutrient formulation) on the nutrient uptake and yield of tomato (Pusa hybrid-1) in Pantnagar, Uttaranchal, India, during the summer of 2002 and 2003. Zinc, iron, copper, boron and manganese were applied at 1000 ppm each, whereas molybdenum was applied at 50 ppm. Foliar spraying was conducted at 40, 50 and 60 days after transplanting. All treatments significantly enhanced dry matter yield, fruit yield and nutrient uptake over the control. The mixture of the micronutrients was superior in terms of dry matter yield of shoot (53.25 g ha^{-1}); dry matter content of shoot (27.25%); nitrogen (152.38kg ha^{-1}), phosphorus (47.49kg ha^{-1}), potassium (157.48 kg ha^{-1}), sulfur (64.87 kg ha^{-1}), zinc (123.70 g ha^{-1}), iron (940.36 g ha^{-1}), copper (72.70 g ha^{-1}), manganese (359.17 g ha^{-1}) and boron (206.58 g ha^{-1}) uptake by shoots; total fruit yield (266.60 kg ha^{-1}); dry matter yield of fruit (1698 kg ha^{-1}); manganese (34.08 g ha^{-1}) and boron (95.23 g ha^{-1}) uptake by fruits.

Basavarajeshwari *et al.* (2008) carried out a field experiment to study the effect of foliar application of micronutrients on growth and yield of tomato at the all Indian Coordinated Vegetables Improvement Project (AICVIP) in the University of Agricultural Sciences, Dharwad. The result based on two years mean revealed that out of nine different treatments, the application of boric acid @ of 100 ppm resulted in maximum number of primary branches (18.30), yield per plant (2.07 kg) and fruit yield (30.50 t/ha). Followed by the best treatment was the mixture of micronutrients (Bo, Zn, Mn and Fe 100ppm and Mo @ 50ppm recording fruit yield of 27.98 t/ha and differed significantly from the control as well as other treatments.

Shoba *et al.* (2005) conducted a field experiment in Tamil Nadu, during the 2002 rabi season, to investigate the effects of calcium (Ca) and boron (B) fertilizer and ethrel (ethephon) applications and 45x45 and 65x45 spacing against fruit cracking in the tomato genotypes LCR I and LCR 1x H24. Between the 2 genotypes, the fruit cracking percentage was low in LCR xH24. Among the 2 spacing, closer spacing showed less fruit cracking and among the different nutrient treatments, the spraying of B with Ca was effective in controlling fruit cracking.

Smit and Combrink (2004) used four nutrient solutions with only B at different levels (0.02; 0.16; 0.32 and 0.64 mg l^{-1}) in greenhouse tomatoes planted in acid-washed river sand. 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. Fruit lacked firmness at the low B level and this problem worsened during storage. At the 0.16 mg kg^{-1} B-level, fruit set, fruit development, colour, 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. However using 'Solubor' as a source of B, high levels decreased soluble Mn concentrations in nutrient solutions, probably owing to the precipitation of insoluble MnO.

Oyinlola (2004) conducted a field trail in the Sudan savanna ecological zone in Nigeria to identify the effects of 0, 1, 2, 3, 4, and 5 kg B/ha on the growth, dry matter yield and nutrient concentration of tomato cultivars Roma VF and Dandino. Application of boron significantly ($P<0.05$) increased the number of leaves and dry matter yield of the crop. Nutrient concentration of potassium and phosphorus in the plant tissue fell within the deficiency range established for tomato plants, while calcium, magnesium, boron, zinc, manganese and copper concentrations fell within and iron concentration above the sufficient nutrient range. Significant correlation existed between growth, yield parameters and nutrient concentrations and also among the nutrient concentrations. Plants supplied with 2 kg B ha^{-1} recorded the highest number of leaves and dry matter yield than cv. Roma VF.

Oyinlola and Chude (2004) studied the effects of 0, I, 2, 3, 4 and 5 kg B/ha on the yield and biochemical properties of tomato cultivars Roma VF and Dandino. Matured ripe fruits were analysed for biochemical properties such as ascorbic acid, reducing sugar and total soluble solid content and titratable acidity. Boron rates significantly ($P<0.01$) increased the yield and yield attributes of the crop such as number of fruits and average weight of fruits, as well improved the biochemical properties of the fruits. In both years, the yield attributes of the crop such as number of fruits and average weight of fruits, as well improved the biochemical properties of the fruits. In both years, the highest fruit yield and best fruit quality were obtained at 2 kg B/ha. Fruit yield increased by 121 and 72% relative to the control in 1992/93 and 1993/94, respectively. Cultivar Dandino recorded higher ascorbic acid, total soluble solids, titratable acidity, reducing sugars and yield compared to cv. Roma VF, whereas cv. Roma VF flowered earlier than Dandino. Fruit yield correlated with all the yield attributes and biochemical properties determined for both years.

Paithankar *et al.* (2004) reported in tomato highest number of fruits (25.13) by spaying mixture of 0.1% boron and 3% DAP followed by less number of fruits (19.67%) in 0.2% borax and 3% DAP sprayed plants, compared to the control (17.40). He also reported more number of healthy fruits (18.13) in 0.1% borax and 3% DAP sprayed plants, compared to the control sprayed with water only (8.53).

Amarchandra and Verma (2003) conducted an experiment during the rabi seasons of 1998 and 1999 at Jabalpur, Madhya Pradesh, India, to evaluate the effects of boron and calcium on the growth and yield of tomato cv. Jawahar Tomato 99. Boron (1, 2, and 3 kg/ha, calcium carbonate), along with phosphorus (60 kg/ha) and potassium (40 kg/ha) were applied before transplanting, whereas nitrogen (100 kg/ha) was applied in split doses at 25 and 50 days after transplanting. Data were recorded for plant height, number of branches per plant, fruit yield and seed yield. Application of 2 kg B/ha + 2kg Ca/ha recorded the highest yield.

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 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.

Davis *et al.* (2003) carried out an experiment to compare the effects of foliar and soil applied B on plant growth, fruit yield, fruit quality, and tissue nutrient levels. Regardless of the application method, B was associated with increased tomato growth and the concentration of K, Ca and B in plant tissue. Boron application was associated with increased N uptake by tomato in field culture, but not under hydroponic culture. In field culture, foliar and/or soil applied B similarly increased fresh-market tomato plant and root dry weight, uptake and tissue concentrations of N, Ca, K, B and improved fruit set, total yields responses of tomato to foliar and root B application suggests that B is translocated in the phloem in tomatoes. Fruits from plants receiving foliar or root-applied B contained more B and K than fruits from plants not receiving B, indicating that B was translocated from leaves to fruits and is important factor in the management of K nutrition in tomato.

Naresh (2002) carried out an investigation in Nagaland, India during 1998-2000 to deteimine the effects of foliar application of boron (50, 100, 150, 200, 250 and 300 ppm) on the growth, yield and quality of tomato cv. Pusa Ruby. Boron improved the yield and quality of crop. The highest yield (327.18 and 334.58 q/ha) was obtained when the plant was drenched with 250 ppm aqueous solution of boron. B also had positive effects on plant height, number of branches, flowers and number of fruit set per plant, resulting in an increase in the number of fruits per plant and total yield. At lower rates, B improved the chemical composition of tomato fruits and at higher rates increased the total soluble solids, reducing sugar and ascorbic acid contents of the fruits. Acidity of fruits showed a marked increase with increasing levels of B up to 250 ppm. However, the significant effects of B were recorded in the second year only.

Alpaslam and Gunes (2001) investigation a greenhouse study to determine interactive effects of NaCl salinity and B on the growth, sodium (Na), chloride (Cl), boron (B), potassium (K) concentration and membrane permeability of salt- resistant tomato *(Lycopersicon esculentum* cv. Lale Fl). Plants were grown in a factorial combination of NaCl (0 and 40 mM for tomato) and B (0, 5, 10 and 20 mg kg^{-1} soil). Boron toxicity symptoms appeared at 3 mg kg^{-1} B treatments in tomato plants. Salinity caused an increase in leaf injury due to B toxicity. Dry weights of the plants decreased with the increasing levels of applied B in non-saline conditions. Salinity x B interaction on the concentration of B in tomato plants was found significant. B concentration of tomato decreased under saline conditions when compared to non-saline conditions. Salinity increased Na and Cl concentrations of tomato were not affected by salinity and B treatments. Membrane permeability of the plants was increased by salinity while toxic levels of B had no effect on membrane permeability in non-saline conditions. Membrane permeability was significantly increased in the presence of salinity by the increasing levels of applied B.

Cardozo *et al.* (2001) concluded the effects of Ca and B fertilizers on the productivity of tomato cv. Debora Max were investigated in Espirito Santo do

Pinhal, Sao Paulo, from April to July 2000. Aminobor at 300 ml/100 litres gave the highest value for fruit weight, while Ca at 60 g/100 litres and B at 150 g/ 100 litres recorded the highest number of fruits.

Chude and Oyinlola (2001) concluded that plant responses to soil and applied boron vary widely among species and among genotypes within a species. This assertion was verified by comparing the differential responses of Roma VF and Dandino tomato cultivars to a range of boron levels in field trials at Kadawa (11 degrees 39' N, 8 degrees 2' E) and Samaru (11 degrees 12', 7 degrees 3 7` 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. Total soluble solids, titratable acidity and reducing sugar contents of the two cultivars differed significantly (P=0.05). Dandino contained higher amounts of these indexes than Roma VF. This cultivars seems to be more B efficient than Roma VF even at low external B level.

Yadav *et al.* (2001) designed 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, 7.5 and 10.0 ppm) and four levels of boron (0, 0.50, 0.75 and 1.0 ppm) as soil application, as well as 0.5% zinc and 0.3% boron as foliar application. The highest fruit length, fruit breadth and fruit number were obtained with the application of 7.5 ppm zinc and 1.0 ppm boron.

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) was conducted 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.

Singaram and Prabha (1999) conducted a pot experiment using calcareous soil with tomato hybrid cv. Naveen (115 days duration) and non hybrid cv. Co 3 (105 days duration), to investigate the effects of B application either to the soil or as a foliar spray on B uptake, biomass and fruit yields. Application of borax increased B concentration of the shoot at both flowering and final harvest in both cultivars whereas in the roots, the treatments involving the soil application of borax produced higher concentration of B than the foliar spray of borax. The B concentration of the fruits was influenced by the treatments. The foliar application of borax was generally associated with higher B uptake in shoots as a result of the twin effects of high concentration in shoots combined with enhanced shoot dry matter. The application of borax generally increased the dry weight of tomato shoots at both the flowering and harvest stages. At 50% flowering and harvest application of borax at 20-30 kg/ha, or as foliar applications at 0.2-0.3% produced the highest dry weights. Fruit yield was highest in the hybrids but the response was similar to Co 3 whereas the maximum fruit yield, in contrast to shoot and root dry weight, and was obtained with the spray of 0.2-0.3% borax.

Plese *et al.* (1998) observed in a greenhouse trials in 1996, tomato cv. Diva was grown on a sandy red-yellow podzol and supplied with 0, 1.0 or 2.0 g B/pit (containing 2 plants) as boric acid, with or without foliar applications of 0.6% CaCl2 at intervals of 7 days or 14 days. Application of 1.0 g B/pit with foliar application of 0.6% CaCl2 at 14-day intervals or application of 0.6% CaCl2 at intervals of 7 days without B resulted in the lowest percentages of fruits affected by blossom-end rot (3.6 and 4.8%, respectively).

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).

Vasil *et al.* (1997) observed in the field experiments during 1994 and 1995 at the Agricultural Institute in Strumica, Republic of Macedonia, tomato cv. AT-70-14 on a low carbonate alluvial soil on 21 sq. m plots and given the following treatments: (1) control (no fertilizer); (2) N100 P100 K150; (3) NPK as (2) + 1% Mg; (4) NPK + 0.5% B; (5) NPK + 1% Mg + 0.5% B. Treatments 2-5 gave the higher yields than the control treatment in both years. The NPK + Mg + B fertilizer was calculated to be the most profitable treatment and is recommended for production of industrial tomatoes in Strumica.

Delibas and Akgun (1996) evaluated the effects of irrigation water with 0.5, 1.0, 2.5 or 4.0 ppm B on the growth and yield of tomato in Turkey under field conditions. The irrigation water with 1.0 ppm B was suitable for onion based on plant height, number of branches, stem radius, number of fruits, fruit yield, maturity, radius of fruit and fruit weight. Higher concentrations of B significantly reduced the evaluated parameters.

Efkar *et al.* (1995) conducted an experiment to investigate the responses of tomato cv. Desiree to the application of boron fertilizer in Pakistan using 4 levels of boron (0, 1, 1.5, and 2 kg B/ha). The crop also received a basal dressing of NPK fertilizers and FYM (5 t/ha). They evaluate that generally all the fertilizer treatments increased yield over control. Application of 1.5 kg B/ha gave the highest tuber yield of 10.9 t/ha compared with the control yield of 7.8 t/ha.

Paithankar *et al.* (1995) was conducted a field trial at the main garden of the Department of Horticulture, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, India in a randomized block design with 16 treatments and three replications to evaluate the effect of boron and diammonium phosphate (DAP) on the quality and performance of tomato. Foliar sprays of 0.1, 0.2 and 0.3% borax as well as 1, 2 and 3% DAP were given each alone and in combination at 60 days after transplanting. They have conclude that Borax at 0.3% provided the maximum fruit size and ascorbic acid content and the 0.3% borax + 3% DAP treatment recorded the maximum total soluble solids. The treatment 0.3% borax + 2% DAP reduced the cracking of fruits.

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 p.p.m. as H3BO3, and Ca at 0, 40, 80 and 160 p.p.m. 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 p.p.m. increased leaf number, stem diameter, number of flowers and fruit yield, and reduced per cent flower abortion. Boron application at rates higher than 2 p.p.m. 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. Calcium when applied singly at higher levels (80 and 160 p.p.m.) increased total chlorophyll content of the leaf. Tomato fruit yield was greatest (166 g/plant) at B:Ca treatment combination of 2 p.p.m. B (4.48 kg/ha) and 160 p.p.m. Ca (358.4 kg/ha Ca).

Pregno and Arour (1992) conducted an experiment to find out boron deficiency and toxicity in tomato cv. Sebago 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. They evaluated that total tuber yield was the 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.

Baevre (1990) reported that growing the glasshouse cultivar Jet in peat with different levels of B (1.4, 2.2 or 4.6 g/m3), reduced mean fruit weight and increased the proportion of fruits weighing 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 no significant effect on the relationship between seed weight/fruit and fruit weight.

Porter *et al.* (1986) conducted a field experiment to study the responses of tomato cv. Kathdin to B application. They evaluated that band application in a complete fertilizer was the most efficient technique and the tuber yield was not affected by application of <2.2 kg B/ha. They also evaluated that plants were stunted and yields reduced at application of > 4.5 kg B/ha. They concluded that reduced yield was associated with tubers per hill rather than the reduced tuber size.

Sahota and Grewal (1982) concluded that application of Zn and B significantly increased the tuber yields with NPK fertilizers on acidic brown hill soils at Shillong, India.

Kiryukhin and Bezzubtseva (1980) evaluated the responses of tomatoes to application of zinc and boron with NPK fertilizers on derho-podzolic soil in Moscow region. It was found that zinc and boron increased 9-12.9% and 5-13% average tuber yields, respectively over control. It was also found that Zn and B increased dry matter and starch, protein and ascorbic acid contents of tubers.

Sobulo (1975) obtained the highest yield of tomato when a mixture of NPK and 0.01% Borax was applied compared with mixtures of NPK and other micronutrients.

Gargantini *et al.* (1970) studied the effects of NPK and several micronutrients as basal dressing on tomato cv. Gunda and Feldslohn, grown under irrigation. They concluded that boron application increased tomato yield by 54% in

Gunda and 28% in Feldslohn as compared to NPK only. But application of Fe, Cu, Zn, and Mn had no significant effect.

Gjurov *et al.* (1996) reported increased yields in glasshouse tomatoes by steeping seeds for 18 hours in 0.02% boric acid followed by three foliar spray application of 0.015% solution. This increased the tomato fruit yields by 5.2 per cent.

Chenshen *et al.*, 1956 observed that, mixture of boron, copper, manganese and zinc of 10 to 20 ppm were applied at 10 days interval after transplanting of tomato seedlings. The combination of these micronutrients gave increased vigour and yield was 50 per cent or more over control.

Marx and Sutim (1950) said that the application of 114 mg of boric acid (solid) twice or four times to each plant in pots of good unfertilized garden soil was reported to have increased the yield of tomato plant grown in pots.

2.3 Effect of copper on tomato

Copper is necessary for carbohydrate and nitrogen metabolism. Inadequate copper results in stunting of plants. Copper also is required for lignin synthesis which is needed for cell wall strength and prevention of wilting. Deficiency symptoms of copper are dieback of stems and twigs, yellowing of leaves, stunted growth and pale green leaves that wither easily. Copper deficiencies are mainly reported on organic soils (peats and mucks), and on sandy soils which are low in organic matter. Copper uptake decreases as soil pH increases. Increased phosphorus and iron availability in soils decreases copper uptake by plants. Again excess copper may cause antagonistic effect on plants.

Harris and Lavanya (2016) evaluated that foliar application of boron, copper, and their combinations significantly influenced yield and quality parameters such as acidity, ascorbic acid, TSS and pH. Foliar application of Cu alone significantly enhanced ascorbic acid ($CuSO_4$ - 350 ppm) and TSS ($CuSO_4$- 250ppm)

Ashagr *et al.* (2013) investigated the effect of copper and zinc on germination, phytotoxicity, seedling vigor and tolerance. Copper and zinc concentrations significantly ($p<0.05$) decreased germination percentage and rate, shoot and root lengths, seedling vigor, and tolerance. However, toxicity percentage to shoot and root increased significantly ($p<0.05$) with increasing metals concentrations. Maximum germination, shoot and root lengths, tolerance, and seedling vigor were obtained with controls. Minimum value for the germination percentage (76.6%), germination rate(4.6plants/day), shoot and root lengths, tolerance and vigor were expressed at 600ppm - zinc; however, copper ≥300ppm induced total failure on tomato seeds germination. The highest toxicity to shoot (92.3%) and root (93.4%) appeared at 600ppm zinc, whereas ≥300 ppm copper caused 100% toxicity on shoot and root. 100ppm, copper was toxic to shoot (61%) and roots (85%), while zinc showed toxicity of 68% of shoot and 66% of root toxicity. Hence, other than 100ppm, copper is more toxic than zinc for germination and seedling growth of Roma VF.

Gad and Kandil (2010) evaluated the effect of copper and different sources of phosphorus fertilizers on the growth, yield quantity and quality of tomato. Treatments can be arranged in descending order as follows: Mono super phosphate (MSP) > Triple super phosphate (TSP) > Rock phosphate (RP). Mono super phosphate (MSP) had superior effect on all growth parameters of tomato shoots and roots yield quantity and quality as well as mineral nutrient constituents of tomato fruits compared with other phosphorus sources. Rock phosphate (RP) treatment gave the lowest values of tomato growth, yield, chemical constituents and mineral composition of tomato fruits. Copper addition enhanced all parameters of tomato growth and yield with all sources of phosphorus fertilizers especially with mono super phosphate.

Guang (2007) says plants are very much sensitive to copper. He also mentioned that 3 μ mol/L Cu^{2+} can restrict the root growth of tomato and decrease of chlorophyll and carotenoid in cabbage leaf. There was higher copper concentration in cabbage root, but lower in shoot. Copper concentration in plant roots and shoots increased with the increment of copper concentration in solution.

Sonmez *et al.* (2006) used copper-containing fertilizers, fungicides and bactericides extensively in greenhouses in Turkey to investigate effects of Cu application to a calcareous soil and to leaves on the yield and growth of tomato plants. Cu was first applied to soil as $CuSO_4.5H_2O$ in three different levels (0, 1000, and 2000 mg Cu kg^{-1}) and then to leaves in three different frequencies (no application, biweekly and weekly) using two cupric fungicides (Cu oxychloride, and Cu salts of fatty and rosin acids) in pot experiments carried out in a computer-controlled greenhouse. Total yield, fruit number, dry root weight and plant height decreased with increasing Cu application to soil. Increasing levels of Cu applied to soil and leaves resulted in decreasing final fruit number, dry root weight and plant height in 4th, 5th and 6th weeks. Combined applications of Cu to soil and leaves could be more deleterious to plants than when Cu is applied only to soil or leaves.

Nadia (2005a) indicated that, the rate of copper at 7.5 ppm significantly increased tomatoes, growth parameters, fruits yield, nutrient concentration as well as total soluble solids, total soluble sugars and L-Ascorbic acid while titratable acidity was decreased. On the other hand, higher copper addition in growing media resulted in a negative response.

Copper was shown to promote all growth parameters of tomato plants significantly in vegetative, flowering and fruiting stages (Nadia Gad, 2005 b).

Yong *et al.* (2004) reported that the whole volume of low concentration of copper (<70 mg/kg) had a significant increase in cabbage yield, high concentration (>100 mg/kg) caused cabbage cut. Copper stress caused a significant decline in cabbage root vigor and Chlorophyll value with increasing concentration of copper declined.

Boureto *et al.* (2001) found that, 2.5 ppm copper in sand culture was found to be promotive effect on the absorption of N, P and K content in tomato plants.

Mallic and Muthukrishnan (1980) observed application of Cu and Zn increased the titratable acidity in fruits of tomato. Application of copper, manganese and boron, separately and in combination to tomato seedlings at 2-6 leaf stage in the seed bed increased the marketable yields.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted during the period from October, 2015 to March, 2016 to study the productivity and profitability of tomato as influenced by micronutrients. This chapter includes materials and methods that were used in conducting the experiment and presented below under the following headings:

3.1 Location of the experimental field

The experiment was conducted at Horticultural farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during the period from October, 2015 to March, 2016. The location of the experimental site was at 23^0 $46'$ N latitude and 90^0 $22'$ E longitudes with an elevation of 8.24 meter from sea level.

3.2 Climate of the experimental area

The experimental area is characterized by subtropical rainfall during the month of May to September and scattered rainfall during the rest of the year. Information regarding average monthly temperature as recorded by Bangladesh Meteorological Department (climate division) during the period of study has been presented in Appendix I.

3.3. Soil of the experimental field

Soil of the study site was silty clay loam in texture belonging to series. The area represents the Agro-Ecological Zone of Madhupur tract (AEZ No. 28) with pH 5.8-6.5, ECE-25.28 (Haider, 1991). The analytical data of the soil sample collected from the experimental area were determined in the Soil Resources Development Institute (SRDI), Soil Testing Laboratory, Khamarbari, Dhaka and have been presented in Appendix II.

3.4 Plant materials collection

The tomato variety used in the experiment was "BARI Tomato-14". This is a high yielding semi-indeterminate type variety. The seeds were collected from Olericulture division of Horticulture Research Centre, Bangladesh Agricultural Research Institute (BARI) Joydebpur, Gazipur.

3.5 Treatments and design

The four levels of Zinc, four levels of Boron and four levels of copper fertilizers formed eleven (11) treatments according to the rules of soil science division, North Carolina University, USA are given below:

SL. No.	Name of Treatment	Name of fertilizer	Dose/ha (Kg ha^{-1})	SL. No.	Name of Treatment	Name of fertilizer	Dose/ha (Kg ha^{-1})
1	**T_0**	Zn B Cu	0 0 0	**7**	**T_6**	Zn B Cu	6 2 0
2	**T_1**	Zn B Cu	0 4 2	**8**	**T_7**	Zn B Cu	6 6 2
3	**T_2**	Zn B Cu	4 4 2	**9**	**T_8**	Zn B Cu	6 4 0
4	**T_3**	Zn B Cu	6 4 2	**10**	**T_9**	Zn B Cu	6 4 1
5	**T_4**	Zn B Cu	8 4 2	**11**	**T_{10}**	Zn B Cu	6 4 3
6	**T_5**	Zn B Cu	8 0 2				

The experiment was laid out in Randomized Complete Block Design (RCBD) having single factor with three replications. The whole experimental area was divided into three equal blocks. Each block was consists of 11 plots where 11 treatments were allotted randomly. There were 33 unit plots in the experiment. The size of each plot was 2 m x 1.8 m. The distance between two blocks and two plots were kept 1 m and 0.5 m respectively. A layout of the experiment has been shown in figure 1.

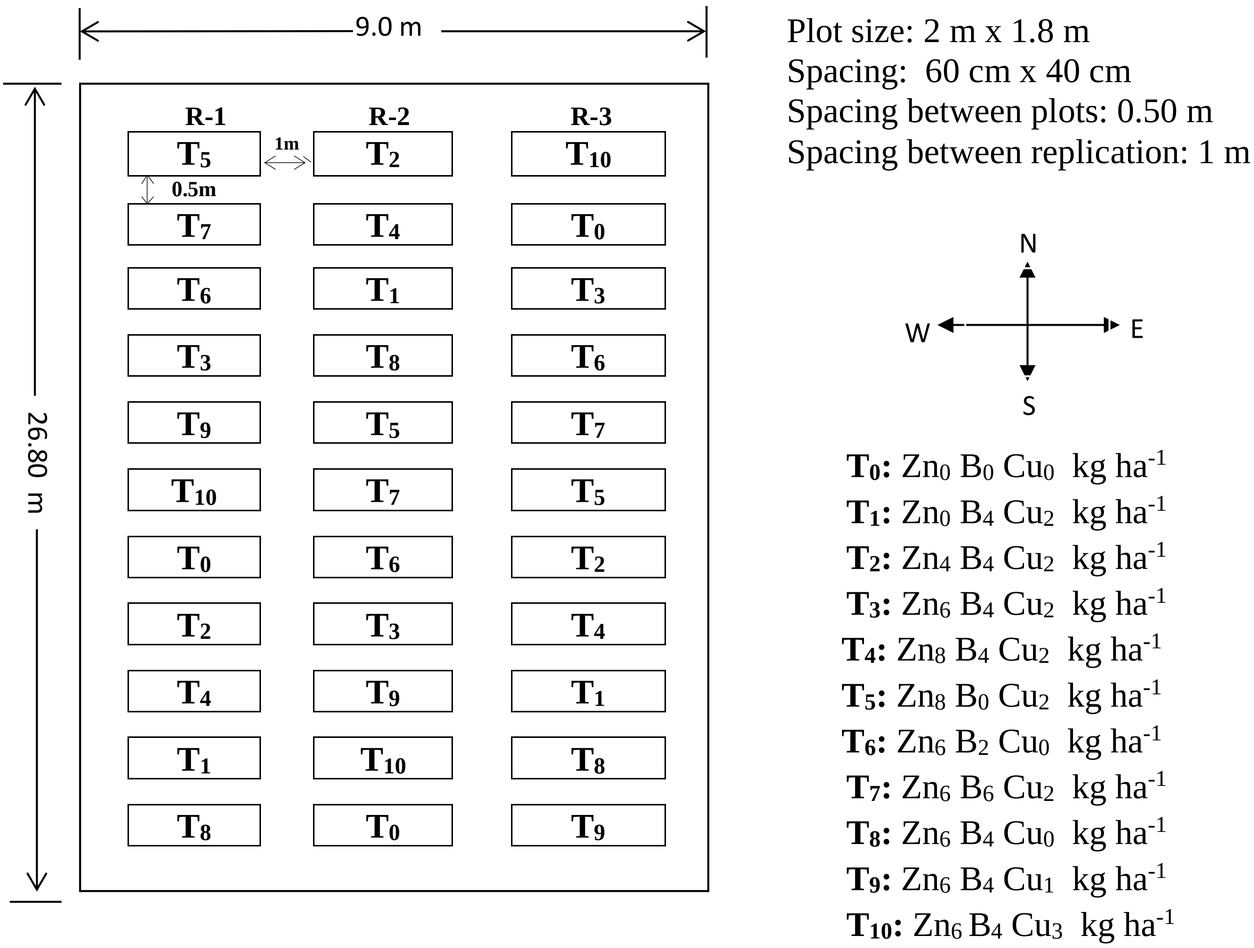


Fig 1: Field layout of the experimental plot

3.6 Manures and fertilizers and its methods of application

Fertilizer	Quantity	Application method
Cow dung	15 t/ha	Basal dose
Urea	400 kg/ha	20, 30 and 40 DAT
TSP	300 kg/ha	Basal dose
MOP	250 kg/ha	20, 30 and 40 DAT
Zinc ($ZnSO_4$)	As per treatment	Final land preparation
Boron (Boric acid)	As per treatment	Basal dose at 25 DAT
Copper ($CuSO_4.5H_2O$)	As per treatment	Basal dose at 25 DAT

Rashid (2012)

According to Rashid (2012), the entire amount of cow dung, TSP, Zinc, Boron and Copper were applied as basal dose during land preparation. Urea, TSP and

MOP were applied in all treatments at the rate of 400 kg/ha, 300 kg/ha and 250 kg/ha respectively. Urea and MOP were used as top dressing in equal splits at 20, 30 and 40 days after transplanting. As per treatment requirement the micro nutrients used in this experiment all are lab grade chemicals collected from “Scientific Store”, Tikatuli, Motijhil, Dhaka.

3.7 Cultivation procedure

3.7.1 Raising of seedlings

Tomato seedlings were raised in two seedbeds of 2 m x 1m size. The soil was well prepared and converted into loose friable and dried mass by spading. All weeds and stubbles were removed and 5 kg well rotten cow dung was mixed with the soil. Five (5) gram of seeds was sown on each seedbed on 5 October, 2015. After sowing, seeds were covered with light soil. The emergence of the seedlings took place within 6 to 7 days after sowing and 25 days old seedlings were transplanted. Weeding, mulching and irrigation were done as and when required.

3.7.2 Land preparation

The soil was well prepared and good tilth was ensured for commercial crop production. The land of the experimental field was ploughed with a power tiller on 25 October 2015. Later on the land was ploughed three times followed by laddering to obtain desirable tilth. 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 and then the land was made ready. The field layout and design was followed after land preparation.

3.7.3 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 1 November, 2015 maintaining a spacing of 60 cm x 40 cm between the rows and plants, respectively. This allowed an accommodation of 12 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. Seedlings were also planted around the border area of the experimental plots for gap filling.

3.7.4 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:

3.7.4.1 Gap filling

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

3.7.4.2 Weeding

Numbers of weeding were accomplished as and whenever necessary to keep the crop free from weeds.

3.7.4.3 Staking

When the plants were well established, staking was given to each plant by rope and plastic wire to keep them erect. Within a few days of staking, as the plants grew up and other cultural operations were carried out.

3.7.4.4 Irrigation

Number of irrigation was given throughout the growing period by garden pipe and watering cane. The first irrigation was given immediate after the transplantation and when required depending upon the condition of soil.

3.7.4.5 Plant protection

From seedling to harvesting stage i.e. any stage, tomato is very sensitive to diseases and pest. After getting a maturity stage protection measure was taken against diseases and pests. So that, any insect or fungal infection and insect infestation cannot appear in the plant.

3.7.4.6 Insect pests

Bavistin 50 WP and Ripcord 10 EC were applied @ 10 ml/L against the fungal diseases, leaf curl disease and insect pests like cut worm, leaf hopper, fruit borer and others. The insecticide application was made fortnightly for a week after transplanting to two weeks before first harvesting.

3.8 Harvesting

Fruits were harvested at 5 to 6 days intervals during early ripe stage when they attained slightly red color. Harvesting was started from 25 January, 2015 and was continued up to end of 10 March, 2016.

3.9 Data collection

Six 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.

3.9.1 Plant height (cm)

Plant height was measured in centimeters from the base of plant to the terminal growth point of main stem on tagged plants was recorded at 10 days interval starting from 20 days of planting up to 60 days and to observe the plant height. The average height was measured and expressed in centimeter.

3.9.2 Number of leaves plant^{-1}

Number of leaves per plant was manually counted at 20, 30, 40, 50 and 60 days after transplanting from randomly selected tagged plants. The average of six plants were calculated and expressed in average number of leaves per plant.

3.9.3 Number of branches plant^{-1}

Number of branches per plant was counted at 20, 30, 40, 50 and 60 days after transplanting from randomly selected tagged plants. The average of six plants were computed and expressed in average number of branch per plant.

3.9.4 Canopy size (cm)

Canopy size of the plant was measured at 20, 30, 40, 50 and 60 days after transplanting from randomly selected tagged plants. The average of six plants was find out and expressed in average canopy size of the plant.

3.9.5 Stem diameter (cm)

Stem diameter of the plant was measured by slide calipers at 20, 30, 40, 50 and 60 days after transplanting from randomly selected plants. The average of six plants were measured and expressed in centimeter.

3.9.6 Carbon assimilation rate (%)

The Carbon assimilation rate of the plant was measured by an automatic "LC*pro*$^+$ (advanced photosynthesis measurement system) meter" which is a product of *ADC Ltd.*, Hertfordshire EN11 0NT, United Kingdom, at 60 days after transplanting from six tagged plants of each plot. This machine gives the direct calculated result of carbon assimilation rate of the plant. The Carbon assimilation rate of five tagged leaves of each plant was measured and calculated the average Carbon assimilation rate of one plant.

3.9.7 Days to first flowering

Date of first flowering was recorded at 20, 30, 40, 50 and 60 days after transplanting from randomly selected tagged plants and their mean value was calculated.

3.9.8 Number of clusters plant^{-1}

The number of clusters per plant was counted at 50 and 60 days after transplanting from the six randomly selected plants and the average number of clusters produced per plant was recorded.

3.9.9 Number of flowers cluster^{-1}

The number of flowers per cluster was counted at 50 and 60 days after transplanting from the six randomly selected plants. From each plant six clusters were selected and counted the number of flowers per cluster to make an average value for one plant. The final average value of number of flowers per cluster was calculated from six averages from six plants.

3.9.10 Number of fruits cluster^{-1}

The number of fruits per cluster was counted at 60 DAT and harvesting time from randomly selected six plants. From each plant randomly six clusters were selected and counted the number of fruits per cluster to make an average value for one plant. The final average value of number of fruits per cluster was calculated from six averages from six plants.

3.9.11 Fruit length (cm)

Among the total number of fruit harvested during the period from first to final harvest, the fruits, except the first and last harvest, were considered for determine the length of fruit by slide calipers. The length of fruit was calculated by making the average of five fruits from each of the six plants.

3.9.12 Fruit diameter (cm)

Except the first and last harvested fruits, were considered for determine the diameter of fruit by slide calipers. The diameter of fruit was calculated by making the average of five fruits from each of the six plants.

3.9.13 Individual fruit weight (g)

Only the first and last harvested fruits, were considered for determine the individual fruit weight in gram. The weight was calculated from total weight of fruits was divided by total number of fruits of every harvest and finally making the average was made from four times harvesting data.

3.9.14 Chlorophyll content in leaf (%)

Chlorophyll percentage of leaf of the plant was measured by a SPAD meter, a product of Konica Minolta Sensing Ltd, Singapore, at 60 days after transplanting from randomly selected six tagged plants. This machine gives the direct calculated value of the chlorophyll percentage of leaf of the plant. The Chlorophyll percentage of five tagged leaves of each plant was measured and calculated the average Chlorophyll percentage of leaf of each plant of 6 sample plants

3.9.15 TSS (Total Soluble Solid) (%)

Brix refractometer (Model RHB 32 ATC) was used to measure TSS. One tomato sample was collected from each of the treatment. Tomato sample was cut with the sharp knife and inside was squeeze with the needle for sample juice. A drop of juice was placed on the transparent glass and it was covered by the upper glass. Brix refractometer was directly showed the TSS as percentage.

3.9.16 Dry matter content of fruit (%)

After harvesting, randomly selected 100 gram of fruit sample previously sliced in to very thin pieces. The fruits were then dried in the sun for one day and placed in oven maintained at 70 ^{0}C for 72 hrs. The sample was then transferred into desiccators and allowed to cool down to the room temperature. The final weight of the sample was taken. The dry matter was calculation by the following formula:

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

3.9.17 Yield plant^{-1} (kg)

An electric balance was used to measure the weight of fruits per plant. The total fruit yield of each plant measured separately from each sample plant during the harvesting period and was expressed in kilogram (kg).

3.9.18 Yield plot^{-1} (kg)

Yield of tomato per plot was recorded from six randomly selected plants and their value was calculated by the following formula and was expressed in kilogram (kg).

Weight of fruit plot^{-1} (kg) = Total weight of fruits in six sample plants x 6

3.9.19 Yield per hectare^{-1} (t ha^{-1})

The yield per hectare was calculated out by converting from the per plot yield data to per hectare and was expressed in ton (t). It was measured by the following formula:

$$\text{Yield of tomato (t/ha)} = \frac{\text{Fruit yield per unit plot (kg) x 10000}}{\text{Area of unit plot in square meter x 1000}}$$

3.10 Statistical analysis

The recorded data on various parameters were statistically analyzed using MSTAT-C statistical package program. The mean for all the treatments was calculated and analysis of variance for all the characters were performed by F-Difference between treatment means were determined by LSD according to Gomez and Gomez, (1984) at 5% level of significance.

3.11 Economic analysis

Economic analysis was done in order to find out the most profitable treatment combination. The calculation was done in details according to the procedure of Alam *et al.,* (1989).

3.11.1 Analysis of total cost of production of tomato

Total input cost, miscellaneous cost, all the non-material cost, interest on fiexed capital of land were considered for calculation of the total cost of production. Interest was calculated @13% and miscellaneous cost was considered as 5% of the total input cost.

3.11.2 Gross income

Gross income was calculated on the sale of marketable price of tomato. The price of tomato in the market was considered as Tk. 4,50,000-8,41,300/ton. Prices of tomato were considered to the whole sale market rate (7 Tk./kg) of Karwan Bazar, Dhaka.

Gross return = (Total yield of produce × Market rate of per unit produce) Tk.

3.11.3 Net income

Net income was calculated by deducting total production cost from the gross income for each treatment combination.

Net income = (Gross income – Total cost of production) Tk.

3.11.4 Benefit cost ratio (BCR)

The economic indicator BCR was calculated using following formula for each treatment combination.

$$\text{Benefit cost ratio (BCR)} = \frac{\text{Net income (Tk.)}}{\text{Total cost of production per hectare (Tk.)}}$$

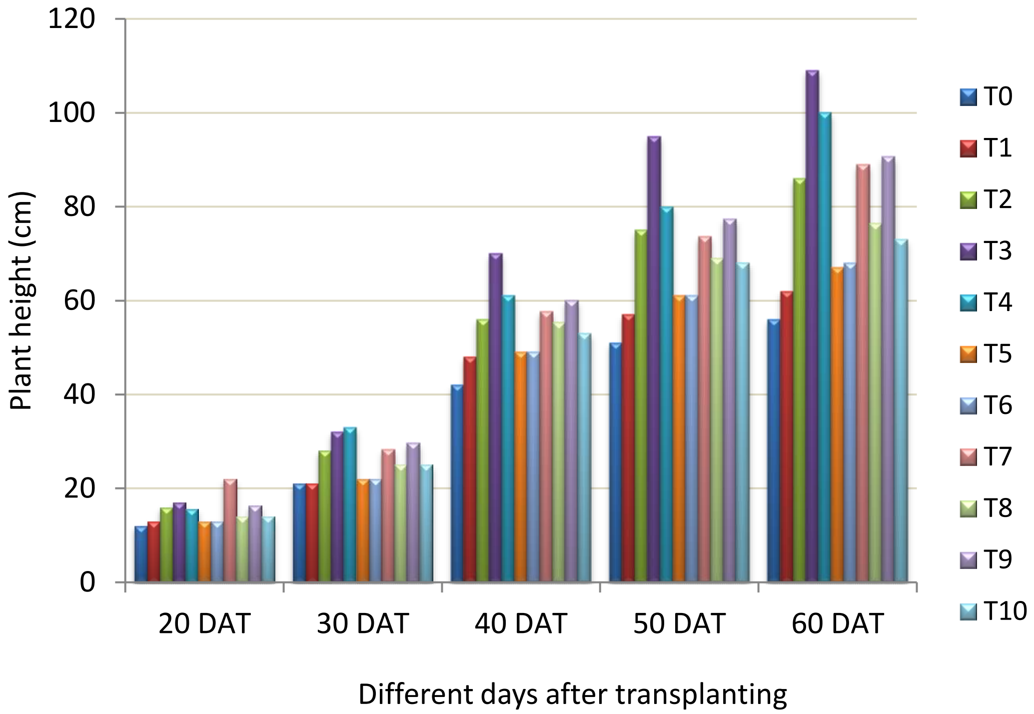
CHAPTER IV

RESULT AND DISCUSSION

The present study was conducted to find the productivity and profitability of tomato as influenced by micronutrients. Data on different growth and yield contributing characters were recorded. The analysis of variance (ANOVA) of the data on different growth and yield parameters are given in Appendix III - IX. The results have been presented and discussed with the help of tables and graphs and possible interpretations were given under the following headings:

4.1 Plant height

Significant difference was observed on plant height due to the application of different micro nutrients at 30, 40, 50 and 60 DAT except 20 DAT (Appendix III). At 30 DAT, the highest plant height (33.0 cm) was recorded from T_4 (Zn_8 B_4 Cu_2 kg ha^{-1}) treatment which is statistically similar T_3 (Zn_6 B_4 Cu_2 kg ha^{-1}) treatment and the shortest plant (21.0 cm) was found from T_0 (control) which is statistically identical T_1 treatment. At 40 DAT, the longest plant (70.0 cm) was found from T_3 (Zn_6 B_4 Cu_2 kg ha^{-1}) treatment and the shortest plant (42.0 cm) was obtained from T_0 (control) treatment. The longest plant (95.0 cm) was recorded from T_3 (Zn_6 B_4 Cu_2 kg ha^{-1}) and the shortest plant (51.0 cm) was found from T_0 (control) treatment at 50 DAT. At 60 DAT, the longest plant (109.0 cm) was obtained from T_3 (Zn_6 B_4 Cu_2 kg ha^{-1}) treatment which is statistically similar T_4 (Zn_8 B_4 Cu_2 kg ha^{-1}) treatment while the shortest plant (56.00 cm) was found from T_0 (control) treatment which is statistically similar T_1 (Zn_0 B_4 Cu_2 kg ha^{-1}) treatment (Fig. 2). Makhan *et al.* (2000) found that highest increase in plant height (54.80 cm) was recorded with application of Zinc sulphate. They have concluded that Zinc may serve as source of energy for synthesis of auxin which helps in elongation of stem. Ali *et al.* (2015) conducted an experiment to increase the yield of BARI hybrid tomato 4, cultivated in summer season of Bangladesh, foliar application of zinc and boron and supported the similar results. Shnain *et al.* (2014) supported the results.



T_0: Zn_0 B_0 Cu_0 kg ha^{-1}
T_1: Zn_0 B_4 Cu_2 kg ha^{-1}
T_2: Zn_4 B_4 Cu_2 kg ha^{-1}
T_3: Zn_6 B_4 Cu_2 kg ha^{-1}
T_4: Zn_8 B_4 Cu_2 kg ha^{-1}
T_5: Zn_8 B_0 Cu_2 kg ha^{-1}
T_6: Zn_6 B_2 Cu_0 kg ha^{-1}
T_7: Zn_6 B_6 Cu_2 kg ha^{-1}
T_8: Zn_6 B_4 Cu_0 kg ha^{-1}
T_9: Zn_6 B_4 Cu_1 kg ha^{-1}
T_{10}: Zn_6 B_4 Cu_3 kg ha^{-1}

Fig 1. Effect of micronutrients on plant height at different days after transplanting (DAT) of tomato

4.2 Number of leaves plant^{-1}

Significant differences on number of leaves per plant was showed due to the application of different concentration of micro nutrients at all observation except 20 DAT (Appendix IV). The maximum number of leaves per plant (14.0) was counted from T_4 (Zn_8 B_4 Cu_2 kg ha^{-1}) and the minimum number of leaves per plant (8.0) was found from T_0 (control) treatment at 30 DAT.

Table 1. Effect of micronutrients on Number of leaves plant^{-1} at different days after transplanting (DAT) of tomato

Treatment	Number of leaves plant^{-1}				
	20 DAT	**30 DAT**	**40 DAT**	**50 DAT**	**60 DAT**
T_0	6.00	8.00 f	24.00 h	37.00 g	46.00 f
T_1	6.00	9.00 e	27.00 gh	40.00 f	50.00 e
T_2	7.00	9.00 e	33.00 de	50.00 cd	61.00 cd
T_3	6.00	11.00 b	48.00 a	68.00 a	85.00 a
T_4	7.00	14.00 a	40.00 b	56.00 b	70.00 b
T_5	7.00	9.00 e	28.00 g	41.00 f	52.00 e
T_6	6.00	9.00 e	29.00 fg	44.00 e	58.00 d
T_7	7.00	9.66 cd	35.33 cd	50.66 cd	64.00 c
T_8	7.00	9.33 de	32.00 ef	48.00 d	59.66 d
T_9	7.00	10.00 c	36.66 c	52.33 c	64.33 c
T_{10}	7.00	9.00 e	32.00 ef	48.00 d	60.00 d
LSD $_{(0.05)}$	**1.15**	**0.43**	**3.17**	**2.88**	**3.43**
CV %	**3.21**	**2.65**	**5.61**	**3.48**	**5.84**

In a column, means with similar letter (s) are not significantly different by LSD at 5% level of significance.

T_0: Zn_0 B_0 Cu_0 kg ha^{-1}
T_1: Zn_0 B_4 Cu_2 kg ha^{-1}
T_2: Zn_4 B_4 Cu_2 kg ha^{-1}
T_3: Zn_6 B_4 Cu_2 kg ha^{-1}
T_4: Zn_8 B_4 Cu_2 kg ha^{-1}
T_5: Zn_8 B_0 Cu_2 kg ha^{-1}
T_6: Zn_6 B_2 Cu_0 kg ha^{-1}
T_7: Zn_6 B_6 Cu_2 kg ha^{-1}
T_8: Zn_6 B_4 Cu_0 kg ha^{-1}
T_9: Zn_6 B_4 Cu_1 kg ha^{-1}
T_{10}: Zn_6 B_4 Cu_3 kg ha^{-1}

At 40 DAT, the maximum number of leaves per plant (48.0) was recorded from T_3 treatment followed by (40.0) T_4 (Zn_8 B_4 Cu_2 kg ha^{-1}) treatment and the minimum number of leaves per plant (24.0) was obtained from T_0 (control) treatment which is statistically similar T_1 (Zn_0 B_0 Cu_0 kg ha^{-1}) treatment. The maximum number of leaves per plant (68.0) was found from T_3 (Zn_6 B_4 Cu_2 kg ha^{-1}) and the minimum number of leaves per plant (37.0) was observed from T_0 (control) treatment at 50 DAT. At 60 DAT, the maximum number of leaves per plant (85.0) was counted from T_3 (Zn_6 B_4 Cu_2 kg ha^{-1}) followed by (70.00) T_5

(Zn_8 B_0 Cu_2 kg ha^{-1}) and the minimum number of leaves per plant (46.00) was obtained from T_0 (control) treatment (Table 1). This result indicated that combine application of Zn, B and Cu fertilizers might have induced better growing condition which perhaps due to supply of adequate plant nutrients which ultimately had to produced more leaves per plant. Ejaz *et al.* (2011) found that individual application of nutrient provide better results as compared to control but their combined effect provided substantial results in plant heights, no. of leaves of the plant. Cakmak *et al.* (1999) reported that zinc also helps in various metabolic processes; its deficiency inhibits growth and development of plants.

4.3 Number of branches plant^{-1}

The significant difference was observed on Number of branches plant^{-1}due to the application of different micro nutrients (Appendix V). The maximum number of branches per plant (9.00) was obtained from T_3 (Zn_6 B_4 Cu_2 kg ha^{-1}) treatment and followed by (8.00) T_2 (Zn_4 B_4 Cu_2 kg ha^{-1}) treatment which is statistically identical to T_4 (Zn_8 B_4 Cu_2 kg ha^{-1}) and T_9 (Zn_6 B_4 Cu_1 kg ha^{-1}) treatment. On the other hand, the minimum number of branches per plant (5.00) was recorded from T_0 (control) treatment (Table 2). Ullah *et al.* (2015) found among different levels of Zn 0.4% showed significant increased in number of branches plant^{-1}and yield (t ha^{-1}). Boron also significantly affected growth and yield components. Shnain *et al.* (2014) supported the results.

4.4 Canopy size (cm)

The significant difference was observed on canopy size due to the application of different micro nutrients (Appendix V). The maximum canopy size (109.00 cm) was obtained from T_4 (Zn_8 B_4 Cu_2 kg ha^{-1}) treatment and followed by (105.00 cm) T_3 (Zn_6 B_4 Cu_2 kg ha^{-1}) treatment. On the other hand, the minimum canopy size (72.00 cm) was recorded from T_0 (control) treatment (Table 2). Ejaz *et al.* (2011) found that individual application of nutrient provide better results as compared to control but their combined effect provided substantial results in plant heights and canopy size.

Table 2. Effect of micronutrients on number of branches plant^{-1}, canopy size, stem diameter and carbon assimilation rate of tomato

Treatment	No. of branches plant^{-1}	Canopy size (cm)	Stem diameter (cm)	Carbon assimilation rate (%)
T_0	5.00 f	72.00 i	2.00 i	3.00 h
T_1	6.00 e	85.00 h	2.12 h	5.80 g
T_2	8.00 b	99.00 d	2.40 cd	8.70 cd
T_3	9.00 a	105.00 b	2.55 b	11.00 a
T_4	8.00 b	109.00 a	2.53 b	9.39 b
T_5	7.00 d	94.00 g	2.25 g	6.12 g
T_6	7.00 d	95.00 f	2.30 f	7.07 f
T_7	7.66 bc	102.00 c	2.62 a	8.62 cd
T_8	7.33 cd	97.67 e	2.38 de	8.04 e
T_9	8.00 b	98.67 d	2.41 c	8.84 bc
T_{10}	7.00 d	97.67 e	2.36 e	8.27 de
LSD $_{(0.05)}$	**0.43**	**0.76**	**0.03**	**0.54**
CV %	**3.55**	**5.47**	**5.90**	**4.16**

In a column, means with similar letter (s) are not significantly different by LSD at 5% level of significance.

T_0: Zn_0 B_0 Cu_0 kg ha^{-1}
T_1: Zn_0 B_4 Cu_2 kg ha^{-1}
T_2: Zn_4 B_4 Cu_2 kg ha^{-1}
T_3: Zn_6 B_4 Cu_2 kg ha^{-1}
T_4: Zn_8 B_4 Cu_2 kg ha^{-1}
T_5: Zn_8 B_0 Cu_2 kg ha^{-1}
T_6: Zn_6 B_2 Cu_0 kg ha^{-1}
T_7: Zn_6 B_6 Cu_2 kg ha^{-1}
T_8: Zn_6 B_4 Cu_0 kg ha^{-1}
T_9: Zn_6 B_4 Cu_1 kg ha^{-1}
T_{10}: Zn_6 B_4 Cu_3 kg ha^{-1}

4.5 Stem diameter (cm)

The significant difference was observed on stem diameter due to the application of different micro nutrients (Appendix V). The maximum stem diameter (2.62 cm) was obtained from T_7 (Zn_6 B_6 Cu_2 kg ha^{-1}) treatment and followed by (2.55 cm) T_3 (Zn_6 B_4 Cu_2 kg ha^{-1}) treatment which is statistically identical to T_4 (Zn_8 B_4 Cu_2 kg ha^{-1}) treatment. On the other hand, the minimum stem diameter (2.00 cm) was recorded from T_0 (control) treatment (Table 2). Shnain *et al.* (2014) supported the results. Guang (2007) says plants are very much sensitive to copper and it helps to shoot growth.

4.6 Carbon assimilation rate (%)

The significant difference was observed on carbon assimilation rate due to the application of different micro nutrients on Carbon assimilation rate (Appendix V). The maximum carbon assimilation rate (11.00 %) was found from T_3 (Zn_6 B_4 Cu_2 kg ha^{-1}) treatment and followed by (9.39 %) T_4 (Zn_8 B_4 Cu_2 kg ha^{-1}) treatment which is statistically similar to T_9 (Zn_6 B_4 Cu_1 kg ha^{-1}) treatment. On the other hand, the minimum carbon assimilation rate (3.00 %) was recorded from T_0 (control) treatment (Table 2). Shnain *et al.* (2014) supported the results. Sivaiah *et al.* (2013) found combined application of micronutrients controls all the physiological activities which helps in photosynthesis and produced the maximum fruit yield followed by application of boron and zinc combined.

4.7 Days to first flowering

The significant difference was observed on days to first flowering due to the application of different micro nutrients on Days to first flowering (Appendix VI). The maximum days required to first flowering (41.00 days) was found from T_0 (control) treatment which is statistically identical to T_1 (Zn_0 B_4 Cu_2 kg ha^{-1}) treatment. On the other hand, the minimum days required to first flowering (32.89 days) was recorded from T_3 (Zn_6 B_4 Cu_2 kg ha^{-1}) treatment which is statistically similar to T_2 (Zn_4 B_4 Cu_2 kg ha^{-1}), T_4 (Zn_8 B_4 Cu_2 kg ha^{-1}) and T_7 (Zn_6 B_6 Cu_2 kg ha^{-1}) treatment (Table 3). Patil *et al.* (2010) was conducted an experiment to evaluate the effect of foliar application of micronutrients on flowering and fruit-set of tomato. The minimum number of days (30.00) for initiation of flowering and 50% flowering (38.86) were recorded with Boron 50ppm and 100ppm while the maximum number of days were recorded in control.

4.8 Number of clusters plant^{-1}

The significant difference was observed on number of clusters plant^{-1} due to the application of different micro nutrients (Appendix VI). The maximum number of clusters plant^{-1} (9.35) was obtained from T_3 (Zn_6 B_4 Cu_2 kg ha^{-1}) treatment and followed by (9.17) T_4 (Zn_8 B_4 Cu_2 kg ha^{-1}) treatment. On the other hand, the minimum number of clusters plant^{-1} (6.00) was recorded from T_0 (control) treatment which is statistically identical to T_1 (Zn_0 B_4 Cu_2 kg ha^{-1}) treatment (Table 3). Ullah *et al.* (2015) found among different levels of Zn 0.4% showed significant increased in number of flowers cluster plant^{-1}, number of flowers cluster^{-1}, number of fruits cluster^{-1}, number of branches plant^{-1}and yield (t ha^{-1}). Boron also significantly affected growth and yield components.

4.9 Number of flowers cluster^{-1}

The significant difference was observed on number of flowers cluster^{-1} due to the application of different micro nutrients (Appendix VI). The maximum number of flowers cluster^{-1} (7.75) was found from T_3 (Zn_6 B_4 Cu_2 kg ha^{-1}) treatment and followed by (7.00) T_4 (Zn_8 B_4 Cu_2 kg ha^{-1}) treatment which is statistically identical to T_9 (Zn_6 B_4 Cu_1 kg ha^{-1}) treatment. On the other hand, the minimum number of flowers cluster^{-1} (4.75) was recorded from T_0 (control) treatment which is statistically similar to T_1 (Zn_0 B_4 Cu_2 kg ha^{-1}) treatment (Table 3). Ullah *et al.* (2015) found among different levels of Zn 0.4% showed significant increased in number of flowers cluster plant^{-1}, number of flowers cluster^{-1}, number of fruits cluster^{-1}, number of branches plant^{-1}and yield (t ha^{-1}). Boron also significantly affected growth and yield components.

4.10 Number of fruits cluster^{-1}

The significant difference was observed on number of fruits cluster^{-1} due to the application of different micro nutrients (Appendix VI). The maximum number of fruits cluster^{-1} (4.25) was found from T_3 (Zn_6 B_4 Cu_2 kg ha^{-1}) treatment which is statistically similar to T_4 (Zn_8 B_4 Cu_2 kg ha^{-1}) treatment and followed by (3.08) T_9 (Zn_6 B_4 Cu_1 kg ha^{-1}) treatment which is statistically similar to T_2

Table 3. Effect of micronutrients on days to first flowering, number of clusters plant^{-1}, number of flowers cluster^{-1} and number of fruits cluster^{-1} of tomato

Treatment	Days to first flowering	No. of clusters plant^{-1}	No. of flowers cluster^{-1}	No. of fruits cluster^{-1}
T_0	41.55 a	7.44 f	4.05 f	3.08 e
T_1	40.86 a	7.44 f	5.00 ef	3.08 e
T_2	33.48 de	8.84 cd	6.40 c	3.75bc
T_3	32.89 e	9.35 a	7.75 a	4.25 a
T_4	33.18 de	9.17 b	6.23 b	4.09 ab
T_5	37.28 b	7.99 ef	5.33 e	3.08 e
T_6	37.75 b	7.99 ef	5.83 d	3.23 de
T_7	34.01 cde	8.85 cd	6.58 bc	3.77 bc
T_8	37.75 b	8.14 e	6.22 cd	3.39 d
T_9	34.29 cd	8.99 c	6.23 b	3.91 b
T_{10}	34.78 c	8.29 de	6.33 c	3.55 cd
LSD $_{(0.05)}$	**1.21**	**0.15**	**0.42**	**0.16**
CV %	**6.12**	**7.13**	**5.00**	**5.42**

In a column, means with similar letter (s) are not significantly different by LSD at 5% level of significance.

T_0: Zn_0 B_0 Cu_0 kg ha^{-1}
T_1: Zn_0 B_4 Cu_2 kg ha^{-1}
T_2: Zn_4 B_4 Cu_2 kg ha^{-1}
T_3: Zn_6 B_4 Cu_2 kg ha^{-1}
T_4: Zn_8 B_4 Cu_2 kg ha^{-1}
T_5: Zn_8 B_0 Cu_2 kg ha^{-1}
T_6: Zn_6 B_2 Cu_0 kg ha^{-1}
T_7: Zn_6 B_6 Cu_2 kg ha^{-1}
T_8: Zn_6 B_4 Cu_0 kg ha^{-1}
T_9: Zn_6 B_4 Cu_1 kg ha^{-1}
T_{10}: Zn_6 B_4 Cu_3 kg ha^{-1}

(Zn_4 B_4 Cu_2 kg ha^{-1}) and T_7 (Zn_6 B_6 Cu_2 kg ha^{-1}) treatment. On the other hand, the minimum number of fruits cluster^{-1} (3.00) was recorded from T_0 (control) treatment which is statistically identical to T_1 (Zn_0 B_4 Cu_2 kg ha^{-1}) treatment (Table 3). Ullah *et al.* (2015) found among different levels of Zn 0.4% showed significant increased in number of fruits $cluster^{-1}$, number of branches $plant^{-1}$and yield (t ha^{-1}). Boron also significantly affected growth and yield components. Sivaiah *et al.* (2013) found combined application of micronutrients produced the maximum fruit yield followed by application of boron and zinc.

4.11 Fruit length (cm)

The significant difference was observed on fruit diameter due to the application of different micronutrients (Appendix VII). The maximum diameter of fruit (6.63 cm) was found from T_9 (Zn_6 B_4 Cu_1 kg ha^{-1}) treatment and followed by (5.45 cm) T_4 (Zn_8 B_4 Cu_2 kg ha^{-1}) treatment which is statistically identical to T_3 (Zn_6 B_4 Cu_2 kg ha^{-1}) treatment. On the other hand, the minimum length of fruit (4.00 cm) was recorded from T_0 (control) treatment (Table 4). Huang and Snapp (2009) and Nada *et al.* (2010) supported the similar results.

4.12 Fruit diameter (cm)

The significant difference was observed on fruit diameter due to the application of different micronutrients (Appendix VII). The maximum length of fruit (6.90 cm) was found from T_4 (Zn_8 B_4 Cu_2 kg ha^{-1}) treatment and followed by (6.53 cm) T_3 (Zn_6 B_4 Cu_2 kg ha^{-1}) treatment. On the other hand, the minimum diameter of fruit (4.33 cm) was recorded from T_0 (control) treatment (Table 4). Luis *et al.* (2012) conducted a study to evaluate the effect of boron on two variety of tomato and supported the similar results.

4.13 Individual fruit weight (g)

The significant difference was observed on individual fruit weight due to the application of different micro nutrients (Appendix VII). The maximum fresh weight of fruit (92.50 a) was found from T_3 (Zn_6 B_4 Cu_2 kg ha^{-1}) treatment and followed by (89.75 g) T_4 (Zn_8 B_4 Cu_2 kg ha^{-1}) treatment which is statistically similar to T_2 (Zn_4 B_4 Cu_2 kg ha^{-1}) and T_9 (Zn_6 B_4 Cu_1 kg ha^{-1}) treatment. On the other hand, the minimum fresh weight of fruit (72.00 g) was recorded from T_0 (control) treatment which is statistically similar to T_1 (Zn_0 B_4 Cu_2 kg ha^{-1}) treatment (Table 4). Huang and Snapp (2009) and Nada *et al.* (2010) supported the similar results. Paithankar *et al.* (2004) reported in tomato highest number of fruits and weight due to micro nutrient application.

Table 4. Effect of micronutrients on fruit length, fruit diameter and individual fruit weight of tomato

Treatment	Fruit length (cm)	Fruit diameter (cm)	Individual fruit weight (g)
T_0	4.00 g	4.33 h	72.00 g
T_1	4.18 f	4.90 g	75.43 gf
T_2	5.20 cd	6.38 cd	86.90 bc
T_3	5.39 b	6.53 b	92.50 a
T_4	5.45 b	6.90 a	89.75 b
T_5	4.98 e	5.10 f	78.31 ef
T_6	5.00 e	6.25 e	78.30 ef
T_7	5.32 bc	6.39 cd	84.03cd
T_8	5.19 cd	6.32 d	81.17 de
T_9	6.63 a	6.43 c	86.88 bc
T_{10}	5.14 d	6.33 d	81.16 de
LSD $_{(0.05)}$	**0.13**	**0.06**	**2.87**
CV %	**5.53**	**6.68**	**9.21**

In a column, means with similar letter (s) are not significantly different by LSD at 5% level of significance.

T_0: Zn_0 B_0 Cu_0 kg ha^{-1}
T_1: Zn_0 B_4 Cu_2 kg ha^{-1}
T_2: Zn_4 B_4 Cu_2 kg ha^{-1}
T_3: Zn_6 B_4 Cu_2 kg ha^{-1}
T_4: Zn_8 B_4 Cu_2 kg ha^{-1}
T_5: Zn_8 B_0 Cu_2 kg ha^{-1}
T_6: Zn_6 B_2 Cu_0 kg ha^{-1}
T_7: Zn_6 B_6 Cu_2 kg ha^{-1}
T_8: Zn_6 B_4 Cu_0 kg ha^{-1}
T_9: Zn_6 B_4 Cu_1 kg ha^{-1}
T_{10}: Zn_6 B_4 Cu_3 kg ha^{-1}

4.14 Chlorophyll content in leaf (%)

The significant difference was observed on chlorophyll content in leaf due to the application of different micro nutrients (Appendix VIII). The maximum chlorophyll content in leaf (64.55 %) was found from T_9 (Zn_6 B_4 Cu_1 kg ha^{-1}) treatment and followed by (54.90 %) T_4 (Zn_8 B_4 Cu_2 kg ha^{-1}) treatment. On the other hand, the minimum chlorophyll content in leaf (44.90 %) was recorded from T_0 (control) treatment (Table 5). Salam *et al.* (2010) found the highest pulp weight (88.14%), chlorophyll-a, chlorophyll-b, from Zn and B combine application.

4.15 TSS (Total Soluble Solid) (%)

The significant difference was observed on total soluble solid due to the application of different micro nutrients (Appendix VIII). The maximum TSS of fruit (8.86 %) was found from T_3 (Zn_6 B_4 Cu_2 kg ha^{-1}) treatment and followed by (7.58 %) T_4 (Zn_8 B_4 Cu_2 kg ha^{-1}) treatment which is statistically identical to T_9 (Zn_6 B_4 Cu_1 kg ha^{-1}) treatment. On the other hand, the minimum TSS of fruit (6.13 %) was recorded from T_0 (control) treatment (Table 5). Salam *et al.* (2010) found the highest pulp weight (88.14%), dry matter content, TSS, acidity, chlorophyll-a, chlorophyll-b, from Zn and B combine application. Harris and Lavanya (2016) evaluated that foliar application of boron, copper, and their combinations significantly influenced yield and quality parameters such as acidity, ascorbic acid, TSS and pH.

4.16 Dry matter content of fruit (%)

The significant difference was observed on dry matter content of fruit due to the application of different micro nutrients (Appendix VIII). The maximum dry matter content of fruit (15.73 %) was found from T_3 (Zn_6 B_4 Cu_2 kg ha^{-1}) treatment and followed by (13.42 %) T_4 (Zn_8 B_4 Cu_2 kg ha^{-1}) treatment which is statistically similar to T_9 (Zn_6 B_4 Cu_1 kg ha^{-1}) treatment. On the other hand, the minimum dry matter content of fruit (10.00 %) was recorded from T_0 (control) treatment which is statistically similar to T_1 (Zn_0 B_4 Cu_2 kg ha^{-1}) treatment (Table 5). Salam *et al.* (2010) found the highest pulp weight (88.14%), dry matter content, from Zn and B combine application. Bhatt and Srivastava (2005) investigated the effects of the foliar applications of boron (boric acid), zinc (zinc sulfate) and supported the similar results.

Table 5. Effect of micronutrients on chlorophyll content in leaf, TSS and dry matter content of tomato

Treatment	Chlorophyll content in leaf (%)	TSS (%)	Dry matter content of fruit (%)
T_0	44.90 i	6.13 g	10.00 g
T_1	46.33 h	6.31 f	10.43 fg
T_2	52.10 de	7.33 cd	12.79 cd
T_3	53.36 c	8.76 a	15.37 a
T_4	54.90 b	7.58 b	13.42 b
T_5	48.12 g	7.11 e	10.64 f
T_6	50.80 f	7.13 e	11.55 e
T_7	53.13 cd	7.45 bc	12.75 cd
T_8	51.80 ef	7.32 cd	12.33 d
T_9	64.55 a	7.52 b	13.04 bc
T_{10}	51.90 ef	7.27 d	12.38 d
LSD (0.05)	**1.11**	**0.13**	**0.47**
CV %	**5.26**	**5.08**	**6.26**

In a column, means with similar letter (s) are not significantly different by LSD at 5% level of significance.

T_0: Zn_0 B_0 Cu_0 kg ha^{-1}
T_1: Zn_0 B_4 Cu_2 kg ha^{-1}
T_2: Zn_4 B_4 Cu_2 kg ha^{-1}
T_3: Zn_6 B_4 Cu_2 kg ha^{-1}
T_4: Zn_8 B_4 Cu_2 kg ha^{-1}
T_5: Zn_8 B_0 Cu_2 kg ha^{-1}
T_6: Zn_6 B_2 Cu_0 kg ha^{-1}
T_7: Zn_6 B_6 Cu_2 kg ha^{-1}
T_8: Zn_6 B_4 Cu_0 kg ha^{-1}
T_9: Zn_6 B_4 Cu_1 kg ha^{-1}
T_{10}: Zn_6 B_4 Cu_3 kg ha^{-1}

4.17 Yield plant^{-1} (kg)

The significant difference was observed on yield per plant due to the application of different micro nutrients (Appendix IX). The highest yield per plant (2.88 kg) was found from T_3 (Zn_6 B_4 Cu_2 kg ha^{-1}) treatment and followed by (2.83 kg) T_4 (Zn_8 B_4 Cu_2 kg ha^{-1}) treatment. On the other hand, the lowest yield per plant (2.55 kg) was recorded from T_0 (control) treatment which is statistically similar to (2.58 kg) T_1 (Zn_0 B_4 Cu_2 kg ha^{-1}) treatment (Table 6). Sultana *et al.* (2016) found that the tomato yield and its contributing yield traits were significantly affected by foliar fertilizer treatments as against soil application of B and Zn fertilizers and he observed foliar application of Zn (0.05 %) + B (0.03%) produced maximum fruit yield. Harris and Mathuma (2015) supported the results. Ejaz *et al.* (2011) said that, It is confirmed from the results that combination of macro-nutrients and micro-nutrients as foliar application has the ability to enhance the growth and yield of tomato positively. Hossein (2008) found that, the highest fruit yield (74.88 t ha^{-1}) was obtained due to the application of 1.8 kg Zn and 0.1kg B ha^{-1}.

4.18 Yield plot^{-1} (kg)

The significant difference was observed on yield per plot due to the application of different micro nutrients (Appendix IX). The highest yield per plot (34.56 kg) was found from T_3 (Zn_6 B_4 Cu_2 kg ha^{-1}) treatment and followed by (34.02 kg) T_4 (Zn_8 B_4 Cu_2 kg ha^{-1}) treatment. On the other hand, the lowest yield per plot (30.60 kg) was recorded from T_0 (control) treatment which is statistically similar to (30.90 kg) T_1 (Zn_0 B_4 Cu_2 kg ha^{-1}) treatment (Table 6). Ali *et al.* (2015) conducted an experiment to increase the yield of BARI hybrid tomato 4, cultivated in the summer season of Bangladesh, foliar application of zinc and boron and supported the similar results. Naz *et al.* (2012b) conducted a study to observe the effect of Boron on physiological growth on tomato. He said boron also plays an important role in production of any crop in terms of yield, quality and control of some diseases and increase the yield.

Table 6. Effect of micronutrients on yield plot^{-1}, yield plant^{-1}, yield hectare^{-1} of tomato

Treatment	Yield plant^{-1} (kg)	Yield plot^{-1} (kg)	Yield hectare^{-1} (t ha^{-1})
T_0	2.55 f	30.60 f	85.00 f
T_1	2.58 ef	30.90 ef	86.00 ef
T_2	2.73 cd	32.83 cd	91.20 cd
T_3	2.88 a	34.56 a	96.00 a
T_4	2.83 b	34.02 b	94.50 b
T_5	2.61 e	31.32 e	87.00 e
T_6	2.61 e	31.32 e	87.00 e
T_7	2.68 cd	32.04 cd	89.20 cd
T_8	2.67 d	32.11 d	88.00 d
T_9	2.79 c	33.48 c	93.00 c
T_{10}	1.90 e	31.33 e	87.00 e
LSD $_{(0.05)}$	**0.19**	**2.33**	**1.50**
CV %	**6.06**	**6.06**	**6.06**

In a column, means with similar letter (s) are not significantly different by LSD at 5% level of significance.

T_0: Zn_0 B_0 Cu_0 kg ha^{-1}
T_1: Zn_0 B_4 Cu_2 kg ha^{-1}
T_2: Zn_4 B_4 Cu_2 kg ha^{-1}
T_3: Zn_6 B_4 Cu_2 kg ha^{-1}
T_4: Zn_8 B_4 Cu_2 kg ha^{-1}
T_5: Zn_8 B_0 Cu_2 kg ha^{-1}
T_6: Zn_6 B_2 Cu_0 kg ha^{-1}
T_7: Zn_6 B_6 Cu_2 kg ha^{-1}
T_8: Zn_6 B_4 Cu_0 kg ha^{-1}
T_9: Zn_6 B_4 Cu_1 kg ha^{-1}
T_{10}: Zn_6 B_4 Cu_3 kg ha^{-1}

4.19 Yield (t ha^{-1})

The significant difference was observed on yield due to the application of micro nutrients (Appendix IX). The highest yield per hectare (96.00 ton) was found from T3 (Zn6 B4 Cu2 kg ha-1) treatment and followed by (94.50 ton) T4

(Zn8 B4 Cu2 kg ha-1) treatment. On the other hand, the lowest yield per Shectare (85.00 ton) was recorded from T_0 (control) treatment which is statistically similar to T_1 (Zn_0 B_4 Cu_2 kg ha^{-1}) treatment (Table 6). Harris and Lavanya (2016) evaluated that foliar application of boron, copper, and their combinations significantly influenced yield and quality parameters. Nadia Gad, (2005a) indicated that, the rate of copper at 7.5 ppm significantly increased tomatoes, growth parameters, fruits yield, nutrient concentration. Huang and Snapp (2009) and Nada *et al.* (2010) supported the similar results. Ejaz *et al.* (2011) found that individual application of nutrient provide better results as compared to control but their combined effect provided substantial results in plant heights, no. of leaves, no of flowers, no of fruits, average fruit weight and yield per plant.

4.20 Economic analysis

For calculating the economic analysis, input costs for land preparation, seed cost, fertilizer, micro nutrients (Lab grade $ZnSO_4$ @ 1400 Tk./kg, $CuSO_4.5H_2O$ @ 1200 Tk./kg, Boric acid @ 1800 Tk./kg), irrigation and man power required for all the operations from sowing to harvesting of tomato were recorded for unit plot and converted into cost per hectare (Appendix X & XI). The economic analysis was done to find out the gross and net return and the benefit cost ratio (BCR) in the present experiment and presented under the following headings

4.20.1 Gross return

In the combination of different micronutrients showed different gross return under the different trials. The highest gross return per hectare (Tk. 960000) was obtained from T_3 (Zn_6 B_4 Cu_2 kg ha^{-1}) and the second highest gross return (Tk. 945000) was recorded from T_4 **(** Zn_8 B_4 Cu_2 kg ha^{-1} . The lowest gross return (Tk. 850000) was recorded from T_0 (control) treatment (Table 7).

4.20.2 Net return

In case of net return different treatment combinations were showed different amount of net return. The highest net return (Tk. 674944 /ha) was recorded from the treatment combination of T_3 (Zn_6 B_4 Cu_2 kg ha^{-1}) and the second highest net return (Tk. 630956 t/ha) was recorded from the treatment combination of T_2 (Zn_8 B_4 Cu_2 kg ha^{-1}). The lowest net return (Tk. 579303 /ha) was recorded from the treatment combination of T_0 that is control treatment (Table 7).

Table 7. Cost and return of tomato production influenced by micro nutrients

Treatments	Cost of Production (Tk. /ha)	Yield of Tomato (t/ha)	Gross return (Tk. /ha)	Net Return (Tk. /ha)	BCR
T_0	270697	85.00	850000	579303	2.14
T_1	271132	86.00	860000	588868	2.17
T_2	278794	91.20	449750	630956	2.32
T_3	285057	**96.00**	**960000**	**674944**	**2.37**
T_4	285557	94.50	945000	659443	2.30
T_5	272005	87.00	870000	597995	2.19
T_6	271925	87.00	870000	598075	2.19
T_7	285357	89.20	892000	606843	2.23
T_8	279241	88.00	880000	598109	2.25
T_9	280583	93.00	930000	656897	2.29
T_{10}	285267	87.00	870000	589763	2.18

T_0: Zn_0 B_0 Cu_0 kg ha^{-1}
T_1: Zn_0 B_4 Cu_2 kg ha^{-1}
T_2: Zn_4 B_4 Cu_2 kg ha^{-1}
T_3: Zn_6 B_4 Cu_2 kg ha^{-1}
T_4: Zn_8 B_4 Cu_2 kg ha^{-1}
T_5: Zn_8 B_0 Cu_2 kg ha^{-1}
T_6: Zn_6 B_2 Cu_0 kg ha^{-1}
T_7: Zn_6 B_6 Cu_2 kg ha^{-1}
T_8: Zn_6 B_4 Cu_0 kg ha^{-1}
T_9: Zn_6 B_4 Cu_1 kg ha^{-1}
T_{10}: Zn_6 B_4 Cu_3 kg ha^{-1}

4.20.3 Benefit cost ratio (BCR)

The benefit cost ratio (BCR) was different from each other among all the treatment combinations of micronutrient. The highest (**2.37**) benefit cost ratio was obtained from T_3 and the lowest benefit cost ratio (2.14) was recorded from T_0 (control) treatment (Table 7). From the economic point of view based on this study we can say that 6 kg Zinc ha^{-1}, 4 kg boron ha^{-1} and 2 kg copper ha^{-1} was more profitable compare to other treatments in tomato production.

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted in the Horticultural Farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during the period from October 2015 to March 2016 to find out the productivity and profitability of tomato as influenced by micronutrients. This is a single factor experiment and consisted of 11 treatments. The treatments are the combination of different doses of micro nutrients according to North Caroline University law, USA. The treatments are **T_0:** (Zn_0 B_0 Cu_0 kg ha^{-1}), **T_1:** (Zn_0 B_4 Cu_2 kg ha^{-1}), **T_2:** (Zn_4 B_4 Cu_2 kg ha^{-1}), **T_3:** (Zn_6 B_4 Cu_2 kg ha^{-1}), **T_4:** (Zn_8 B_4 Cu_2 kg ha^{-1}), **T_5:** (Zn_8 B_0 Cu_2 kg ha^{-1}), **T_6:** (Zn_6 B_2 Cu_0 kg ha^{-1}), **T_7:** (Zn_6 B_6 Cu_2 kg ha^{-1}), **T_8:** (Zn_6 B_4 Cu_0 kg ha^{-1}) **T_9:** (Zn_6 B_4 Cu_1 kg ha^{-1}) and **T_{10}:** (Zn_6 B_4 Cu_3 kg ha^{-1}). The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Data on different growth and yield contributing characters and yield were recorded to find out the optimum level of micronutrient for better growth and yield of tomato.

The longest plant height at 60 DAT (109.00 cm), maximum number of leaves per plant at 60 DAT (85.00), maximum number of branches per plant (9.00), the highest carbon assimilation rate (11.00 %), minimum days to flowering (32.89 days), maximum number of clusters $plant^{-1}$ (9.35), the maximum number of flowers $cluster^{-1}$ (7.75), maximum number of fruits $cluster^{-1}$ (4.25), maximum fresh weight of fruit (92.50 g), the maximum dry matter content of fruit (15.37 %), the highest TSS (8.76 %), maximum yield of fruit $plot^{-1}$ (34.56 kg), maximum yield of fruit $plant^{-1}$ (2.88 kg), and the maximum yield $hectare^{-1}$ (96.00 t/ha) were recorded from the T_3 (Zn_6 B_4 Cu_2 kg ha^{-1}) treatment. maximum size of canopy (102.74 cm), maximum fruit diameter (6.90 cm) were recorded from T_4 (Zn_8 B_4 Cu_2 kg ha^{-1}) treatment, maximum size of stem diameter (2.40 cm) was recorded from T_7 (Zn_6 B_6 Cu_2 kg ha^{-1}) treatment, maximum days to flowering (41.55 days) was recorded from T_0 (control) treatment, the highest length (6.63 cm) of fruit and chlorophyll content in leaf (64.55 %) were recorded from T_9 treatment. In case of economic analysis the maximum benefit cost ratio (2.37) was observed from T_3 (Zn_6 B_4 Cu_2 kg ha^{-1}) treatment.

On the other hand the shortest plant height at 60 DAT (56.00 cm), minimum number of leaves per plant at 60 DAT (46.00), minimum number of branches per plant (5.00), the lowest carbon assimilation rate (3.00 %), minimum number of clusters $plant^{-1}$ (7.44), the minimum number of flowers $cluster^{-1}$ (4.05), minimum number of fruits $cluster^{-1}$ (3.08), minimum fresh weight of fruit (72.00 g), the minimum dry matter content of fruit (10.00 %), the lowest TSS (6.13 %), minimum yield of fruit $plot^{-1}$ (30.60 kg), minimum yield of fruit $plant^{-1}$ (2.55 kg), and the minimum yield $hectare^{-1}$ (45.00 t/ha), minimum size of canopy (72.00 cm), minimum fruit diameter (4.33 cm), minimum size of stem diameter (2.00 cm), the lowest length of fruit (4.00 cm), and chlorophyll content in leaf (44.90 %) and maximum days to flowering (41.55 days), were recorded from T_0 (control) treatment and in case of economic analysis the minimum benefit cost ratio (2.14) was observed from T_0 (control) treatment.

Conclusion

Based on the experimental results it may be concluded here that-

- In this experiment treatment combination of T_3 (Zn_6 B_4 Cu_2 kg ha^{-1}) was more effective than control treatment combination of T_0 (Zn_0 B_0 Cu_0 kg ha^{-1}) and from economic point of view the treatment combination of T_3 (Zn_6 B_4 Cu_2 kg ha^{-1}) is the best irrespective of net income per hectare. So it is thus concluded that the treatment combination of T_3 (Zn_6 B_4 Cu_2 kg ha^{-1}) is good for generating higher income.

Micro nutrients are required in small amount for the plant. Based on this study we can say that at conclusion 6 kg Zinc ha^{-1}, 4 kg boron ha^{-1} and 2 kg copper ha^{-1} that is T_3 (Zn_6 B_4 Cu_2 kg ha^{-1}) treatment performed the best results on yield and yield contributing characters. However this findings need to be further investigated and evaluated in different agro ecological zones (AEZ) of Bangladesh before final recommendation to the farmers.

Further research should be conducted by setting more treatments on different doses of micronutrients for tomato and should be conducted at different locations of Bangladesh.

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APPENDICES

Appendix I. Monthly average temperature, relative humidity and total rainfall of the experimental site during the period from October 2015 to May 2016

Month	Air temperature (^{0}C)		R. H. (%)	Total rainfall (mm)
	Maximum	Minimum		
October,15	29.18	18.26	81	39
November,15	25.82	16.04	78	0
December,15	22.4	13.5	74	0
January,16	24.5	12.4	68	0
February,16	27.1	16.7	67	3
March,16	31.4	19.6	54	11
April, 16	35.3	22.4	51	15
May, 16	38.2	23.2	62	17

Source: Bangladesh Metrological Department (Climate and weather division) Agargaon, Dhaka

Appendix II. Results of morphological, mechanical and chemical analysis of soil of the experimental plot

A. Morphological Characteristics

Morphological features	Characteristics
Location	Horticulture Farm, SAU, Dhaka
AEZ	Modhupur Tract (28)
General Soil Type	Shallow redbrown terrace soil
Land Type	Medium high land
Soil Series	Tejgaon
Topography	Fairly leveled
Flood Level	Above flood level
Drainage	Well drained

B. Mechanical analysis

Constituents	Percentage (%)
Sand	28.78
Silt	42.12
Clay	29.1

C. Chemical analysis

Soil properties	Amount
Soil pH	5.8
Organic carbon (%)	0.95
Organic matter (%)	0.77
Total nitrogen (%)	0.075
Available P (ppm)	15.07
Exchangeable K (%)	0.32
Available S (ppm)	16.17

Source: Soil Resource Development Institute (SRDI)

Appendix-III. Analysis of variance of data on plant height (cm) at different days after transplanting of tomato

Source of variation	Degrees of freedom (df)	Mean square of plant height at				
		20 DAT	30 DAT	40 DAT	50 DAT	60 DAT
Replication	2	$1.28E^{-29}$	$5.72E^{-29}$	$1.19E^{-28}$	$3.84E^{-28}$	$6.19E^{-28}$
Factor A (Micro nutrient)	2	23.739	57.539*	176.030**	454.158*	823.921*
Error	22	0.866	3.466	3.266	10.466	36.866
** : Significant at 1% level of probability; * : Significant at 5% level of probability						

Appendix-IV. Analysis of variance of data on number of leaves at different days after transplanting of tomato

Source of variation	Degrees of freedom (df)	Mean square of plant height at				
		20 DAT	30 DAT	40 DAT	50 DAT	60 DAT
Replication	2	$1.74E^{-29}$	$2.07E^{-29}$	$3.30E^{-28}$	$6.65E^{-28}$	$1.32E^{-27}$
Factor A (Micro nutrient)	2	0.763	7.721*	135.758*	221.83*	334.739*
Error	22	5.25E-62	0.066	3.466	2.866	4.066
** : Significant at 1% level of probability; * : Significant at 5% level of probability						

Appendix-V. Analysis of variance of data on number of branches plant^{-1}, canopy size, stem diameter and carbon assimilation rate of tomato

Source of variation	Degrees of freedom (df)	Mean square of number of			
		No. of branches plant^{-1}	Canopy size (cm)	Stem diameter (cm)	Carbon assimilation rate (%)
Replication	2	$2.96E^{-30}$	$6.27E^{-28}$	$2.90E^{-31}$	$1.46E^{-29}$
Factor A (Micro nutrient)	2	3.521*	302.873**	0.102*	13.782**
Error	22	0.066	0.200	4.47E-04	0.102
** : Significant at 1% level of probability; * : Significant at 5% level of probability					

Appendix-VI. Analysis of variance of data on number of clusters plant^{-1}, number of flowers cluster^{-1} and number of fruits cluster^{-1} of tomato

Source of variation	Degrees of freedom (df)	Mean square of number of		
		No. of clusters plant^{-1}	No. of flowers cluster^{-1}	No. of fruits cluster^{-1}
Replication	2	5.12E^{-30}	2.42E^{-30}	8.59E^{-31}
Factor A (Micro nutrient)	3	46.9394**	2.435**	8.939*
Error	22	1.86667	0.061	0.466
** : Significant at 1% level of probability; * : Significant at 5% level of probability				

Appendix-VII. Analysis of variance of data on length of fruit, diameter of fruit and fresh weight of fruit of tomato

Source of variation	Degrees of freedom (df)	Mean square of SPAD value at		
		Fruit length (cm)	Fruit diameter (cm)	Fresh weight of fruit (g)
Replication	2	1.36E^{-30}	1.80E^{-30}	4.59E^{-28}
Factor A (Micro nutrient)	3	1.404**	1.998*	1300.85*
Error	22	6.18E-03	1.65E-03	48.6
** : Significant at 1% level of probability; * : Significant at 5% level of probability				

Appendix-VIII. Analysis of variance of data on chlorophyll content in leaf, TSS and dry matter content of tomato

Source of variation	Degrees of freedom (df)	Mean square of SPAD value at		
		Chlorophyll content in leaf (%)	TSS (%)	Dry matter content of fruit (%)
Replication	2	7.40E^{-28}	1.44E^{-29}	4.65E^{-29}
Factor A (Micro nutrient)	3	80.453*	1.404*	7.127**
Error	22	0.428	6.18E-03	0.076
** : Significant at 1% level of probability; * : Significant at 5% level of probability				

Appendix-IX. Analysis of variance of data on yield plot^{-1}, yield plant^{-1} and yield hectare^{-1} of tomato

Source of variation	Degrees of freedom (df)	Mean square of SPAD value at		
		Yield plot^{-1} (kg)	Yield plant^{-1} (kg)	Yield hectare^{-1} (t ha^{-1})
Replication	2	1.47E^{-28}	2.54E^{-31}	8.28E^{-28}
Factor A (Drought stress)	3	53.582**	0.369**	413.274**
Error	22	1.873	0.013	14.456
** : Significant at 1% level of probability; * : Significant at 5% level of probability				

Appendix-X. Input cost

Treatments	Labour Cost (TK.)	Ploughing Cost (TK.)	Seedling cost (TK.)	Irrigation Cost (TK.)	Pesticides cost (TK.)	Zinc cost (Tk.)	Boron cost (TK.)	Copper cost (TK.)	Manure and fertilizers cost (TK.)				Sub Total (A)
									Cowdung	Urea	TSP	MP	
T_0	78000	10000	4700	18000	3600	0	0	0	30000	7800	1200	4600	143900
T_1	98000	10000	4700	18000	3600	0	7200	2400	30000	7800	1200	4600	153500
T_2	98000	10000	4700	18000	3600	5600	7200	2400	30000	7800	1200	4600	159100
T_3	98000	10000	4700	18000	3600	8400	7200	2400	30000	7800	1200	4600	161900
T_4	98000	10000	4700	18000	3600	11200	7200	2400	30000	7800	1200	4600	164700
T_5	98000	10000	4700	18000	3600	11200	0	2400	30000	7800	1200	4600	157500
T_6	98000	10000	4700	18000	3600	8400	3600	0	30000	7800	1200	4600	155900
T_7	98000	10000	4700	18000	3600	8400	10800	2400	30000	7800	1200	4600	165500
T_8	98000	10000	4700	18000	3600	8400	7200	0	30000	7800	1200	4600	159500
T_9	98000	10000	4700	18000	3600	8400	7200	1200	30000	7800	1200	4600	160700
T_{10}	98000	10000	4700	18000	3600	8400	7200	3600	30000	7800	1200	4600	163100

Appendix- XI. Total cost of production

Treatments	Cost of lease of land for 6 months (13% of value of land Tk. 7,00,000/year) (B)	Sub Total Cost of Production (A+B)	Interest on running capital for 6 months (Tk. 13% of cost/year) (C)	Total (A+B+C) (TK.)	Miscellaneous cost (Tk.) 5% of the input cost	Grand Total Cost of Production (TK.)
T_0	45500	189400	12311	201711	10086	270697
T_1	45500	199000	12935	211935	10597	271132
T_2	45500	204600	13299	217899	10895	278794
T_3	45500	207400	13481	220881	11044	285057
T_4	45500	210200	13663	223863	11193	285557
T_5	45500	203000	13195	216195	10810	272005
T_6	45500	201400	13091	214491	10725	271925
T_7	45500	211000	13715	224715	11236	285357
T_8	45500	205000	13325	218325	10916	279241
T_9	45500	206200	13403	219603	10980	280583
T_{10}	45500	208600	13559	222159	11108	285267