EFFECT OF ZINC AND BORON FERTILIZATION ON THE YIELD OF BARI TOMATO 17 (*Solanum lycopersicum* L.)

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CERTIFICATE

This is to certify that the thesis entitled **“EFFECT OF ZINC AND BORON FERTILIZATION ON THE YIELD OF BARI TOMATO 17 (*Solanum lycopersicum* L.)”** submitted to the **DEPARTMENT OF SOIL SCIENCE**, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTERS OF SCIENCE (MS)** in **SOIL SCIENCE**, embodies the result of a piece of bonafide research work carried out by **MD. JAWAD NOOR JUSTICE**, Registration No. 13-05445 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.

June, 2021

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Dedicated to

My

Beloved Parents

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The Author

EFFECT OF ZINC AND BORON FERTILIZATION ON THE YIELD OF BARI TOMATO 17 (*Solanum lycopersicum* L.)

ABSTRACT

The experiment was conducted during October 2019 to March 2020 in the farm of Sher-e-Bangla Agricultural University. The experiment consisted of two factors: Factor A: three Zn levels *viz*. Zn_0 (0 kg Zn ha^{-1}; control), Zn_1 (2 kg Zn ha^{-1}) and Zn_2 (4 kg Zn ha^{-1}) and Factor B: three B levels *viz*. B_0 (0 kg B ha^{-1}; control), B_1 (1.5 kg B ha^{-1}) and B_2 (3 kg B ha^{-1}). The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. BARI tomato 17 was used as plant material. Different zinc and boron levels influenced significantly on most of the recorded parameters. In case of different Zn levels, the highest results regarding growth, yield and yield contributing parameters were obtained from Zn_1 (2 kg Zn ha^{-1}) compared to Zn_2 (4 kg Zn ha^{-1}) and control. Zn_1 (2 kg Zn ha^{-1}) showed the highest number of fruits $plant^{-1}$ (22.42), fruit weight $plant^{-1}$ (1.67 kg) and fruit yield (69.63 t ha^{-1}). Regarding boron treatment, B_1 (1.5 kg B ha^{-1}) showed best results on most of the yield and yield contributing parameters compared to B_2 (3 kg B ha^{-1}) and control. B_1 (1.5 kg B ha^{-1}) gave the highest number of fruits $plant^{-1}$ (23.07), fruit weight $plant^{-1}$ (1.71 kg) and fruit yield (71.19 t ha^{-1}). In terms of treatment combination of zinc and boron, the highest number of branches $plant^{-1}$ (9.67), number of flowers $plant^{-1}$ (32.53), number of fruits $plant^{-1}$ (24.80), fruit weight $plant^{-1}$ (1.86 kg) and yield (77.57 t ha^{-1}) were recorded from Zn_1B_1 (2 kg Zn ha^{-1} 1.5 kg B ha^{-1}) whereas the lowest was recorded from Zn_0B_0 (0 kg Zn ha^{-1} with 0 kg B ha^{-1}). So, the treatment combination of Zn_1B_1 (2 kg Zn ha^{-1} with 1.5 kg B ha^{-1}) can be considered as best compared to the rest of the treatment combinations.

LIST OF CONTENTS

LIST OF CONTENTS (Cont'd)

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABBREVIATIONS AND ACRONYMS

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

CHAPTER I

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) originated in tropical America (Salunkhe *et al*., 1987) is an important vegetable crop, which belongs to the family Solanaceae and also used wordwide in daily diet due to its good taste and nutritional quality. It is a key vegetable crop grown throughout the world (Srividya *et al*., 2014). It is also a major vegetable crop grown in Bangladesh.

Tomato is a good source of high nutritive value especially vitamin A, B and vitamin C, carotenoids, lycopene, minerals (Ca, Fe, Na, K, Mg), protein (USDA, 2016, Bose and Som, 1990; Rashid, 1983), antioxidant and carotenoids (Di Masico *et al*., 1989) that helps in retarding cancer and degenerative diseases (Giovannucci, 1999). It is a nutritious and delicious vegetable used in salads, soups and processed into stable products like ketchup, sauce, marmalade, chutney and juice. They are extensively used in the canning industry for production of canned products. Therefore, it can meet up some degree of vitamin A and C requirement, adds flavor to the foods, rich in medicinal value and also can contribute to solve malnutrition problem (Osman *et al*., 2019).

Tomato ranks third in the world's vegetable production, next to potato and sweet potato, placing itself first as processing crop among the vegetables (Islam *et al*., 2011). The production of tomato in our country in 2017-18 was 385 thousand metric tons whereas it was only 190 thousand metric tons in 2009-10 (BBS, 2018). Although the production of tomato in Bangladesh is increasing day by day but it is not enough to fulfill the demand of the peoples.

The most logical way to increase the total production at the national level from our limited land resources is to increase yield per unit area. Nutrients management is essential to maximize crop yield (Menzel and Simpson, 1987), enhance fruit quality and increase profitability (Ganeshamurthy *et al*., 2011).

Tomato plant requires macro and micro nutrients for growth and development as well as to complete its life cycle (Fageria, 1992; Brady and Weil, 2002).

Application of micronutrients particularly Zn and B seem to be one of the important practices to boost up tomato production in micronutrient deficient areas of Bangladesh (Mallick *et al*., 2020). Micronutrients play an important role in not only plant growth but also different metabolic processes in the plant body such as photosynthesis, enzyme activity, respiration, cell development, nitrogen fixation and hormone synthesis, but they are required in small quantity for the plant body (Marschner, 1995; Mengel *et al*., 2001).

Micronutrient deficiencies are not only hampering crop productivity but also are deteriorating quality. The low micronutrient feed and food stuffs are causing health hazards in human beings and animals. Micronutrient acts as catalyst in the uptake and use of certain macronutrients (Phillips, 2004). Fruit size and quality as well as quality of some crops, are improved with micronutrient (Zn and B) use. In spite of adequate application of NPK fertilizer, normal growth of high yielding varieties could not be obtained due to little or no application of micronutrients. High fertilizer responsive varieties express their full yield potential when trace elements are applied along with NPK fertilizers (Nataraja *et al*., 2006).

Boron plays an important role directly and indirectly in improving the yield and quality of tomato in addition to checking various diseases and physiological disorders (Magalhaes *et al*., 1980). Boron affects the quality of tomato fruit, particularly size and shape, color, smoothness, firmness, keeping quality and chemical composition. Demoranville and Deubert (1987) reported that fruit shape, yield and shelf life of tomato were also affected by boron nutrition. The increase in vegetative growth of tomato could be attribute to physiological role of boron and its involvement in the metabolism of protein, synthesis of pectin, maintaining the correct water relation within the plant, resynthesis of adenosine triphosphate (ATP) and translocation of sugar at development of the flowering and fruiting stages (Bose and Tripathi, 1996). Boron also has effect on many functions of the plant such as hormone movement, active salt absorption, flowering and fruiting process, pollen germination, carbohydrates, nitrogen metabolism and water relations in the plants (Osman *et al*., 2019). Besides, application of Zinc increased significantly the dry biomass, fruit yield, fruit fresh weight and numbers of fruits per plants (Gurmani *et al*., 2012). The basic Zn functions in plants are related to metabolism of carbohydrates, proteins, phosphates and also of auxins, RNA, and ribosome formations (Shkolnik, 1974). Chaudry *et al*. (2007) stated that micronutrients especially zinc (Zn) and boron (B) significantly increased the crop yield over control when applied single or in combination with each other, while Mandal *et al*. (2007) observed significant positive interaction between fertilizer treatments and physiological stages of crop growth.

Considering the aforementioned facts, it is felt necessary to study the factors responsible for fertilizer efficiency improvement. Keeping in view the key role played by Zn and B nutrition in plant growth, this study is designed to find out the suitable doses of Zn and B and their combination for tomato production. The objectives of this research, therefore, were

(i) To know the individual effect of zinc and boron on the yield and yield parameters of tomato (cv. BARI tomato-17) and

(ii) To examine the interaction effects of zinc and boron on the yield and yield parameters of tomato (cv. BARI tomato-17).

CHAPTER II

REVIEW OF LITERATURE

Zinc (Zn) and boron (B) are the most important micronutrients for maximizing the yield of tomato. The proper fertilizer management basically influences its growth and yield performance. Experimental evidences showed that there is a profound influence of Zn and B fertilizers on this crop. The fertilizer requirements, however, varies with the soil and cultural conditions. Research works have been done in various parts of the world including Bangladesh is not adequate and conclusive. Some of the important and informative works conducted home and abroad in this aspect, have been furnished in this chapter.

2.1 Effect of zinc

Prasad *et al*. (2021) carried out investigations with one green house experiment and two field experiments to assess the impact of zinc on tomato. Results suggested that all parameters were significantly improved in both deficient and sufficient soils upon the addition of external zinc along with RDF. The treatment T_9 in high zinc soils significantly improved the quality parameters like TSS (6.00^0 Brix), titratable acidity (0.39%), Vitamin C (53.71 mg 100 g^{-1}), lycopene (13.24 mg 100 g^{-1}) and shelf life (24 days) when compared with other treatments. The zinc uptake and zinc use efficiency was recorded higher in T_9 as 238.91 g ha^{-1} and 2.47% which is more than that of RDF. The zinc uptake and zinc use efficiency was recorded higher in T_{10} as 291.53 g ha^{-1} and 2.64% which is more than that of RDF.

Ahmed (2021) reported that tomatoes are one of the world’s most commonly planted vegetable crops. The nutritional arrangement of the tomato depends on the quantity and type of nutrients taken from the growing medium, such assoil and foliar application; therefore, an adequate amount of macro- and micro-nutrients, including zinc (Zn) and zinc oxide nanoparticles (ZnO-NPs), are crucial for tomato production. Zinc foliar spraying is one of the effective procedures that may improve crop quality and yield. Zinc oxide nanoparticles (ZnO-NPs) are represented as a biosafety concern for biological materials. Foliar application of Zn showed better results in increasing soluble solids (TSS), firmness, titratable acidity, chlorophyll-a, chlorophyll-b, ascorbic acid, amount of lycopene. Researchers have observed the effect of nanoparticles of zinc oxide on various crops, including tomatoes. Foliar spraying of ZnO-NPs gave the most influential results in terms of best planting parameters, namely plant height, early flowering, fruit yields as well as lycopene content. Therefore, more attention should be given to improving quantity and quality as well as nutrient use efficiency of Zn and ZnO-NPs in tomato production. Recent information on the effect of zinc nutrient foliar spraying and ZnO-NPs as a nano fertilizer on tomato productivity is reviewed in this article.

Gopal and Sarangthem (2018) carried out a field experiment with four replications and four treatment, considering four levels each of zinc (0, 2.5, 5.0, and 10.0 Zn kg/ha in form of $ZnSO_4.7H_2O$). The results of experiment indicated that, application of different dose of Zn significantly increased plant growth and yield of tomato. The maximum plant height (cm), number of branches per plant, number of leaves per plant, first day flowering 29.83 days (first year) and 29.57 (second year), number of fruits per plant 27.90 (first year) and 28.76 (second year), fruit weight per plant 1.37 kg (first year) and 1.39 kg (second year) and fruit yield 50.69 (first year) and 51.54 (second year) t/ha were obtained in both the years under 10 Zn kg/ha.

Harris and Mathuma (2015) noticed that application of zinc at 250 ppm on tomato had significant effect on plant height, total dry weight of plants, and number of fruits per plant and weight of fruits per plant.

Muhammad *et al.* (2014) studied the impact of foliar spray of zinc on fruit yield of chillies *(Capsicum annuurn* L) revealed that with the increasing zinc level, the growth and yield contributing traits of chilli variety Talhari were gradually improved. However the fruit yield per hectare did not increase significantly under 5 ml L^{-1} water Zn concentration when compared with 4ml L^{-1} water, which indicates that zinc at 4 ml L^{-1} water was an optimum level for obtaining economical fruit yield in chilli variety Talhari.

Saravaiya *et al.* (2014) found that tomato yield obtained with treatment Zn^{2+} Recommended doses of macro nutrients + other micronutrient recorded significantly higher plant height (131.73 cm), number of branches plant (5.81), fresh weight of plants (25.65 t ha^{-1}), dry matter yield of plants (7670.03 kg ha^{-1}), maximum days to last picking (166.68), number of fruits $plant^{-1}$ (34.26), fruit length (5.52 cm), fruit diameter (4.64 cm), fruit volume (67.53 cm^3), single fruit weight (49.20 g), fruit weight $plant^{-1}$ (1.68 kg), number of locules $fruit^{-1}$ (3.03), pericarp thickness (6.23 mm), fruit yield ha^{-1} (46.78 t) and marketable fruit yield ha^{-1} (45.62 t).

Gurmani *et al*. (2012) conducted a glasshouse pot experiment, to study the effect of soil applied Zinc (@ 0, 5, 10 and 15 mg kg^{-1}) on the growth, yield and biochemical attributes of two tomato cultivars; VCT-1 and Riogrande. 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 this study suggest 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.

Gurmani *et al.* (2012) conducted pot experiment to study the soil applied zinc (0, 5, 10 and 15 mg kg^{-1}) on the growth, yield and biochemical attributes on two cultivars of tomato VCT-1 and Riogrande. Soil application of zinc significantly increased the dry biomass, fruit yield, fruit fresh weight and number of fruits $plant^{-1}$ of both the tomato cultivar.

Hanan (2008) studied the effect of five Cd as well as Zn levels on growth and amino acids content of tomato. It was clear that addition of 0.1 µmol L^{-1} of Cd and Zn induced a slight increase in plant height and leaf number. However, at higher levels, *i.e.*, 5 and 10 µmol L^{-1}, root length, plant height and leaf number values were all significantly reduced. The exposure to 10 µmol L^{-1} Cd and Zn for 12 d reduced plant height by 46.4, 36.7 percent compared with control, respectively. Similarly, root length was reduced by 41.1 percent and 25.8 percent respectively. The addition of Cd and Zn in the growth medium also had significant deleterious effect on chlorophyll content of tomato seedlings. Total amino acids content decreased with increasing in Cd and Zn in growth medium.

Baldev *et al.* (2008) studied that effect of trickle irrigation along with micronutrients on growth and yield of tomato F1 hybrid and reported that higher marketable yield of tomato was obtained with drip irrigation and zinc spray at 0.5 percent combination.

Patil *et al.* (2008) studied effect of foliar application of zinc on growth and yield of tomato and found that best treatment was application of zinc as zinc sulphate which recorded highest benefit cost ratio of 1.80.

Dube *et al.* (2003) studied the effect of zinc on yield and quality of tomato and concluded that soil application of Zn through $ZnSO_4$ @ 5 mg kg^{-1} significantly increased fruit yield and improved fruit quality, biomass, total pulp weight, acidity and lycopene, ascorbic acid, total carotenoid and water content.

Manoj and Sharma (2003) studied the effect of foliar application of zinc on growth and yield of tomato and found that best treatment was application of zinc at 40 kg zinc sulphate ha^{-1} which gave the higher plant height, fruit weight and yield of tomato, okra and peas.

Patnaik *et al.* (2001) studied the response of tomato to zinc and iron application and observed that among all treatments tried, application of $ZnSO_4$ @ 12.5 kg ha^{-1} to soil followed by foliar sprays of 0.2 percent $ZnSO_4$ and 0.5 percent $FeSO_4$ thrice at weekly interval resulted in higher fruit yield of tomato i.e. 39.88 t ha^{-1}.

2.2 Effect of boron

Gopal and Sarangtham (2021) carried out a field experiment during *Rabi* seasons of 2016-17 and 2017-18, respectively to evaluation of the effect of boron on yield of tomato in acid soil. Results revealed in evident from both first and second year, boron showed effect on the yield and yield attributes of tomato. During experimentation, results reported that soil application of boron at 2.0 kg B/ha (T_4) showed highest number of fruits $plant^{-1}$ and maximum weight of fruits $plant^{-1}$ (27.60 in first year and 29.8 in second year), (1.39 kg in first year and 1.53 kg in second year) and yield ha^{-1} (51.31t ha^{-1} in first year and 56.7t ha^{-1} in second year) respectively, over boron control (T_1) plot. Hence, it was concluded that, the soil application of Boron at 2.0 B kg/ha effective among all the treatments in the experiment in Tomato under acid soil conditions during Rabi 2016-17 and 2017-18.

Xu *et al*. (2021) investigated the effect of application methods with different boron levels on the growth, fruit quality and flavor of tomato *(Solanum lycopersicum* L., cv. 'Jinpeng No.1') under greenhouse conditions. Seven treatments used included two application methods (leaf and root application) with four boron levels (0, 1.9, 3.8 and 5.7 mg-L^{-1} H_3BO_3). Experimental outcomes revealed that both application methods significantly increased net photosynthetic rate and chlorophyll content, and stabilized leaf structure of tomato. Leaf spray of 1.9 mg-L^{-1} H_3BO_3 was more effective at improving plant growth and photosynthetic indices in tomato compared to other treatments.

Additionally, root application of 3.8 mg-L^{-1} H_3BO_3 resulted in better comprehensive attributes of fruit quality and flavor than other treatments in terms of amounts of lycopene, □-carotene, soluble protein, the sugar/acid ratio and characteristic aromatic compounds in fruit. The appropriate application of boron can effectively improve the growth and development of tomato, and change the quality and flavor of fruit, two application methods with four boron levels had different effects on tomato.

Sturiao *et al*. (2020) found that boron deficiency is very harmful in tomato (*Solanum lycopersicum* L.) cultivation. Boron foliar sprays can be used as a mean of preventing plant stunting, that results in low growth, poor onset of flowers and fruits, fruit physiological disorders, and hence, low tomato productivity. Boron sources and polyol like surfactants can affect foliar sprays' effectiveness. This work had the objective of evaluating foliar sprays of boric acid, borax and B-ethanolamine, with or without, polyol surfactant. The experiment was carried out in a 3×2+2 factorial arranged in randomized blocks with four replications. Plants of tomato cultivar 'Tangerine' F_1 were fed with complete nutrient solution containing 5 μmol L^{-1} of B. These plants were sprayed with the three sources of boron, with or without a polyol like surfactant at 14 days intervals until the production cycle was complete. The additional treatments were: a positive control (C^+), in which the plants received 20 μmol L^{-1} B, and a negative control (C^-), in which the plants received 5 μmol L^{-1} B via nutrient solution, both without supply of B via foliar sprays. They evaluated plant height, root volume, number of flowers and fruits; dry matter production; nutrient contents and accumulation, in four phenological stages, and fresh and dry matter of fruits at the harvest. The data obtained were subjected to analysis of variance and the treatments compared by mean test. Leaf sprays improved the tomato growth and production compared to the (C^-) treatment, but the adequate B supply by roots (C^+) was the most efficient method for nutrition of tomato plants with boron. Among the boron sources, B-ethanolamine and boric acid were those which promoted the best results in tomato production, compared to the foliar application of borax. The use of the polyol like surfactant did not result in significant improvements on growth and production of the tomato plants.

Roy and Monir (2020) conducted an experiment at Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from October 2016 to April 2017. The experiment was conducted to assess the effect of two factors, for example; I, two levels of foliar spray of boron as: 100 ppm boric acid (B1) and 200 ppm boric acid (B2) in relation to a control and II, three different tomato cultivars/lines as: L1: Exotic Tomato Line -1, L2: Exotic Tomato Line-2, L3: BARI Tomato-15. The two factorial experiments were laid out in Randomized Complete Block Design with three replications. Fruit setting (56.73%), yield (64.89 t/ha) and total soluble solid (TSS) (4.3%) were considerably higher in B1 and low in B2. Whereas, significantly higher yield (79.87 t/ha) was recorded in L3 in in comparison to L1. Considering quality parameters, Vitamin C (20 mg) was the highest in L3 whereas TSS (4.58%) was the highest in L1. In interaction effect, the highest yield (85 t/ha) was obtained from B1L3 and the lowest (31.23 t/ha) in B2L1. The study suggested cultivating BARI Tomato-15, but other two exotic lines adapted well and showed good performance in terms of yield and quality parameters.

Sanjida *et al*. (2020) conducted a study to investigate the effects of varieties and boron (B) levels on growth and yield of summer tomato (*Lycopersicon escuientum* Mill.) during the period from May, 2018 to September, 2018. Fifteen treatments were comprising (i) three summer tomato varieties (BARI hybrid tomato 4, 8 and 10) and (ii) five levels of boron as boric acid (0,1,2, 3 and 5 kg B ha^{-1}) in all combinations. Randomized complete block design with three replications was used in the earthen pot (0.79 ft^3) experimentation. The effects of varieties and boron levels showed significant variations ($p < 0.05$) on growth and yield of summer tomato at different days after transplanting. Among the varieties at final count $plant^{-1}$, delayed flowering (32.6 days), the highest plant height (93.8 cm), number of leaves (99.93), number of branches (26.27), number of flower clusters (18.53), number of flowers (82.73), number of fruits (51.87), longest fruit length (41.87 mm) and maximum fruit width (48.0 mm), weight of individual fruit (55.71 g) and total weight of fruits (2892.88 g) were observed in BARI hybrid tomato 8. In contrast, the lowest plant height (87.3 cm), number of leaves (86.47), number of branches (24.06), number of flower clusters (15.87), number of flowers (66.07), number of fruits (37.33), weight of individual fruit (43.60 g) and total weight of fruits (1630.57g) were found in BARI hybrid tomato 4; and early flowering (31.93 days), shortest fruit length (33.07 mm) and maximum fruit width (34.60 mm) were noticed in BARI hybrid tomato 10. Among the boron levels at final count plant^{-1}, early flowering (29.67 days), the maximum number of flower clusters (18.44), number of flowers (89.11), number of fruits (46.22) and total weight of fruits (2364.29 g) were recorded in 2 kg B ha^{-1} treatment; the maximum plant height (96.50 cm), number of leaves (102.89), number of branches (28.11), longest fruit length (42.89 mm) and maximum fruit width (46.78 mm) and weight of individual fruit (51.74 g) were obtained in 3 kg B ha^{-1} treatment. Conversely, delayed flowering (34.67 days), minimum plant height (83.50 cm), number of leaves (87.56), number of branches (21.78), number of flower clusters (15.89), number of flowers (63.56), number of fruits (40.33), shortest fruit length (31.78 mm) and minimum fruit width (34.67 mm), weight of individual fruit (47.47 g) and total weight of fruits (1936.00 g) were recorded in control (0 kg B ha^{-1}) treatment. Our results suggest that the inclusion of B (2-3 kg ha^{-1}) with the current fertilization practice will enhance the growth and yield of summer tomato grown at AEZ (agro-ecological zone) 13 while BARI hybrid tomato 8 could be recommended as one of the promising varieties.

Gazala *et al.* (2016) carried out an experiment on boron its importance in crop production status in Indian soils and crop responses to its application and summarizes their result by saying that “application of boron at different rates in different crop have shown a positive influence on yield and other agronomic parameters of different crops reflecting the significant of boron in enhancing the yield of different crops".

El-Hameed *et al*. (2014) conducted a germination and pot experiments in order to assess the possible effects of boron (0.0, 100, 200, 300 and 400 ppm) on the growth and some metabolic activities of tomato at 9 and 30 days of growth. Application of different concentrations of boron significantly increased fresh and dry weights at low boron concentrations (100 and 200 ppm) compared with control. In addition, the content of Ca and B were increased in shoot and root of tomato, K was increased in shoot and decreased in root, while Na increased in root and decreased in shoot in response to boron application. The activity of glutamate-oxoloacetate and glutamate-pyruvate transaminases enzymes was significantly increased with the applied boron concentrations. Moreover, the root and shoot soluble proteins were increased gradually with increasing boron concentrations. El-Hameed *et al*. (2014) also reported that boron is an essential micronutrient for normal growth of higher plants, when it absorbed in excess amounts, it can be toxic and induce a number of deleterious effects. Tomato is one of the crops which respond well to boron application.

Maria and Ladislav (2014) performed an experiment at the Research - Breeding Station - Pstrusa to investigate the effect of increasing doses of boron on oil production of oilseed rape. Doses of nitrogen and sulfur (183 kg N.ha^{-1}, 46.5 kg S.ha^{-1}) and different doses of boron (200 g B ha^{-1}, 400 g B ha^{-1}, 800 g B ha^{-1}) were applied. The result shows that the boron nutrition positively influences the oil content in seeds of oilseed rape *(Brassica napusL.)*.

Moura *et al.* (2013) conducted an experiment with the objective to evaluate the effect of boron on the nutritional status of the cocoanut palm trees and its productivity when artificially applied to the culture soil. The treatments consisted of five levels of boron dosages: zero, 1, 2, 4, and 6 kg ha^{-1}. Boron (borax) dosages were applied in equal halves directly into the soil. The outcome of the research shows that ninety five percent of palm trees maximum production was obtained with the use of boron dosage at 2.1kg ha^{-1}.

Naz *et al.* (2012) conducted an experiment to study the effect of Boron (B) on the growth and yield of Rio Grande and Rio Figue cultivar of tomato. 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 outcome of the experiment was positive with Rio Grande cultivar of tomato showing significant respond on all parameters. They concluded that 2 kg B ha^{-1} significantly affected flowering and fruiting of Rio Grande cultivar.

Riaz and Muhammad (2011) conducted an experiment to evaluate the response of wheat, rice and cotton to B application. Boron was applied at 1 kg ha^{-1} as Borax decahydrate (11.3% B) at different times along with recommended doses of N, P and K. The results revealed that B application at sowing time to wheat increased significantly the number of tillers plant (15%), number of grains spike (11%), 1000-grain weight (7%) and grain yield (10%) over control. Among the treatments, B application at sowing time showed best results followed by B application at 1st irrigation and at booting stage. In rice (coarse), B application before transplanting substantially increased number of tillers $hill^{-1}$ (21%), plant height (3%), panicle length (10%), and number of paddy grains $panicle^{-1}$ (17%), 1000-grain weight (11%) and paddy yield (31%) over control. Response of fine rice to the B application was similar for all yield parameters as in coarse rice. In cotton, B application considerably increased plant height (3%), number of mature bolls $plant^{-1}$ (12%), seed weight $boll^{-1}$ (8%) and seed cotton yield (9%) over control.

Soomro *et al*. (2011) conducted a field experiment to compare the effect of foliar and soil applied boron on the different growth stages and fodder yield of maize (Zea *mays* L.) variety Akbar. Experimental results revealed that the foliar application of 0.5% boron as a boric acid at early, mid and late whorl stages resulted in significant increase in all parameters recorded. Soil and applied boron at 2 kg ha^{-1} did not remain effective for growth and yield of maize crop as compared to foliarly applied boron. There was significant effect of boron on its concentration in straw and its uptake when applied on foliage. It can be concluded from the study that application of B (0.5%) as foliar spray at early, mid and late whorl stage along with recommended dose of NPK fertilizers may be considered for getting higher fodder yield of maize.

Hossain *et al.* (2011) carried out a research to find out the optimum rate of B application for maximizing nutrient uptake and yield of mustard in calcareous soil, boron was applied at 0, 1, and 2 kg/ha. Effect of B was evaluated in terms of yield and mineral nutrients (N, P, K, S, Zn, and B) uptake. The mustard crop responded significantly to B application. Boron and N concentrations of grain and stover were significantly increased with increased rate of B application indicating that B had positive role on protein synthesis. In case of P, S, and Zn, the concentrations were significantly increased but in case of K, it remained unchanged in stover. The grain B concentration increased from 19.96 pg/g in B control to 45.99 pg/g and 51.29 pg/g due to application of 1 kg and 2 kg B/ha, respectively. Concerning the effect of B on the nutrient uptake, six elements followed the order K> N> S> P> B> Zn and these were significantly influenced by B application.

Sathya *et al.* (2010) conducted a field experiment to investigate the effect of application of boron on growth, quality and fruit yield of PKM 1 tomato. The biometric characters such as plant height and number branches were significantly influenced by soil and foliar application of boron. It was observed that among the various levels of soil application of boron, borax @ 20 kg ha^{-1} recorded increase in height and number of branches whereas among the various levels of foliar application of boron, 0.25 percent borax spray produced taller plants with more no. of branches. The quality parameters of PKM 1 tomato fruit such as lycopene, ascorbic acid, crude protein and total soluble sugars were significantly increased due to the soil application of borax @ 20 kg ha^{-1} recording a value of 3.99 mg $100g^{-1}$, 23.0 mg $100g^{-1}$, 10.13 percent and 9.20° brix respectively. The crude fibre and titratable acidity were found to be highest in control that received the recommended dose of NPK alone, whereas the lowest value was recorded in soil application of borax @ 20 kg ha^{-1}. The results also revealed that the highest fruit yield of 33 tonnes per hectare was recorded in treatment that received borax @ 20 kg ha^{-1} recording 33.6 percent increase over control and was found to be significantly superior to rest of the treatments. The physical and economic optimum of borax for maximum yield of tomato was found to be 18.36 kg ha^{-1} and 18.29 kg ha^{-1} respectively at a price level of Rs.10 per kg of tomato and Rs.40 per kg of borax.

Hellal *et al.* (2009) investigated the application of nitrogen and boron rates on root yield and nutrient contents of sugar beet *(Beta vulgaris* L.) *cv.* pamela grown in calcareous soil conditions. The obtained results showed that increasing N level up to 80 mg N kg^{-1} significantly increased root and shoot yield and P, K and Fe. Application of 50 ppm Boron significantly improved the parameters of the yield of roots and above ground growth and nutrient contents and balance ratio of sugar beet. The combined application of N-B treatments at the rate of 100 mg N kg-1 + 50 ppm B gave the maximum shoot and root yield and nutrient balance whereas increasing the B application until 100 ppm appeared to have a toxic effect on plant growth. The results concluded that B found also to interact positively with nitrogen to affect yield components of sugar beet. The interaction from the applied N and B increased N, K and Fe distribution between root and shoot. The yield of sugar beet was highly and positively correlated with N, K and B content in root and shoot.

Yadav *et al.* (2006) evaluated the effects of boron (0.0, 0.10, 0.15, 0.20, 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 (0.79 kg), yield per plot (12.78 kg) and yield/ha (319.50 quintal) were obtained with 0.20% boron, whereas the greatest fruit weight (27.27 g) was recorded for 0.10% boron.

Bhatt and Srivastava (2005) investigated the effects of the foliar application of boron (boric acid), zinc (zinc sulfate), molybdenum (ammonium molybdate), copper (copper sulfate), iron (ferrous sulfate), manganese (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); dry matter content of shoot (27.25%); nitrogen (152.38 kg/ha), phosphorus (47.49 kg/ha), potassium (157.48 kg/ha), sulfur (64.87 kg/ha), zinc (123.70 g/ha), iron (940.36 g/ha), copper (72.70 g/ha), manganese (359.17 g/ha) and boron (206.58 g/ha) uptake by shoots; total fruit yield (266.60 kg/ha); dry matter yield of fruit (16.98 kg/ha); and nitrogen (78.78 kg/ha), phosphorus (8.51 kg/ha), potassium (34.31 kg/ha), sulfur (16.14 kg/ha), iron (141.81 g/ha), copper (23.13 g/ha), zinc (63.06 g/ha), manganese (34.08 g/ha) and boron (95.23 g/ha) uptake by fruits.

Shoba *et al.* (2005) conducted a field experiment in Tamil Nadu, India, during the 2002 rabi season, to investigate the effects of calcium (Ca) and boron (B) fertilizer and ethrel [ethephon] applications and 45x45 and 65x45 spacings against fruit cracking in the tomato genotypes LCR 1 and LCR 1 x H 24. Between the 2 genotypes, the fruit cracking percentage was low in LCR 1 x H 24. Among the 2 spacings, 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) observed that insufficient fruit set of tomatoes owing to poor pollination in low cost greenhouses is a problem in South Africa, as bumblebee pollinators may not be imported. Since sub-optimum boron (B) levels may also contribute to fruit set problems, this aspect was investigated. Four nutrient solutions with only B at different levels (0.02; 0.16; 0.32 and 0.64 mg L^{-1}) were used. Leaf analyses indicated that the uptake of Ca, Mg, Na, Zn and B increased with higher B levels. At the low B level, leaves were brittle and appeared pale-green and very high flower abscission percentages were found. 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.

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. 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.

Chude *et al.* (2001) reported that plant response to soil and applied boron varies widely among species and among genotypes within a species. This assertion was verified by comparing the differential responses of Roma VF and Dandino tomato cultivars to a range of boron levels in field trials. 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.

Prasad *et al.* (1997) carried out a field experiment with B treatments in tomato cv. Pusa Ruby and 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).

2.3 Combined effect of zinc and boron

Mallick *et al.* (2021) conducted a pot experiment in the net house of the Department of Agricultural Chemistry, Bangladesh Agricultural University, Mymensingh, to examine the effect of different levels of Zn and B on the major biochemical and nutritional quality of tomato fruits. The experiment was laid out in a completely randomized design (CRD) with 4 replications along with two treatment factors *viz*., (i) four levels of Zn- like control, Zn @ 4.0 kg ha^{-1}, Zn @ 6.0 kg ha^{-1} and Zn @ 8.0 kg ha^{-1}; and (ii) three levels of B- like control, B @ 2.0 kg ha^{-1} and B @ 3.0 kg ha^{-1}. Among the biochemical parameters- lycopene, total acidity, and vitamin C contents in tomato fruits ranged from 3.24-3.76 mg 100 g^{-1}, 0.26-0.36%, and 21.76-26.40 mg 100 g^{-1} samples, respectively. The study results revealed that the highest amounts of lycopene and vitamin C were recorded from B @ 2.0 kg ha^{-1}. Combined Zn and B applications showed a highly significant effect on total acidity, lycopene, and vitamin C contents of tomato fruits. Similarly, the application of Zn and B alone or in combination significantly affected the major nutrient contents of tomato fruits. The highest amounts of Ca, Mg, Na, K, and P were obtained from the application of Zn @ 4.0 kg ha^{-1}, while the maximum amounts of Fe and Zn were recorded from Zn @ 8.0 kg ha^{-1} treatment. However, the application of B alone significantly reduced the contents of Ca, P, S, Fe, and Zn in tomato fruits while the contents of Mg, K, and Na remained almost unchanged. Finally, the study results concluded that the combined application of Zn and B (@ 4.0 and 2.0 kg ha^{-1}, respectively) had a significant effect on major nutrients and biochemical characters of tomato fruits.

Mallick *et al*. (2020) conducted a pot experiment to optimize different levels of Zn and B for better growth and yield attributes of tomato (cv. *Ruma VF).* The experiment included two factors [factor- A *viz*., control (Zn_0), Zn @ 4.0 kg ha^{-1} (Zn_4), Zn @ 6.0 kg ha^{-1} (Zn_6) and Zn @ 8.0 kg ha^{-1} (Zn_8) and factor B *viz*., control (B_0), B @ 2.0 kg ha^{-1} (B_2) and B @ 3.0 kg ha^{-1} (B_3)], which was laid out in a completely randomized block design with 4 replications, thus total number of pots were 48. Zinc sulphate and boric acid were applied as the source of Zn and B that were applied during pot preparation along with recommended doses of N, P, K and S. The study revealed that application of different doses of Zn increased number of flower clusters $plant^{-1}$ at 80 days after transplanting, fruit length, fruit diameter, number of fruits $plant^{-1}$ and yield of tomato up to 4.0 kg ha^{-1}. Similarly, application of B @ 2.0 kg ha^{-1} produced the highest number of flower clusters $plant^{-1}$, fruit length and fruit diameter. On the other hand, the highest number of fruits $plant^{-1}$ and yield of tomato were obtained by the application of B @ 3.0 kg ha^{-1}. Together application of Zn @ 4.0 kg ha^{-1} and B @ 2.0 kg ha^{-1} produced the highest number of flower clusters $plant^{-1}$, number of fruits $cluster^{-1}$, fruit length, fruit diameter, number of fruits $plant^{-1}$, fruit weight $plant^{-1}$ and yield of tomato.

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

Haleema *et al*. (2018) investigated the effect of calcium, boron, and zinc foliar application on growth and fruit production of tomato and to optimize calcium, boron and zinc concentration for enhancing the growth and fruit related attributes of tomato. Calcium (0, 0.3, 0.6 and 0.9%), Boron (0, 0.25, 0.5%) and Zinc (0, 0.25, 0.5%) were applied as foliar spray three times. Calcium application at 0.6% increased plant height (88.04 cm), number of primary (2.63) and secondary (7.15) branches, leaves $plant^{-1}$ (182), leaf area (65.52 cm^2), and fruit per plant (66.15). In case of B levels, more plant height (88.14 cm), number of primary (2.61) and secondary (7.44) branches, number of leaves $plant^{-1}$ (177), number fruits $plant^{-1}$ (67.78) were recorded with foliar spray of B at 0.25%, while maximum leaf area was found at 0.5% B. Comparing the means for Zn concentrations, maximum plant height (86.53 cm), number of primary (2.53) and secondary (6.42) branches, leaves $plant^{-1}$ (167), leaf area (63.33 cm^2), and fruit per plant (63.78) were higher with 0.5% foliar Zn application. The interaction between Ca, B and Zn also showed significant results for most of the attributes. Therefore, application of Ca (0.6%), B (0.25%), and Zn (0.5%) as a foliar spray can be used alone or in combination to improve growth and fruit production of tomato.

Sultana *et al*. (2016) carried out field experiments for two consecutive years to study the effectiveness of soil and foliar application of micronutrients on the yield of tomato *(Lycopersicon esculentum* Mill.) at the Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. The micronutrients zinc (Zn) in the form of zinc sulphate ($ZnSO_4.7H_2O$) at the rate of 0.05 % and boron (B) in the form of boric acid (H_3BO_3) at the rate of 0.03% were applied as foliar spray at three different stages of plant growth i.e (i) before flower initiation; (ii) after fruit set when it becomes approximately marble sized; and (iii) at 20 days interval of second spray. 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} (T_5), 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.

Sultan *et al.* (2016) found that foliar applications of micronutrients were more suitable than the soil application, due to the rapid uptake resulting in reduction of deficiency. Foliar application of Zn and B increased the yield of tomato.

Ali *et al*. (2015) conducted an experiment aimed to increase the yield of BARI hybrid tomato 4, cultivated in summer season of Bangladesh, foliar application of zinc and boron [T_0: control; T_1: 25-ppm $ZnSO_4$ (Zinc Sulphate); T_2: 25-ppm H_3BO_3 (Boric Acid) and T_3: 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 H_3BO_3 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).

Rizwan *et al.* (2015) conducted a field experiment to study the growth and yield of tomato as influenced by foliar spray @ four levels of zinc (0, 0.2, 0.4 and 0.6 %) and four levels of boron (0, 0.05, 0.10 and 0.15 %). Among different levels, zinc at 0.4 percent and boron at 0.15 percent showed significant increase in number of cluster per plant, number of flower cluster per plant, number of branches per plant and number fruit cluster per plant.

Ullah *et al*. (2015) carried out an experiment to study the "Growth and yield of tomato *(Lycopersicon esculentum* L.) cv 'Rio Grand as influenced by different levels of zinc and boron as foliar application'. Four levels of zinc (0, 0.2, 0.4 and 0.6%) and four levels of boron (0, 0.05, 0.10 and 0.15%) were applied as foliar spray. Data was recorded on, 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}). Zinc, boron and their interaction significantly increased the growth and yield parameters. 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 (tha^{-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 (tha^{-1}) (23.33). Based on the above results it can be recommended that Zn @ 0.4% and B @ 0.15% should be combined applied to tomato for better growth and yield.

Meena *et al.* (2015) conducted an experiment on improvement of growth, yield and quality of tomato with foliar application of zinc and boron. Study indicated that application of boron and zinc was beneficial for vegetative growth, flowering and fruiting as well as quality improvement of tomato fruits grown in soils with high pH (8.2).

Prasad and Saravanan (2014) while experimenting with tomato reported that higher plant height (2.93 cm), number of leaves per plant (39.33), number of fruits per plant (88.33), mean fruit yield per poly house (3.342 t ha^{-1}), total yield (113.628 t ha^{-1}), application of $ZnSO_4$ at the rate of 250 ppm enhanced the yield by two and a half fold than that of control and benefit cost ratio (4.05) was obtained in B1.25 g L^{-1}+ Zn1.25 g L^{-1}).

Naga-Sivaiah *et al.* (2013) conducted a field experiment to the find out response of tomato to foliar application of micronutrient mixture (boron, zinc, molybdenum, copper, iron, manganese) in two varieties *viz.,* Utkal Kumari and Utkal Raja. All the micronutrient were applied at 100 ppm except manganese (@50 ppm) and resulted in improvement of seed yield characteristics *viz.,* recovery percentage, 100 seed weight and seed yield per plant of tomato.

Sajid *et al.* (2013) evaluated the possible effect of macro and micronutrient at different concentration levels of foliar application on the vegetative growth, flowering and yield of tomato cv. Roma. It was concluded that foliar application of macro and micronutrients enhanced the growth, flowering and marketable yield of tomato.

Shil *et al.* (2013) found that chilli was responsive to both zinc and boron as revealed by consecutive three years of study. Zinc at 3 kg ha^{-1} and boron at 1.0 kg ha^{-1} along with a blanket dose of NPK at 130:60:80 increases yield. From the quadratic response function the optimum dose of boron and zinc were calculated at 1.70 and 3.91 kg ha^{-1}.

Salam *et al*. (2011) carried out an experiment at the Vegetable Research Farm of the Horticulture Research Centre, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur to investigate the effect of boron, zinc, and cowdung on quality of tomato. There were 16 treatments comprising four rates of boron and zinc *viz*., B_0Zn_0, $B_{1.5}Zn_2$, B_2Zn_4 and $B_{2.5}Zn_6$ kg/ha and four rates of cowdung *viz*., CD_0, CD_{10}, CD_{15} and CD_{20} t/ha. Every plot received 253 kg N, 90 kg P, 125 kg K, and 6.6 kg S per hectare. The results reflected that the highest pulp weight (90.24%), dry matter content (5.82%), ascorbic acid (11.2 mg/100g). lycopene content (147 µg/100g), chlorophyll-a (42.0 µg/l00g), chlorophyll-b (61.0 µg/100g), boron content (36 µg/g), zinc content (51 µg/g), marketable fruits at 30 days after storage (74%) and shelf life (17 days) were recorded with the combination of 2.5 kg B/ha + 6 kg Zn/ha, and 20 t/ha cowdung.

Patil *et al.* (2010) conducted research on effect of foliar application of micronutrient on flowering and fruit set of tomato *(Lycopersicon esculentum Mill.) cv.* phule raja and reported that minimum number of days (30) to initiation of flowering and 50 percent flowering (38.86) were recorded with boron 50 ppm and 100 ppm while, the maximum number of days recorded in control. The treatment boron 100 ppm+ iron 100 ppm+ zinc 200 ppm was most effective in increasing number of clusters (13.85) and number of flowers (51.24) per plant. Maximum number of flowers (3.80) per clusters and percent fruit setting (47.76 %) was recorded with boron 50 ppm+ iron 100 ppm+ zinc 100 ppm, while minimum in control.

Hossain (2008) conducted an experiment on effect of zinc and boron on the growth and yield of tomato and they found that yield attributes and chemical constituents of tomato were increased significantly due to the application of zinc and boron fertilizers.

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

Gunes *et al.* (2000) conducted a greenhouse experiment involving 4 rates of B

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

Yadav *et al.* (1999) studied effect of zinc and boron application on yield of tomato and reported that fruit yield increased significantly with increased levels of zinc through soil application of zinc sulphate upto 7.5 ppm and decreased at 10 ppm.

Bose and Tripathi (1996) at Rewa, Madhya Pradesh, India studied the effect of foliar application of micronutrients (Zn, Mn, Fe and B) at 30 and 60 days after transplanting, on growth, yield and quality of tomatoes cv. Pusa Ruby was investigated in the field. The best growth (plant height 81.56 cm, highest number of branches per plant (19), highest number of fruits per plant (31.90) and highest yield per plant (1.407 kg) were observed after 30 and 60 days after transplanting. This treatment also reduced cracking.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at the Sher-e-Bangla Agricultural University farm, Dhaka, Bangladesh during the period from October 2019 to March 2020 to study the effect of zinc and boron fertilization on the yield of BARI tomato 17 (*Solanum lycopersicum* L.). The details of the materials and methods have been presented below:

3.1 Experimental location

The present piece of research work was conducted in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka. The location of the site is 90°33´E longitude and 23°77´N latitude with an elevation of 8.2 m from sea level. Location of the experimental site presented in Appendix I.

3.2 Climate

The climate of experimental site was subtropical, characterized by three distinct seasons, the winter from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October (Edris *et al.*, 1979). Details on the meteorological data of air temperature, relative humidity, rainfall and sunshine hour during the period of the experiment was collected from the Weather Station of Bangladesh, Sher-e-Bangla Nagar, presented in Appendix II.

3.3 Soil

The soil of the experimental area belongs to the Madhupur Tract (UNDP, 1988) under AEZ No. 28 and was dark grey terrace soil. The selected plot was medium high land and the soil series was Tejgaon (FAO, 1988). The characteristics of the soil under the experimental plot were analyzed in the Soil Testing Laboratory, SRDI, Khamarbari, Dhaka. The details of morphological and chemical properties of initial soil of the experiment plot were presented in Appendix III.

3.4 Test crop

BARI tomato-17, high yielding variety of tomato was collected from Bangladesh Agricultural Research Institute (BARI), Joydevpur, Gazipur which was used as plant materials for the present study.

3.5 Treatments of the experiment

Factor A: Zinc application – 3 treatments including control

1. Zn_0 = 0 kg Zn ha^{-1}
2. Zn_1 = 2 kg Zn ha^{-1}
3. Zn_2 = 4 kg Zn ha^{-1}

Factor B: Boron application – 3 treatments including control

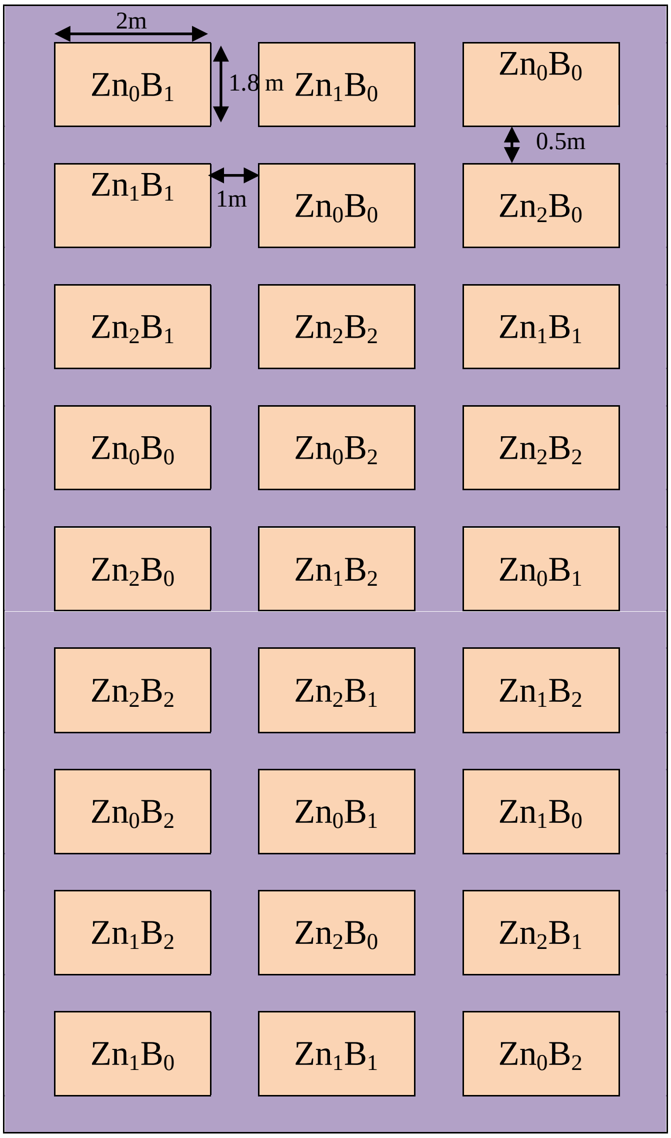
1. B_0 = 0 kg B ha^{-1}
2. B_1 = 1.5 kg B ha^{-1}
3. B_2 = 3 kg B ha^{-1}

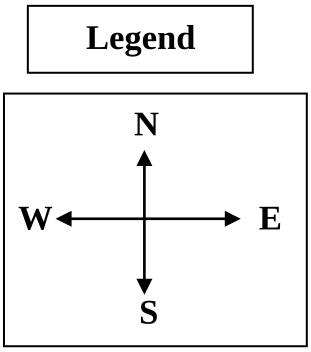
Treatment combinations: 9 (3×3=9) treatment combinations as follows:

Zn_0B_0, Zn_0B_1, Zn_0B_2, Zn_1B_0, Zn_1B_1, Zn_1B_2, Zn_2B_0, Zn_2B_1 and Zn_2B_2.

3.6 Experimental design and layout

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The layout of the experiment was prepared for distributing the combinations of Zn and B doses. The 9 treatment combinations of the experiment were assigned at random into 27 plots. The size of each unit plot was 2.0 m × 1.8 m. The distance between block to block and plot to plot were 1 m and 0.5 m respectively. The layout of the experiment field is presented in Figure 1.





Treatments

Factor A: Zinc– 3 levels

1. Zn_0 = 0 kg Zn ha^{-1}
2. Zn_1 = 2 kg Zn ha^{-1}
3. Zn_2 = 4 kg Zn ha^{-1}

Factor B: Boron– 3 levels

1. B_0 = 0 kg B ha^{-1}
2. B_1 = 1.5 kg B ha^{-1}
3. B_2 = 3 kg B ha^{-1}

Figure 1. Layout of the experimental plot

3.7 Raising of seedlings

The land selected for nursery beds were well drained and were sandy loam type soil. The area was well prepared and converted into loose friable and dried mass to obtain fine tilth. All weeds and dead roots were removed and the soil was mixed with well rotten cowdung at the rate of 5 kg/bed. Seed bed size was 3m × 1m raised above the ground level maintaining a spacing of 50 cm between the beds. Ten (10) grams of seeds were sown in each seed bed on 30 October, 2019. After sowing, the seeds were covered with light soil. Complete germination of the seeds took place with 5 days after seed sowing. Necessary shading was made by bamboo mat (chatai) from scorching sunshine or rain. No chemical fertilizer was used in the seed bed.

3.8 Preparation of the main field

The plot selected for the experiment was opened in the 13 November, 2019 with a power tiller, and was exposed to the sun for a few days, after, which the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a good tilth. Weeds and stubble were removed and finally obtained a desirable tilth of soil for transplanting. The land operation was completed on 20 November 2020. The individual plots were made by making ridges (20 cm high) around each plot to restrict lateral runoff of irrigation water.

3.9 Fertilizers and manure application

The N, P, K, S, Zn and B nutrients were applied through urea, Triple super phosphate (TSP), Muriate of potash (MoP) Gypsum, $ZnSO_4$ and Boric acid, respectively. Zinc (Zn) and boron (B) was applied as per treatment where rest of the nutrients was applied according to Krishi Projukti Hat Boi, BARI, 2019. Name and doses of nutrients were as follows:

Plant nutrients	Manure and fertilizer	Doses ha^{-1}
--	Cowdung	10 t
N	Urea	220 kg
P	TSP	185 kg
K	MoP	110 kg
S	Gypsum	100 kg
Zn	$ZnSO_4$	As per treatment
B	Boric acid	As per treatment

One third of whole amount of Urea and full amount of TSP, MoP, Gypsum, $ZnSO_4$ and boric acid were applied at the time of final land preparation. The remaining Urea was top dressed in two equal installments - at 20 days after transplanting (DAT) and 50 DAT respectively.

3.10 Transplanting of seedlings

Healthy and uniform sized 23 days old seedlings were taken separately from the seed bed and were transplanted in the experimental field on 21 November, 2019 maintaining a spacing of 60 cm × 40 cm. The seedlings were watered after transplanting. Shading was provided by piece of banana leaf sheath for three days to protect the seedlings from the direct sun. A strip of the same crop was established around the experimental field as border crop to do gap filling and to check the border effect.

3.11 Intercultural operation

After establishment of seedlings, various intercultural operations were accomplished for better growth and development of the tomato.

3.11.1 Gap filling and weeding

When the seedlings were established, the soil around the base of each seedling was pulverized. A few gap fillings were done by healthy plants from the border whenever it was required. Weeds of different types were controlled manually as and when necessary.

3.11.2 Irrigation

Irrigation was done at three times. The first irrigation was given in the field at 25 days after transplanting (DAT) through irrigation channel. The second irrigation was given at the stage of maximum vegetative growth stage (40 DAT). The final irrigation was given at the stage of fruit formation (60 DAT).

3.11.3 Plant protection

The crop was infested with cutworm, leaf hopper and others. The insects were controlled successfully by spraying Malathion 57 EC @ 2ml /L water. The insecticide was sprayed fortnightly from a week after transplanting to a week before first harvesting. During foggy weather precautionary measures against disease infestation specially late blight of tomato was taken by spraying Dithane M-45 fortnightly @ 2 g/L.

3.12 Harvesting

Fruits were harvested at 5 days intervals during maturity to ripening stage. The maturity of the crop was determined on the basis of red colouring of fruits. Harvesting was started from 3 February, 2020 and completed by 20 March, 2020.

3.13 Data Collection and Recording

Five plants were selected randomly from each unit plot for recording data on crop parameters and the yield was taken plot wise. The following parameters were recorded during the study:

3.13.1 Growth parameters

1. Plant height (cm)
2. Number of leaves plant^{-1}
3. Number of branches plant^{-1}

3.13.2 Yield contributing parameters

1. Number of flower clusters plant^{-1}

2. Number of flowers plant^{-1}
3. Number of fruits cluster^{-1}
4. Dry matter content of fruit (%)

3.13.3 Yield parameters

1. Number of fruits plant^{-1}
2. Fruit weight plant^{-1} (g)
3. Fruits weight plot^{-1} (kg)
4. Fruit yield ha^{-1} (t)

3.14 Procedure of recording data

3.14.1 Plant height

The height (cm) of plant was recorded in centimeter (cm) at the time of harvest. Data were recorded as the average of 5 plants of each plot. The height was measured from the ground level to the tip of the leaves. Plant height was recorded at 30, 60 and 90 DAT.

3.14.2 Number of leaves plant^{-1}

The number of leaves of the sample plants was counted at 30, 60 and 90 DAT and the average number of leaves produced per plant was recorded. Number of leaves per plant was also recorded at 30 days interval starting from 30 days of transplanting up to 90days to observe the growth rate of plants.

3.14.3 Number of branches plant^{-1}

The total number of branches was counted from 5 plants of each plot. The average branches number was calculated at different days after transplanting. Number of branches plant^{-1} was recorded at 30, 60 and 90 DAT.

3.14.4 Number of flower clusters plant^{-1}

The number of flower clusters was counted from 5 plants of each plot and the average number of clusters produced per plant was calculated.

3.14.5 Number of flowers plant^{-1}

Total number of flowers was recorded from the five sample plants, and the average number of flowers plant^{-1} was calculated by the following procedure

$$\text{Number of flowers plant}^{-1} = \frac{\text{Total number of flowers}}{\text{Number of plants}}$$

3.14.6 Number of fruits cluster^{-1}

The number of fruits and clusters from first harvest to last harvest was recorded from the five plants, and the average number of fruits cluster^{-1} was recorded by the following procedure:

$$\text{Number of fruits cluster}^{-1} = \frac{\text{Total number of fruits from 5 plants}}{\text{Total number of clusters from 5 plants}}$$

3.14.7 Dry matter content of fruit (%)

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

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

3.14.8 Number of fruits plant^{-1}

The total number of fruits was counted at first harvest to last harvest from 5 plants of each plot and then averaged to obtain number of fruits plant^{-1}.

3.14.9 Fruit weight plant^{-1} (g)

At first the total weight (kg) of fruit was taken from the 5 selected plants harvested at different dates using an electric balance and then weight plant^{-1} (kg) was calculated by following formula:

$$\text{Yield plant}^{-1}\text{ (kg)} = \frac{\text{Total weight of fruits from selected 5 plants (kg)}}{\text{Number of sample plants}}$$

3.14.10 Fruits weight plot^{-1} (kg)

All collected fruits from each plot were brought into farm house and were weighed in kg.

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

After collection of per plot yield, it was converted to ton per hectare (t ha^{-1}).

3.15 Statistical Analysis

The data obtained for different characters were statistically analyzed to observe the significant difference among the treatment by using the MSTAT-C computer package program. The mean values of all the characters were calculated and analysis of variance was performed. The significance of the difference among the treatments means was estimated by the Least Significant Difference Test (LSD) at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The study was conducted to find out effect of zinc and boron fertilization on yield of BARI tomato17. Analyses of variance (ANOVA) of the data on different growth, yield parameters, yield and nutrients content are presented in Appendix IV-VIII. The results have been presented and discussed through different tables and graphs and possible interpretations have been given under the following headings:

4.1 Growth parameters

4.1.1 Plant height

Effect of Zn

Plant height of tomato was significantly influenced by different zinc levels at different growth stages (Figure 2 and Appendix IV). Results revealed that at 30 DAT, the highest plant height (43.70 cm) was recorded from the treatment Zn_2 (4 kg Zn ha^{-1}) that was significantly same with Zn_1 (2 kg Zn ha^{-1}) whereas the lowest plant height (37.49 cm) was recorded from the control treatment Zn_0 (0 kg Zn ha^{-1}). At 60 DAT, Zn_2 (4 kg Zn ha^{-1}) gave the highest plant height (66.68 cm) followed by Zn_1 (2 kg Zn ha^{-1}) whereas control treatment Zn_0 (0 kg Zn ha^{-1}) gave the lowest plant height (56.30 cm). Similarly, at 90 DAT, the highest plant height (98.60 cm) was recorded from the treatment Zn_2 (4 kg Zn ha^{-1}) followed by Zn_1 (2 kg Zn ha^{-1}) whereas the lowest plant height (85.97 cm) was recorded from the control treatment Zn_0 (0 kg Zn ha^{-1}). This result indicated that plant height was increased with the increasing of zinc doses. These results are in agreements with the findings of Ahmed (2021), Gopal and Sarangthem (2018) and Harris and Mathuma (2015).

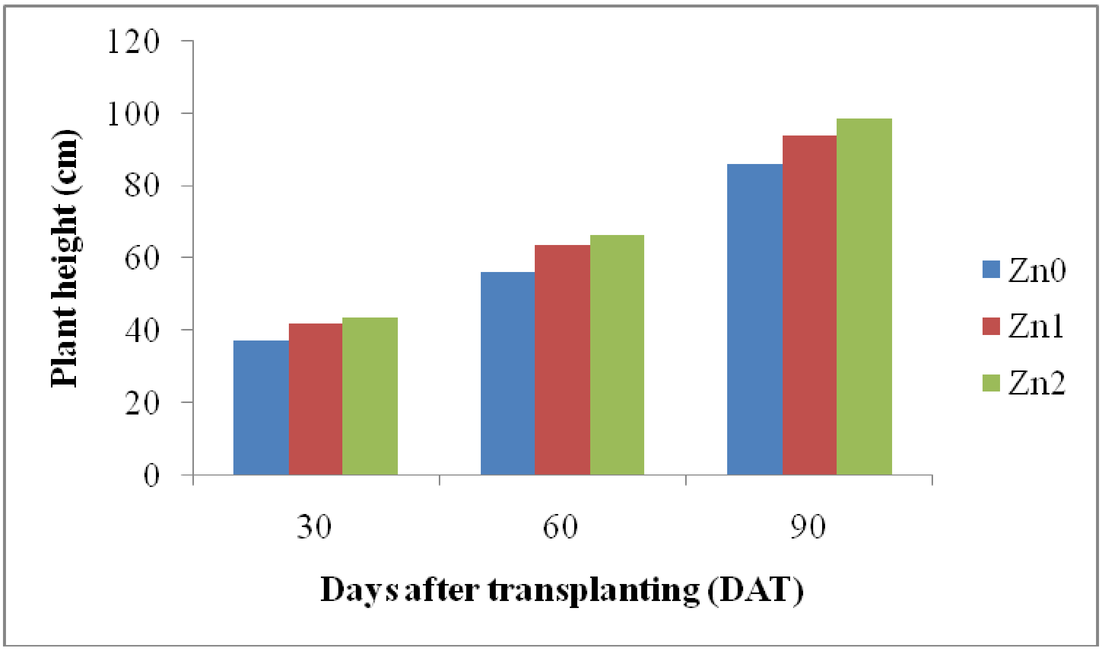


Figure 2. Plant height of tomato at different growth stages as influenced by different zinc levels

Zn_0 = 0 kg Zn ha^{-1}, Zn_1 = 2 kg Zn ha^{-1}, Zn_2 = 4 kg Zn ha^{-1}

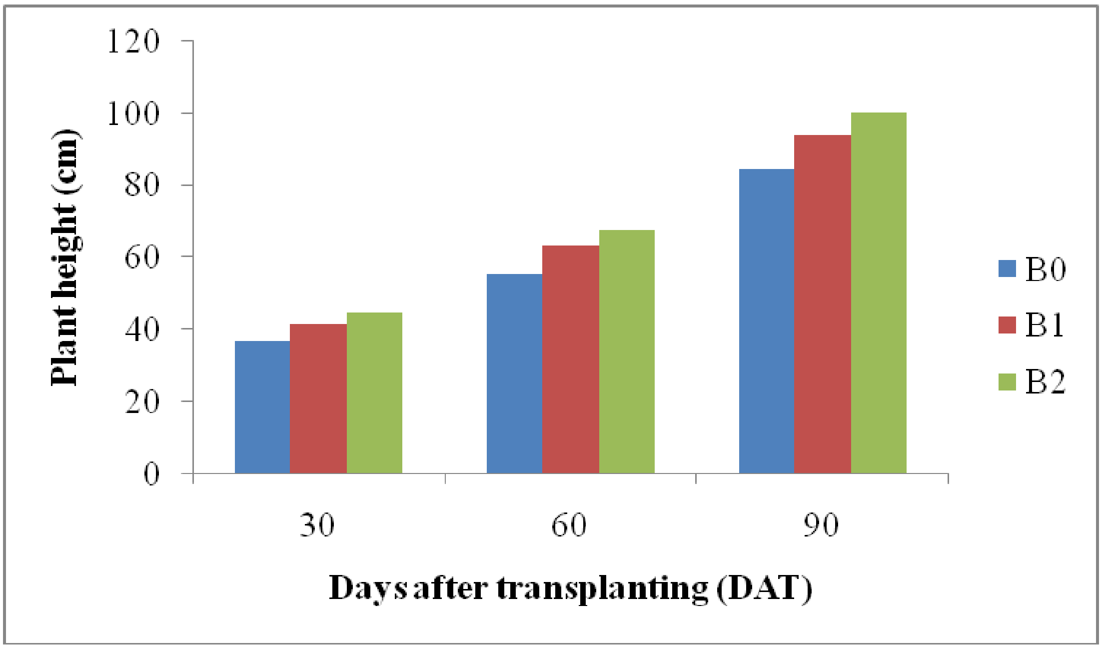


Figure 3. Plant height of tomato at different growth stages as influenced by different boron levels

B_0 = 0 kg B ha^{-1}, B_1 = 1.5 kg B ha^{-1}, B_2 = 3 kg B ha^{-1}

Effect of B

There was significant difference among the different levels of boron in respect to plant height of tomato at different growth stages (Figure 3 and Appendix IV). Results indicated that the treatment B_2 (3 kg B ha^{-1}) showed the highest plant height (44.74 cm) at 30 DAT followed by B_1 (1.5 kg B ha^{-1}) whereas the control treatment B_0 (0 kg B ha^{-1}) showed the lowest plant height (36.95 cm). At 60 DAT, the highest plant height (67.83 cm) was recorded from the treatment B_2 (3 kg B ha^{-1}) which was followed by B_1 (1.5 kg B ha^{-1}) whereas the lowest plant height (55.39 cm) was recorded from the control treatment B_0 (0 kg B ha^{-1}). Likewise, at 90 DAT, the highest plant height (100.20 cm) was given by the treatment B_2 (3 kg B ha^{-1}) followed by B_1 (1.5 kg B ha^{-1}) whereas the lowest plant height (84.52 cm) was recorded from the control treatment B_0 (0 kg B ha^{-1}). This result suggested that application of boron contributed to increase plant height. The result was similar with the findings of Sanjida *et al*. (2020) and Syed *et al.* (2012) who found variation in plant height of tomato due to different boron doses.

Combined effect of Zn and B

The treatment combinations of zinc and boron had significant effect on plant height of tomato at different growth stages (Table 1 and Appendix IV). Results exhibited that at 30 DAT, the treatment combination of Zn_2B_2 registered the highest plant height (48.42 cm) that was significantly differed to other treatment combinations followed by Zn_1B_2 whereas the lowest plant height (35.24 cm) was found from the treatment combination of Zn_0B_0 that was significantly similar to Zn_0B_1 and Zn_1B_0. At 60 DAT, the highest plant height (72.40 cm) was found in the treatment combination of Zn_2B_2 that was significantly differed to other treatment combinations whereas the lowest plant height (51.84 cm) was recorded from the treatment combination of Zn_0B_0 that was significantly similar to Zn_1B_0. Similarly, at 90 DAT, the highest plant height (106.40 cm) was recorded from the treatment combination of Zn_2B_2 that was significantly differed to other treatment combinations followed by Zn_1B_2 and Zn_2B_1 whereas the lowest plant height (81.27 cm) was recorded from the treatment combination of Zn_0B_0 that was significantly differed to other treatment combinations. Osman *et al*. (2019) and Haleema *et al*. (2018) also found similar result with the present study and they observed Zn and B combination had significant effect on plant height of tomato.

Table 1. Plant height of tomato at different growth stages as influenced by zinc and boron combinations

Treatment	Plant height (cm)		
	30 DAT	60 DAT	90 DAT
Zn_0B_0	35.24 f	51.84 f	81.27 f
Zn_0B_1	37.40 ef	55.78 e	85.20 e
Zn_0B_2	39.83 d	61.27 d	91.44 d
Zn_1B_0	37.12 ef	54.20 ef	84.63 e
Zn_1B_1	42.94 c	66.94 c	94.83 c
Zn_1B_2	45.96 b	69.83 b	102.8 b
Zn_2B_0	38.48 de	60.12 d	87.67 e
Zn_2B_1	44.20 bc	67.52 bc	101.7 b
Zn_2B_2	48.42 a	72.40 a	106.40 a
$LSD_{0.05}$	2.418	2.464	3.278
CV(%)	8.40	11.54	9.31

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Zn_0 = 0 kg Zn ha^{-1}, Zn_1 = 2 kg Zn ha^{-1}, Zn_2 = 4 kg Zn ha^{-1}

B_0 = 0 kg B ha^{-1}, B_1 = 1.5 kg B ha^{-1}, B_2 = 3 kg B ha^{-1}

4.1.2 Number of leaves plant^{-1}

Effect of Zn

Different zinc levels at different growth stages of tomato showed significant variation on number of leaves plant^{-1} (Figure 4 and Appendix V). It was observed that at 30 DAT, the highest number of leaves plant^{-1} (25.89) was recorded from the treatment Zn_2 (4 kg Zn ha^{-1}) that was significantly same to the treatment Zn_1 (2 kg Zn ha^{-1}) whereas the lowest number of leaves plant^{-1}

(23.00) was recorded from the control treatment Zn_0 (0 kg Zn ha^{-1}). At 60 DAT, the highest number of leaves $plant^{-1}$ (55.44) was observed from the treatment Zn_2 (4 kg Zn ha^{-1}) that was significantly same to the treatment Zn_1 (2 kg Zn ha^{-1}) whereas the lowest number of leaves $plant^{-1}$ (49.44) was recorded from the control treatment Zn_0 (0 kg Zn ha^{-1}). Accordingly, at 90 DAT, the treatment Zn_2 (4 kg Zn ha^{-1}) gave the highest number of leaves $plant^{-1}$ (60.56) that was significantly same with Zn_1 (2 kg Zn ha^{-1}) whereas the control treatment Zn_0 (0 kg Zn ha^{-1}) showed the lowest number of leaves $plant^{-1}$ (53.44). The result obtained from the present study was similar with the findings of Gopal and Sarangthem (2018) and Hanan (2008) and reported that leaf number of tomato influenced due to different zinc doses.

Effect of B

Significant difference on number of leaves $plant^{-1}$ of tomato at different growth stages was recorded due to application of different boron levels (Figure 5 and ppendix V). Results showed that at 30 DAT, the highest number of leaves $plant^{-1}$ (26.33) was recorded from the treatment B_2 (3 kg B ha^{-1}) which was statistically identical with B_1 (1.5 kg B ha^{-1}) whereas the lowest number of leaves $plant^{-1}$ (21.89) was recorded from the control treatment B_0 (0 kg B ha^{-1}). Similarly, at 60 DAT, the treatment B_2 (3 kg B ha^{-1}) gave the highest number of leaves $plant^{-1}$ (56.00) which was statistically identical with B_1 (1.5 kg B ha^{-1}) whereas the lowest number of leaves $plant^{-1}$ (48.89) was recorded from the control treatment B_0 (0 kg B ha^{-1}). At 90 DAT, the treatment B_2 (3 kg B ha^{-1}) also registered the highest number of leaves $plant^{-1}$ (61.56) which was statistically identical with B_1 (1.5 kg B ha^{-1}) whereas the lowest number of leaves $plant^{-1}$ (52.22) was recorded from the control treatment B_0 (0 kg B ha^{-1}). The result from the present study was in agreement with the findings of Sanjida *et al*. (2020) and they reported that application of boron contributed to increase leaf number of tomato.

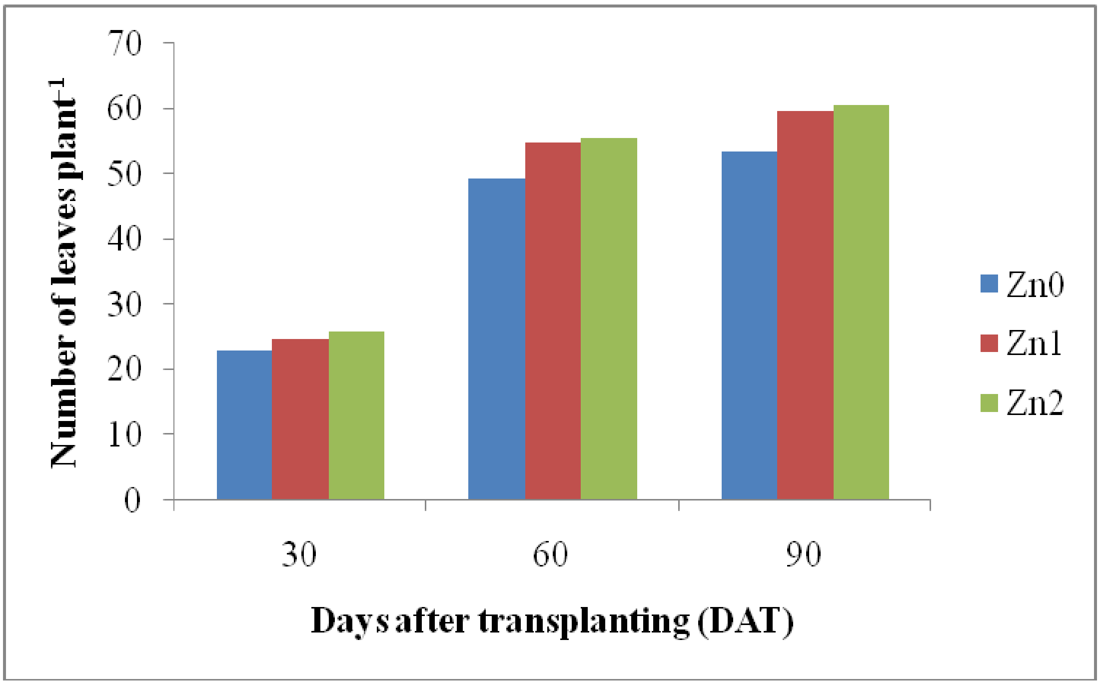


Figure 4. Number of leaves plant^{-1} of tomato at different growth stages as influenced by different zinc levels

Zn_0 = 0 kg Zn ha^{-1}, Zn_1 = 2 kg Zn ha^{-1}, Zn_2 = 4 kg Zn ha^{-1}

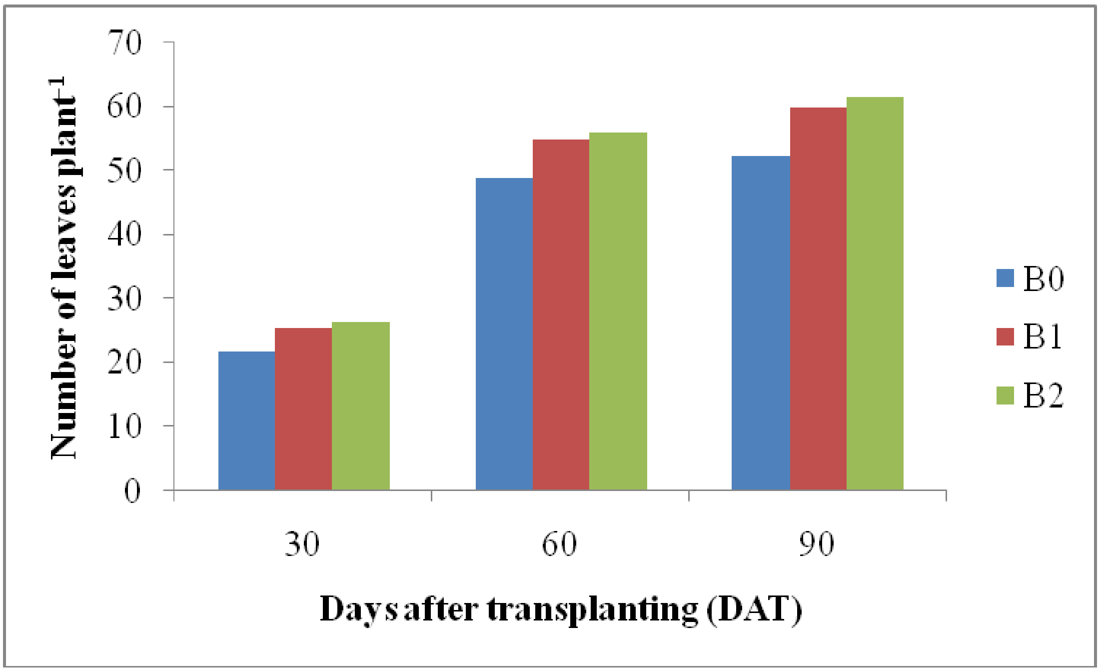


Figure 5. Number of leaves plant^{-1} of tomato at different growth stages as influenced by different boron levels

B_0 = 0 kg B ha^{-1}, B_1 = 1.5 kg B ha^{-1}, B_2 = 3 kg B ha^{-1}

Table 2. Number of leaves $plant^{-1}$ of tomato at different growth stages as influenced by zinc and boron combinations

Treatment	Number of leaves $plant^{-1}$		
	30 DAT	60 DAT	90 DAT
Zn_0B_0	20.00 f	45.33 e	48.67 f
Zn_0B_1	23.67 d	50.67 cd	54.00 de
Zn_0B_2	25.33 bc	52.33 c	57.67 c
Zn_1B_0	21.33 e	49.33 d	52.67 e
Zn_1B_1	27.33 a	58.67 a	65.00 a
Zn_1B_2	26.00 b	56.33 b	61.67 b
Zn_2B_0	24.33 cd	52.00 c	55.33 cd
Zn_2B_1	25.67 b	55.00 b	61.00 b
Zn_2B_2	27.67 a	59.33 a	65.33 a
$LSD_{0.05}$	1.249	1.864	2.524
CV(%)	7.45	12.76	10.52

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Zn_0 = 0 kg Zn ha^{-1}, Zn_1 = 2 kg Zn ha^{-1}, Zn_2 = 4 kg Zn ha^{-1}

B_0 = 0 kg B ha^{-1}, B_1 = 1.5 kg B ha^{-1}, B_2 = 3 kg B ha^{-1}

Combined effect of Zn and B

Different combinations of zinc and boron gave statistically significant influence on number of leaves $plant^{-1}$ of tomato at different growth stages (Table 2 and Appendix V). At 30 DAT, the treatment combination Zn_2B_2 showed the highest number of leaves $plant^{-1}$ (27.67) that was significantly same with Zn_1B_1 followed by Zn_2B_1 whereas Zn_0B_0 gave the lowest number of leaves $plant^{-1}$ (20.00) that was significantly differed to other treatment combinations. Again, at 60 DAT, the highest number of leaves $plant^{-1}$ (59.33) was recorded from the treatment combination of Zn_2B_2 which was statistically identical to Zn_1B_1 whereas Zn_0B_0 recorded the lowest number of leaves $plant^{-1}$ (45.33). Likewise, at 90 DAT, the highest number of leaves $plant^{-1}$ (65.33) was also recorded from the treatment combination of Zn_2B_2 that was significantly same with Zn_1B_1 followed by Zn_1B_2 and Zn_2B_1 whereas the lowest number of leaves $plant^{-1}$ (48.67) was recorded from the treatment combination of Zn_0B_0

that was significantly differed to other treatment combinations. Osman *et al*. (2019) also found similar result with the present study and they observed that combined effect of zinc and boron helps to increase leaf number of tomato. Haleema *et al*. (2018) also found similar result with the present study.

4.1.3 Number of branches plant^{-1}

Effect of Zn

There was a non-significant variation on number of branches plant^{-1} at different growth stages of tomato influenced by different levels of zinc (Figure 6 and Appendix VI). At 60 DAT, the highest number of branches plant^{-1} (6.11) was recorded from the treatment Zn_1 (2 kg Zn ha^{-1}) that was significantly differed to other treatments followed by Zn_2 (4 kg Zn ha^{-1}) whereas the lowest number of branches plant^{-1} (3.89) was recorded from the control treatment Zn_0 (0 kg Zn ha^{-1}). At 90 DAT, the highest number of branches plant^{-1} (8.22) was recorded from the treatment Zn_1 (2 kg Zn ha^{-1}) followed by Zn_2 (4 kg Zn ha^{-1}) whereas Zn_0 (0 kg Zn ha^{-1}) gave the lowest number of branches plant^{-1} (6.78). The result of the present study was not found similar with the findings of Gopal and Sarangthem (2018) and Saravaiya *et al.* (2014); they reported that application of different dose of Zn significantly influenced number of branches plant^{-1} of tomato.

Effect of B

Significant variation was observed on number of branches plant^{-1} of tomato at different growth stages influenced by different levels of boron (Figure 7 and Appendix VI). At 60 DAT, the highest number of branches plant^{-1} (6.12) was recorded from the treatment B_1 (1.5 kg B ha^{-1}) which was statistically identical to B_2 (3 kg B ha^{-1}) whereas the control treatment B_0 (0 kg B ha^{-1}) registered the lowest number of branches plant^{-1} (3.56). Similarly, at 90 DAT, the highest number of branches plant^{-1} (8.44) was recorded from the treatment B_1 (1.5 kg B ha^{-1}) which was statistically identical to B_2 (3 kg B ha^{-1}) whereas the control treatment B_0 (0 kg B ha^{-1}) gave the lowest number of branches plant^{-1} (5.78).

Similar findings were also observed by Sanjida *et al.* (2020) and Sathya *et al.* (2010) and they reported that number branches were significantly influenced by soil and foliar application of boron.

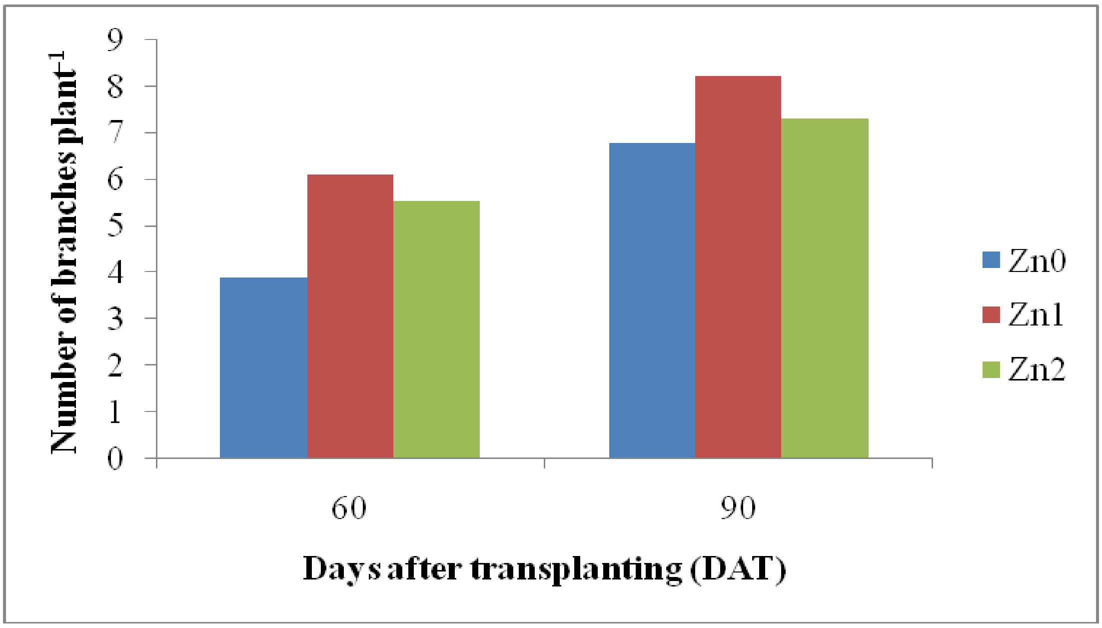


Figure 6. Number of branches plant^{-1} of tomato at different growth stages as influenced by different zinc levels

Zn_0 = 0 kg Zn ha^{-1}, Zn_1 = 2 kg Zn ha^{-1}, Zn_2 = 4 kg Zn ha^{-1}

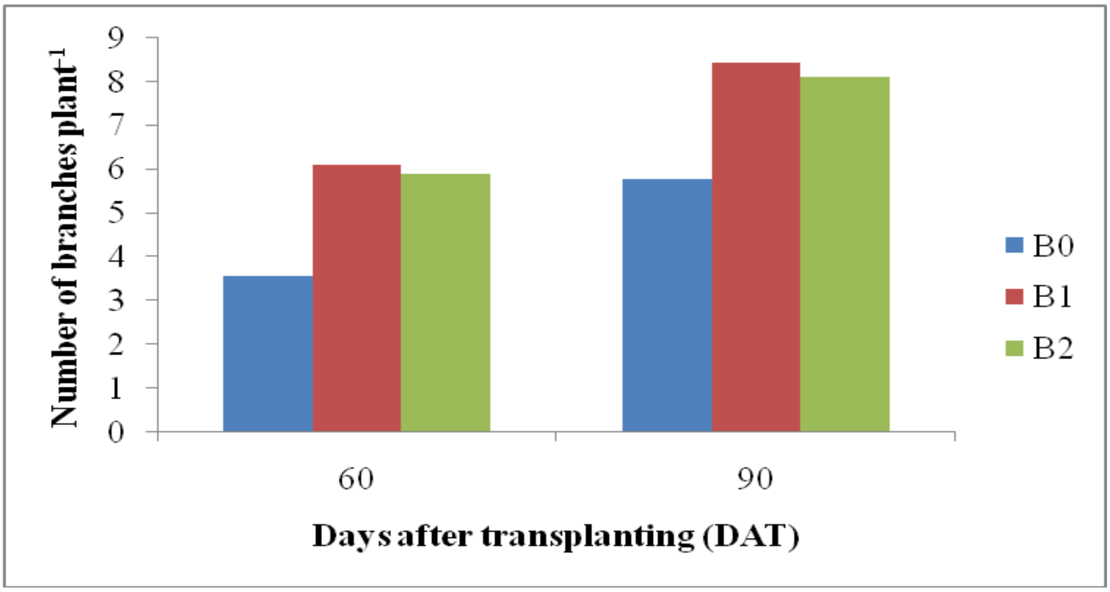


Figure 7. Number of branches plant^{-1} of tomato at different growth stages as influenced by different boron levels

B_0 = 0 kg B ha^{-1}, B_1 = 1.5 kg B ha^{-1}, B_2 = 3 kg B ha^{-1}

Table 3. Number of branches plant^{-1} of tomato at different growth stages as influenced by zinc and boron combinations

Treatment	Number of branches plant^{-1}	
	60 DAT	90 DAT
Zn_0B_0	2.67 e	5.33 e
Zn_0B_1	4.67 c	7.67 bc
Zn_0B_2	4.33 cd	7.33 c
Zn_1B_0	4.00 d	5.67 e
Zn_1B_1	7.33 a	9.67 a
Zn_1B_2	7.00 a	9.33 a
Zn_2B_0	4.00 d	6.33 d
Zn_2B_1	6.33 b	8.00 b
Zn_2B_2	6.33 b	7.67 bc
$LSD_{0.05}$	0.496	0.582
CV(%)	11.92	10.52

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Zn_0 = 0 kg Zn ha^{-1}, Zn_1 = 2 kg Zn ha^{-1}, Zn_2 = 4 kg Zn ha^{-1}
B_0 = 0 kg B ha^{-1}, B_1 = 1.5 kg B ha^{-1}, B_2 = 3 kg B ha^{-1}

Combined effect of Zn and B

Significant influence was found on number of branches plant^{-1} of tomato at different growth stages affected by treatment combinations of zinc and boron (Table 3 and Appendix VI). Results indicated that the treatment combination of Zn_1B_1 registered the highest number of branches plant^{-1} (7.33) at 60 DAT that was statistically identical to Zn_1B_2 followed by Zn_2B_1 and Zn_2B_2. The lowest number of branches plant^{-1} (2.67) at 60 DAT was recorded from the treatment combination of Zn_0B_0 that was significantly differed to other treatment combinations. At 90 DAT, Zn_1B_1 also showed the highest number of branches plant^{-1} (9.67) was recorded from the treatment combination of that was significantly same to Zn_1B_2 whereas Zn_0B_0 gave the lowest number of branches plant^{-1} (5.33) that was significantly differed to other treatment combinations.

Osman *et al*. (2019) and Haleema *et al*. (2018) also found supported result with the present study.

4.2 Yield contributing parameters

4.2.1 Number of flower clusters plant^{-1}

Effect of Zn

The effect of zinc on number of flower clusters plant^{-1} of tomato was significant (Table 4 and Appendix VII). Results revealed that the treatment Zn_2 (4 kg Zn ha^{-1}) registered the highest number of flower clusters plant^{-1} (6.63) which was statistically identical to Zn_1 (2 kg Zn ha^{-1}). On the other hand the lowest number of flower clusters plant^{-1} (6.24) was given by the control treatment Zn_0 (0 kg Zn ha^{-1}). Mallick *et al*. (2020) also found similar result with the present study and noticed that application of different doses of Zn increased number of flower clusters plant^{-1}. Similar result was also observed by Osman *et al*. (2019).

Effect of B

Boron fertilizer had significant effect on number of flower clusters plant^{-1} of tomato (Table 4 and Appendix VII). Results showed that the highest number of flower clusters plant^{-1} (6.99) was recorded from the treatment B_1 (1.5 kg B ha^{-1}) that was significantly same to the treatment B_2 (3 kg B ha^{-1}) whereas the lowest number of flower clusters plant^{-1} (5.66) was recorded from the control treatment B_0 (0 kg B ha^{-1}). Mallick *et al*. (2020) and Osman *et al*. (2019) also found similar result with the present study and reported that application of B @ 2.0 kg ha^{-1} produced the highest number of flower clusters plant^{-1} of tomato. Similar result was also observed by Sanjida *et al*. (2020).

Combined effect of Zn and B

Combined effect of zinc and boron on the number of flower clusters plant^{-1} of tomato showed significant variation (Table 4 and Appendix VII). Results exhibited that the treatment combination Zn_2B_1 exposed the highest number of flower clusters plant^{-1} (7.17) that was significantly similar to the treatment combination of Zn_1B_1, Zn_1B_2, Zn_2B_2 and Zn_0B_1. Reversely, the lowest number of flower clusters plant^{-1} (5.70) was recorded from the treatment combination of Zn_0B_0 that was significantly same to Zn_1B_0 and Zn_2B_0. The result obtained from the present study was similar with the findings of Patil *et al.* (2010), Ali *et al*. (2015) and Rizwan *et al.* (2015).

4.2.2 Number of flowers plant^{-1}

Effect of Zn

Number of flowers plant^{-1} of tomato affected significantly due to application of different levels of zinc (Table 4 and Appendix VII). The highest number of flowers plant^{-1} (28.83) was recorded from the treatment Zn_1 (2 kg Zn ha^{-1}) that was significantly differed to other treatments followed by Zn_2 (4 kg Zn ha^{-1}) whereas the lowest number of flowers plant^{-1} (24.49) was recorded from the control treatment Zn_0 (0 kg Zn ha^{-1}). Ullah *et al*. (2015) also found that among different levels of Zn, 0.4% showed significant increased in number of flowers per plant which supported the present study.

Effect of B

Application of different levels of boron gave significant effect on number of flowers plant^{-1} of tomato (Table 4 and Appendix VII). The highest number of flowers plant^{-1} (29.82) was recorded from the treatment B_1 (1.5 kg B ha^{-1}) which was followed by B_2 (3 kg B ha^{-1}) whereas the lowest number of flowers plant^{-1} (22.70) was recorded from the control treatment B_0 (0 kg B ha^{-1}). Sturiao *et al*. (2020) and Sanjida *et al*. (2020) also recorded similar result with the present study and they reported that boron had significant effect on number of flowers per plant.

Table 4. Yield contributing parameters of tomato as influenced by zinc and boron

Treatment	Yield contributing parameters				
	No. of flower clusters plant^{-1}	No. of flowers plant^{-1}	No. of fruits cluster^{-1}	No. of fruits plant^{-1}	% fruit dry matter
Zn_0B_0	5.70 c	21.13 f	3.01 d	17.03 f	7.81 e
Zn_0B_1	6.72 ab	27.13 c	3.09 cd	20.80 cd	9.96 b
Zn_0B_2	6.31 b	25.20 d	3.20 bc	20.20 d	9.75 b
Zn_1B_0	5.46 c	23.17 e	3.34 ab	18.20 ef	8.480 d
Zn_1B_1	7.07 a	32.53 a	3.51 a	24.80 a	11.10 a
Zn_1B_2	6.97 a	30.80 ab	3.49 a	24.27 a	10.93 a
Zn_2B_0	5.81 c	23.80 de	3.37 ab	19.60 de	9.09 c
Zn_2B_1	7.17 a	29.80 b	3.30 b	23.60 ab	10.81 a
Zn_2B_2	6.93 a	27.90 c	3.20 bc	22.10 bc	10.61 a
$LSD_{0.05}$	0.489	1.754	0.182	1.855	0.602
CV(%)	7.37	5.69	6.57	9.06	6.46

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Zn_0 = 0 kg Zn ha^{-1}, Zn_1 = 2 kg Zn ha^{-1}, Zn_2 = 4 kg Zn ha^{-1}

B_0 = 0 kg B ha^{-1}, B_1 = 1.5 kg B ha^{-1}, B_2 = 3 kg B ha^{-1}

Combined effect of Zn and B

Number of flowers plant^{-1} of tomato influenced significantly due to different combination of zinc and boron (Table 4 and Appendix VII). The highest number of flowers plant^{-1} (32.53) was recorded from the treatment combination of Zn_1B_1 that was significantly similar to Zn_1B_2 whereas the lowest number of flowers plant^{-1} (21.13) was recorded from the treatment combination of Zn_0B_0 that was significantly differed to other treatment combinations. Ullah *et al.* (2015) and Patil *et al.* (2010) also reported supported result with the present study and observed that zinc, boron and their interaction significantly increased the number of flowers plant^{-1}.

4.2.3 Number of fruits cluster^{-1}

Effect of Zn

Significant variation was found on number of fruits cluster^{-1} of tomato by the application of different zinc levels (Table 4 and Appendix VII). Results exhibited that the highest number of fruits cluster^{-1} (3.45) was recorded from the treatment Zn_1 (2 kg Zn ha^{-1}) that was significantly differed to other treatments followed by Zn_2 (4 kg Zn ha^{-1}) whereas the lowest number of fruits cluster^{-1} (3.10) was recorded from the control treatment Zn_0 (0 kg Zn ha^{-1}). Similar result was also observed by Mallick *et al*. (2020).

Effect of B

Non-significant variation was recorded on number of fruits cluster^{-1} of tomato as influenced by the application of different levels of boron (Table 4 and Appendix VII). However, the highest number of fruits cluster^{-1} (3.30) was recorded from the treatment B_1 (1.5 kg B ha^{-1}) whereas the lowest number of fruits cluster^{-1} (3.24) was recorded from the control treatment B_0 (0 kg B ha^{-1}). The result obtained from the present study was similar with the findings of Sanjida *et al*. (2020).

Combined effect of Zn and B

Number of fruits cluster^{-1} of tomato varied significantly among the different combination of zinc and boron (Table 4 and Appendix VII). The highest number of fruits cluster^{-1} (3.51) was recorded from the treatment combination of Zn_1B_1 that was significantly similar to the treatment combination of Zn_1B_2, Zn_1B_0 and Zn_2B_0. Again, the lowest number of fruits cluster^{-1} (3.01) was recorded from the treatment combination of Zn_0B_0 which was statistically similar to Zn_0B_1. Supported result was also observed by Ali *et al*. (2015) and Rizwan *et al.* (2015).

4.2.4 Number of fruits plant^{-1}

Effect of Zn

Number of fruits plant^{-1} of tomato showed significant influence due to application of different zinc levels (Table 4 and Appendix VII). Results revealed that the treatment Zn_1 (2 kg Zn ha^{-1}) exposed the highest number of fruits plant^{-1} (22.42) which was statistically identical to the treatment Zn_2 (4 kg Zn ha^{-1}) but the control treatment Zn_0 (0 kg Zn ha^{-1}) registered the lowest number of fruits plant^{-1} (19.34). Mallick *et al*. (2020) found that application of different doses of Zn increased number of fruits plant^{-1} of tomato. Similar result was also observed by Gopal and Sarangthem (2018), Harris and Mathuma (2015) and Saravaiya *et al.* (2014).

Effect of B

Different levels of boron application gave significant difference on number of fruits plant^{-1} of tomato (Table 4 and Appendix VII). Results showed that the highest number of fruits plant^{-1} (23.07) was recorded from the treatment B_1 (1.5 kg B ha^{-1}) and it was not significantly differed to the treatment B_2 (3 kg B ha^{-1}) whereas control treatment B_0 (0 kg B ha^{-1}) gave the lowest number of fruits plant^{-1} (18.28). Gopal and Sarangtham (2021) reported that soil application of boron at 2.0 kg B/ha showed highest number of fruits plant^{-1} which supported the present study. Similar result was also observed by Sanjida *et al*. (2020) and Yadav *et al.* (2006).

Combined effect of Zn and B

Different treatment combination of zinc and boron showed significant variation on number of fruits plant^{-1} of tomato (Table 4 and Appendix VII). It was observed that the treatment combination Zn_1B_1 gave the highest number of fruits plant^{-1} (24.80) and this was statistically similar to the combination of Zn_1B_2 and Zn_2B_1 whereas the lowest number of fruits plant^{-1} (17.03) was recorded from the treatment combination of Zn_0B_0 that was significantly similar to Zn_1B_0. Similar result was also observed by Osman *et al*. (2019) and Haleema *et al*. (2018).

4.2.5 Dry matter content of fruit (%)

Effect of Zn

Fruit dry matter content of tomato affected significantly due to application of different levels of zinc (Table 4 and Appendix VII). Results revealed that the treatment Zn_1 (2 kg Zn ha^{-1}) showed the highest percent dry matter content of tomato (10.17%) and this treatment was significantly same to Zn_2 (4 kg Zn ha^{-1}) but the control treatment Zn_0 (0 kg Zn ha^{-1}) registered the lowest percent dry matter content (9.18%). Similar result was also observed by Harris and Mathuma (2015), Saravaiya *et al.* (2014) and Gurmani *et al*. (2012) and they reported that application of zinc on tomato had significant effect on dry matter production.

Effect of B

Application of different levels of boron gave significant variation on percent dry matter content of tomato (Table 4 and Appendix VII). The highest percent dry matter content (10.62%) was recorded from the treatment B_1 (1.5 kg B ha^{-1}) and significantly same result was also observed by B_2 (3 kg B ha^{-1}). On the other hand, the lowest percent dry matter content (8.46%) was achieved by the control treatment B_0 (0 kg B ha^{-1}). Supported results with the present study were also observed by Sturiao *et al*. (2020) and El-Hameed *et al*. (2014).

Combined effect of Zn and B

Percent dry matter content of tomato influenced significantly due to different combination of zinc and boron (Table 4 and Appendix VII). The treatment combination of Zn_1B_1 gave the highest percent dry matter content (11.10%) and this was significantly same to the treatment combination of Zn_1B_2, Zn_2B_1 and Zn_2B_2. Again, the treatment combination of Zn_0B_0 showed the lowest percent dry matter content (7.81%) that was significantly differed to other treatment combinations. The result obtained from the present study was similar with the findings of Salam *et al*. (2011).

4.3 Yield parameters

4.3.1 Fruit weight plant^{-1} (kg)

Effect of Zn

Fruit weight plant^{-1} of tomato affected significantly due to application of different levels of zinc (Table 5 and Appendix VIII). The highest fruit weight plant^{-1} (1.67 kg) was recorded from the treatment Zn_1 (2 kg Zn ha^{-1}). The treatment Zn_2 (4 kg Zn ha^{-1}) also showed non-significant variation to Zn_1 (2 kg Zn ha^{-1}) whereas the control treatment Zn_0 (0 kg Zn ha^{-1}) showed the lowest fruit weight plant^{-1} (1.42 kg). Gopal and Sarangthem (2018), Mallick *et al*. (2020), Harris and Mathuma (2015) and Gurmani *et al.* (2012) also noticed significant influenced on fruit weight plant^{-1} due to different doses of zinc.

Effect of B

Application of different levels of boron gave significant effect on fruit weight plant^{-1} of tomato (Table 5 and Appendix VIII). The highest fruit weight plant^{-1} (1.71 kg) was recorded from the treatment B_1 (1.5 kg B ha^{-1}) which was statistically identical to B_2 (3 kg B ha^{-1}) whereas the lowest fruit weight plant^{-1} (1.33 kg) was recorded from the control treatment B_0 (0 kg B ha^{-1}). Gopal and Sarangthem (2018), Sanjida *et al*. (2020) and Mallick *et al*. (2020) also found similar result with present study and they reported that B had significant contribution on per plant fruit yield of tomato.

Combined effect of Zn and B

Fruit weight plant^{-1} of tomato influenced significantly due to different combination of zinc and boron (Table 5 and Appendix VIII). Results revealed that the highest fruit weight plant^{-1} (1.86 kg) was recorded from the treatment combination of Zn_1B_1 that was significantly similar to the treatment combination of Zn_1B_2 and Zn_2B_1. The lowest fruit weight plant^{-1} (1.23 kg) was recorded from the treatment combination of Zn_0B_0 that was significantly similar to the treatment combination of Zn_1B_0. Mallick *et al*. (2020), Osman *et al*. (2019) and Haleema *et al*. (2018) also showed supported result with the present study.

Table 5. Yield parameters of tomato as influenced by zinc and boron

Treatment	Yield parameters		
	Fruit weigh plant^{-1} (kg)	Fruit yield plot^{-1} (kg)	Fruit yield (t ha^{-1})
Zn_0B_0	1.23 f	18.46 g	51.27 g
Zn_0B_1	1.53 cd	23.01 d	63.93 cd
Zn_0B_2	1.49 cd	22.31 de	61.98 de
Zn_1B_0	1.33 ef	19.99 f	55.53 f
Zn_1B_1	1.86 a	27.93 a	77.57 a
Zn_1B_2	1.82 a	27.29 a	75.80 a
Zn_2B_0	1.42 de	21.36 e	59.34 e
Zn_2B_1	1.73 ab	25.94 b	72.06 b
Zn_2B_2	1.61 bc	24.13 c	67.03 c
$LSD_{0.05}$	0.145	0.9559	3.179
CV(%)	6.39	7.82	8.42

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Zn_0 = 0 kg Zn ha^{-1}, Zn_1 = 2 kg Zn ha^{-1}, Zn_2 = 4 kg Zn ha^{-1}
B_0 = 0 kg B ha^{-1}, B_1 = 1.5 kg B ha^{-1}, B_2 = 3 kg B ha^{-1}

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

Effect of Zn

Application of different levels of zinc showed significant difference among the treatments on fruit yield plot^{-1} of tomato (Table 5 and Appendix VIII). The highest fruit yield plot^{-1} (25.07 kg) was recorded from the treatment Zn_1 (2 kg Zn ha^{-1}) followed by Zn_2 (4 kg Zn ha^{-1}) whereas the lowest fruit yield plot^{-1} (21.26 kg) was recorded from the control treatment Zn_0 (0 kg Zn ha^{-1}). Similar result was also observed by Gopal and Sarangthem and Gurmani *et al.* (2012).

Effect of B

Application of different levels of boron had significant influence on fruit yield $plot^{-1}$ of tomato (Table 5 and Appendix VIII). The treatment B_1 (1.5 kg B ha^{-1}) gave the highest fruit yield $plot^{-1}$ (25.63 kg) that was significantly differed to other treatments followed by B_2 (3 kg B ha^{-1}) whereas the lowest fruit yield $plot^{-1}$ (19.94 kg) was found in the control treatment B_0 (0 kg B ha^{-1}). Similar result was also observed by Sanjida *et al*. (2020) and Mallick *et al*. (2020).

Combined effect of Zn and B

Different combination of zinc and boron showed significant variation on fruit yield $plot^{-1}$ of tomato (Table 5 and Appendix VIII). the treatment combination of Zn_1B_1 recorded the highest fruit yield $plot^{-1}$ (27.93 kg) that was significantly same with Zn_1B_2 whereas the lowest fruit yield $plot^{-1}$ (18.64 kg) was recorded from the treatment combination of Zn_0B_0 that was significantly differed to other treatment combinations. Similar result was also observed by Osman *et al*. (2019) and Haleema *et al*. (2018).

4.3.3 Fruit yield ha^{-1} (kg)

Effect of Zn

Fruit yield ha^{-1} of tomato influenced significantly due to application of different levels of zinc (Table 5 and Appendix VIII). Results showed that the highest fruit yield ha^{-1} (69.63 t) was recorded from the treatment Zn_1 (2 kg Zn ha^{-1}) that was significantly differed to other treatments followed by Zn_2 (4 kg Zn ha^{-1}) whereas the lowest fruit yield ha^{-1} (59.06 t) was recorded from the control treatment Zn_0 (0 kg Zn ha^{-1}). Mallick *et al*. (2020), Harris and Mathuma (2015) and Gurmani *et al.* (2012) found considerable influence of zinc on fruit yield of tomato and ther recorded the higher fruit yield with the application of zinc.

Effect of B

Application of different levels of boron showed significant variation on fruit yield ha^{-1} of tomato (Table 5 and Appendix VIII). Results revealed that the treatment B_1 (1.5 kg B ha^{-1}) registered the highest fruit yield ha^{-1} (71.19 t) that was significantly differed to other treatments followed by B_2 (3 kg B ha^{-1}). The lowest fruit yield ha^{-1} (55.38 t) was found in the control treatment B_0 (0 kg B ha^{-1}). Gopal and Sarangthem (2018), Sanjida *et al*. (2020) and Mallick *et al*. (2020) also found similar result with present study and they found that B had significant contribution on fruit yield of tomato.

Combined effect of Zn and B

Significant variation was recorded on fruit yield ha^{-1} of tomato influenced by different combination of zinc and boron (Table 5 and Appendix VIII). Results exhibited that the treatment combination Zn_1B_1 gave the highest fruit yield ha^{-1} (77.57 t) and this treatment combination was significantly same to Zn_1B_2. In contrast, the lowest fruit yield ha^{-1} (51.27 t) was recorded from the treatment combination of Zn_0B_0 that was significantly different from other treatment combinations. The result obtained from the present was conformity with the findings of Mallick *et al*. (2020), Osman *et al*. (2019) and Haleema *et al*. (2018) and they obtained higher tomato yield with the together application of zinc and boron.

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was carried out during the period of October 2019 to March 2020 at the farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207 to find out the effect of zinc and boron fertilization on the yield of BARI tomato 17 (*Solanum lycopersicum* L.). The experiment consisted of two factors: Factor A: zinc application (3 levels) *viz*. Zn_0 = 0 kg Zn ha^{-1}, Zn_1 = 2 kg Zn $ha^{-1}$and Zn_2 = 4 kg Zn ha^{-1} and Factor B: boron application (3 levels) *viz*. B_0 = 0 kg B ha^{-1}, B_1 = 1.5 kg B $ha^{-1}$and B_2 = 3 kg B ha^{-1}. The experiment was laid out in randomized complete block design (RCBD) with three replications. Data on different growth, yield contributing parameters and yield of tomato and soil were recorded and analyzed statistically.

Different levels of zinc (Zn) showed significant variation on most of the studied parameters regarding growth, yield contributing parameters and yield of tomato. Regarding growth parameters influenced by Zn, the highest plant height (43.70, 66.68 and 98.60 cm at 30, 60 and 90 DAT, respectively) and the highest number of leaves $plant^{-1}$ (25.89, 55.44 and 60.56 at 30, 60 and 90 DAT, respectively) were obtained from Zn_2 (4 kg Zn ha^{-1}) but the highest number of branches $plant^{-1}$ (6.11 and 8.22 at 60 and 90 DAT, respectively) was observed from Zn_1 (2 kg Zn ha^{-1}) whereas control treatment Zn_0 (0 kg Zn ha^{-1}) gave the lowest plant height (37.49, 56.30 and 85.97 cm at 30, 60 and 90 DAT, respectively), number of leaves $plant^{-1}$ (23.00, 49.44 and 53.44 at 30, 60 and 90 DAT, respectively) and number of branches $plant^{-1}$ (3.89 and 6.78 at 60 and 90 DAT, respectively). Regarding yield contributing parameters and yield of tomato, Zn_2 (4 kg Zn ha^{-1}) showed the highest number of flower clusters $plant^{-1}$ (6.63) whereas the lowest (6.24) was from control treatment Zn_0 (0 kg Zn ha^{-1}). Similarly, Zn_1 (2 kg Zn ha^{-1}) gave the highest number of flowers $plant^{-1}$ (28.83), number of fruits $cluster^{-1}$ (3.45), number of fruits $plant^{-1}$ (22.42), % fruit dry matter content (10.17%), fruit weight $plant^{-1}$ (1.67 kg), fruit yield $plot^{-1}$ (25.07

kg) and fruit yield ha^{-1} (69.63 t) whereas control treatment Zn_0 (0 kg Zn ha^{-1}) gave the lowest number of flowers plant^{-1} (24.49), number of fruits cluster^{-1} (3.10), number of fruits plant^{-1} (19.34), fruit diameter (11.16 cm), % fruit dry matter content (9.18%), fruit weight plant^{-1} (1.42 kg), fruit yield plot^{-1} (21.26 kg) and fruit yield ha^{-1} (59.06 t).

Different boron (B) levels showed significant variation on growth, yield contributing parameters and yield of tomato. In case of growth parameters, B_2 (3 kg B ha^{-1}) showed the highest plant height (44.74, 67.83 and 100.20 cm at 30, 60 and 90 DAT, respectively) and number of leaves plant^{-1} (26.33, 56.00 and 61.56 at 30, 60 and 90 DAT, respectively) but the treatment B_1 (1.5 kg B ha^{-1}) gave the highest number of branches plant^{-1} (6.12 and 8.44 at 60 and 90 DAT, respectively) whereas control treatment B_0 (0 kg B ha^{-1}) gave the lowest plant height (36.95, 55.39 and 84.52 cm at 30, 60 and 90 DAT, respectively), number of leaves plant^{-1} (21.89, 48.89 and 52.22 at 30, 60 and 90 DAT, respectively) and number of branches plant^{-1} (3.56 and 5.78 at 60 and 90 DAT, respectively). Regarding yield contributing parameters and yield of tomato, B_1 (1.5 kg B ha^{-1}) showed the highest number of flower clusters plant^{-1} (6.99), number of flowers plant^{-1} (29.82), number of fruits plant^{-1} (23.07), % fruit dry matter content (10.62%), fruit weight plant^{-1} (1.71 kg), fruit yield plot^{-1} (25.63 kg) and fruit yield ha^{-1} (71.19 t) whereas control treatment B_0 (0 kg B ha^{-1}) gave the lowest number of flower clusters plant^{-1} (5.66), number of flowers plant^{-1} (22.70), number of fruits plant^{-1} (18.28), % fruit dry matter content (8.46%), fruit weight plant^{-1} (1.33 kg), fruit yield plot^{-1} (19.94 kg) and fruit yield ha^{-1} (55.38 t). Different B levels showed non-significant variation on number of fruits cluster^{-1}, however, the highest and lowest number of fruits cluster^{-1} (3.30 and 3.24, respectively) were recorded from B_1 (1.5 kg B ha^{-1}) and B_0 (0 kg B ha^{-1}), respectively.

Different growth, yield contributing parameters and yield of tomato influenced significantly due to treatment combination of Zn and B. Considering growth parameters, the highest plant height (48.42, 72.40 and 106.40 cm at 30, 60 and 90 DAT, respectively) and number of leaves plant^{-1} (27.67, 59.33 and 65.33 at 30, 60 and 90 DAT, respectively) were recorded from the treatment combination of Zn_2B_2 but the highest number of branches plant^{-1} (7.33 and 9.67 at 60 and 90 DAT, respectively) was achieved from Zn_1B_1 whereas Zn_0B_0 gave the lowest plant height (35.24, 51.84 and 81.27 cm at 30, 60 and 90 DAT, respectively), number of leaves plant^{-1} (20.00, 45.33 and 48.67 at 30, 60 and 90 DAT, respectively) and number of branches plant^{-1} (2.67 and 5.33 at 60 and 90 DAT, respectively). Considering yield contributing parameters and yield of tomato, Zn_2B_1 showed the highest number of flower clusters plant^{-1} (7.17) but Zn_1B_1 gave the highest number of flowers plant^{-1} (32.53), number of fruits cluster^{-1} (3.51), number of fruits plant^{-1} (24.80), % fruit dry matter content (11.10%), fruit weight plant^{-1} (1.86 kg), fruit yield plot^{-1} (27.93 kg) and fruit yield ha^{-1} (77.57 t) whereas control treatment B_0 (0 kg B ha^{-1}) gave the lowest number of flower clusters plant^{-1} (5.70), number of flowers plant^{-1} (21.13), number of fruits cluster^{-1} (3.01), number of fruits plant^{-1} (17.03), % fruit dry matter content (7.81%), fruit weigh plant^{-1} (1.23 kg), fruit yield plot^{-1} (18.46kg) and fruit yield ha^{-1} (51.27 t).

Conclusion

From the present study, the following conclusion may be drawn –

1. Individual effect of zinc and boron on growth and yield of tomato was found significant for most of the parameters except number of fruits cluster^{-1}.
2. Application of zinc @ 2 kg ha^{-1} was the suitable doses of zinc which gave the highest yield of tomato (69.63 t ha^{-1}) compared to 4 kg Zn ha^{-1} (66.15 t ha^{-1}) and control (59.06 t ha^{-1}).
3. Application of boron @ 1.5 kg ha^{-1} was most suitable regarding highest yield of tomato (71.19 t ha^{-1}) compared to other doses including control.
4. The combined effect of zinc and boron enhanced growth, yield and yield attributes of tomato.
5. 2 kg Zn ha^{-1} in combination with 1.5 kg B ha^{-1} gave highest fruit yield of tomato (77.57 t ha^{-1}) compared to other treatment combinations.

Recommendation

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

REFERENCES

Ahmed, R. (2021). Recent Trends in the Foliar Spraying of Zinc Nutrient and Zinc Oxide Nanoparticles in Tomato Production. *J. Agron*. **11**: 2074.

Ali, M. R., Mehraj, H. and Uddin, J. (2015). Effect of foliar application of zinc and boron on growth and yield of summer tomato. Bio sci. Agric. Res. **6**(01): 512-517.

Ali, M.R., Mehraj, H. and Jamal-Uddin, A.F.M. (2015). Effects of foliar application of zinc and boron on growth and yield of summer tomato. *J. Biosci. Agric. Res*. **6**(1): 512-517.

Baldev, A., Sharma, H.G. and Harmukh, N. (2008). Effect of trickle irrigation along with micronutrients on growth and yield of tomato F1 hybrid. Adv. Plant. Sci. **21**(1): 299-302.

BARI (Bangladesh Agricultural Research Institute). (2019). Production technology of tomato – Krishi Projukti Hat Boi. BARI, Joydehpur, Gazipur. p. 122.

BBS (Bangladesh Bureau of Statistics). Statistical Year Book, Bangladesh 2018. 37th edition, Statistics and Informatics Division, Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka, 2018.

Ben, G.A. and Shani, U. (2003). Water use and yield of tomatoes under limited water and excess boron. *J. Plant Soil*. **256**(1): 179-186.

Bhatt, L. and Srivastava, B.K. (2005). Effect of foliar application of micronutrients on nutrient uptake in tomato. *Veg. Sci*. **32**(2): 158-161.

Bose, T.K. and Som, M.G. 1990. Vegetable Crops in India. Published by B. Mitra and Naya Prokash, 206-Bidhan Sarani, Calcutta, India. p. 249.

Bose, U.S. and Tripathi, S.K. (1996). Effect of micronutrients on growth, yield and quality of tomato cv. PUSA RUBY in M.P. Crop. Res. **12**(1): 61-64.

Brady, N.C. and R.R. Weil. 2002. The Nature and Properties of Soils. 13th Ed. Upper Saddle River, NJ: Prentice Hall.

Chaudry, E.H., V. Timmer, A.S. Javed and M.T. Siddique. 2007. Wheat response to micronutrients in rainfed areas of Punjab. *J. Soil Environ*. **26**: 97–101.

Chude, V.O.; Oyinlola, E.Y.; Horst, W.J.; Schenk, M.K. and Burkert, A. (2001). Yield and nutritional qualities of two tomato *(Lycopersicon lycopersicum* Karst) varieties as influenced by boron fertilisation in a tropical environment. Plant-nutrition. Hannover, Germany. pp. 358-359

Demoranville, C.J. and Deubert, K.H. 1987. Effect of commercial calciumboron and manganese-zinc formulations on fruit set of cranberries. *J. Hort. Sci*. **62**: 163-16.

Di-Masico, P., S. Kaiser and H. Sies. (1989). Lycopene as the most efficient biological carotenoid singlet oxygen quencher. *Arch. Biochem. Biophys*. **274**: 532-8.

Edris, K. M., Islam, A. T. M. T., Chowdhury, M. S. and Haque, A. K. M. M. (1979). Detailed Soil Survey of Bangladesh, Dept. Soil Survey, Govt. People’s Republic of Bangladesh. 118 p.

El-Hameed, S.A., Abo-Hamad, and El-Feky, S.S. (2014). Effect of Boron on Growth and Some Physiological Activities of Tomato Plant. *Life Sci J.* **11**(7):403-408.

Fageria, N.K., M.P.B. Filho, A. Moreira and C.M. Guimaraes. 2009. Foliar fertilization of crop plants. *J. Plant Nutr*. **32**: 1044–1064.

FAO. (1988). Production Year Book. Food and Agricultural Organizations of the United Nations Rome, Italy. **42**: 190-193.

Ganeshamurthy, A.N., G.C. Satisha and P. Prakash. 2011. Potassium nutrition on yield and quality of fruit crops with special emphasis on banana and grapes. *Karnataka J. Agric. Sci*. **24**: 29-38.

Gazala. N., Upinder. S. and Pardeep. K. (2016). Boron its importance in crop production status in Indian Soils and crop responses to its application. *Int. J. Adv. Res.* **5**: 654- 600.

Giovannucci, E. (1999). Tomatoes, tomatoes-based products, lycopene and cancer: Review of epidemiologic literature. *J. Natl. Cancer Inst*. **91**: 317- 331.

Gomez, K.H. and Gomez, A.A. (1984). "Statistical Procedures for Agricultural Research". Inter Science Publication, Jhon wiley and Sono, New York. pp. 680.

Gopal, D. and Sarangtham, I. (2021). Effect of boron on the yield of tomato *(Solanum lycopersicum)* in acid soil. *The Pharma Innov. J*. **10**(5): 1096-1098.

Gopal, D. and Sarangthem**,** I. (2018). Effect of zinc on growth and yield of tomato **(***Lycopersicon esculentum* cv. Pusa Ruby**).** *Int. J. Curr. Res.* **10**(9): 73616-73620.

Gunes, A.; Alpaslan, M.; Cikili, Y. and Ozcan, H. (2000). The effect of zinc on alleviation of boron toxicity in tomato plants (Lycopersicon esculentum). *Turkish-Journal-of-Agriculture-and-Forestry.* **24**(4): 505-509.

Gurmani, A. R., J. Uddin., S. U. Khan., R. Andaleep., K. Waseem., A. Khan and Hadyullah. 2012. Soil Application of Zinc Improves Growth and Yield of Tomato. *Int. J. Agric. Culture Biol*. **14**(1):91–96.

Gurmani, A. R" Din, I. U., Khan, S. U., Andaleep, R" Waseem, K" Khan and Hadyatullah. (2012). Soil application of zinc improves growth and yield of tomato. *Int. J. Agric. Biol.* **14**(1): 91-96.

Gurmani, A.R., Din, J.U., Khan, S.U., Andaleep, R., Waseem, K., Khan, A. and Hadyat-Ullah, (2012). Soil Application of zinc improves growth and yield of tomato. *Int. J. Agric. Biol*. **14**: 91–96.

Haleema, B., Rab, A. and Hussain, S.A. (2018). Effect of calcium, boron and zinc foliar application on growth and fruit production of tomato. *Sarhad J. Agric.* **34**(1): 19-30.

Hanan, E.L. and Said, D.E.E.F. (2008). Effect of cadmium and zinc on growth parameter of tomato seedlings. *Academic. J. PL Sci.* **1**(1): 05 -11

Harris, K. D. and Mathuma, V. (2015). Effect of foliar application of boron and zinc on growth and yield of tomato (Lycopersicon esculentum Mill.). Asian J. Pharmaceutical sci. **5**(2)**:** 74-78.

Hellal, F.A., Taalab, A.S. and Safaa, A.M. (2009**). I**nfluence of nitrogen and boron nutrition on nutrient balance and Sugar beet yield grown in calcareous Soil. *Ozean J. Appl. Sci*. **2**(1): 1943-1949.

Hossain, F. (2008). Effect of zinc and boron on the growth and yield of tomato. *M.Sc (Agri) Thesis.,* Dept. Agril. Chemi., BAU, Mymensingh.

Hossain, M., Apostolides, C.G.E. and Goundra, O. (2011). Boron application affects seed yield and seedquality of sugar beets. *J. Agric. Sci*. **145**: 377–384.

Hunter, A.H. (1984). Soil Fertility Analytical Service in Bangladesh. Consultancy Report BARC, Dhaka.

Magalhaes, J.R.Dc., Solwa, C.E.W.L.Dc. and Monnerat, P.H. 1980. Levels and methods of boron application in tomatoes. *Pesquisa AgropecuriaBrasilesia*. **10**(2): 153-157.

Mallick, S., Das, R.C., Zakir, H.M. and Alam, M.S. (2021). Effect of Zinc and Boron Application on Lycopene and Nutritional Qualities of Tomato. *J. Sci. Res. Reports*. **27**(3): 27-36.

Mallick, S., Zakir, H.M. and Alam, M.S. (2020). Optimization of Zinc and Boron Levels for Better Growth and Yield of Tomato (*Lycopersicon esculentum* Mill.). *J. Expt. Agric. Int*. **42**(2): 87-96.

Mandal, A., A.K. Patra, D. Singh, A. Swarup and R.E. Masto. 2007. Effect of long-term application of manure and fertilizer on biological and biochemical activities in soil during crop development stages. *Bioresour. Technol*. **98**: 3585–3592.

Manoj and Sharma, R. D. (2003). Growth and yield in tomato-okra-pea cropping sequence as affected by levels and methods of zinc application. *Prog. Hort.* **35**(1): 96-99.

Maria, V. and, Ladislav, D. (2014). Effect of increasing doses of boron on oil production of oilseed rape (*Brassica napus* L.) Tr. A. Hlinku-2, 949/76, Nitra Slovak Republic.

Marschner H. (1995). Functions of Mineral Nutrients: Macronutrients. Mineral Nutrition of Higher Plants. 2nd Ed., Academic Press, London. pp. 379-396.

Meena, D. C., Maji, S., Meena, J. K,, Govind, Kumawat, R,, Meena, K. R., Kumar, S. and Sodh, K. (2015). Improvement of growth, yield and quality of tomato *(Lycopersicon esculentum* MILL.) with foliar application of zinc and boron. *Int. J. Bio Sci. Stress Manag.* **6**(5): 598-601.

Mengel K, Kosegarten H, Kirkby EA, Appel T. (2001). Principles of Plant Nutrition. Springer Science and Business, Media, 2001.

Menzel, C.M. and D.R. Simpson. 1987. Lychee nutrition: A review. *Sci. Hort*. **31**: 195-224.

Moura, J. Z., Prado, R.M., Benvindo, R.N. and Chaves, A. L. (2013). Applying boron to coconut palm plants: effects on the soil, on the plant nutritional status and on productivity boron to coconut palm trees. *J. Soil Sci. Plant Nutr*. **13**(1): 79-857.

Muhammad, W. K., Amir, M. L., Muhammad, S. D., ALI, S. C., Attaullah, K. P., Hamz, A. S. and Beahri L. (2014). Impact of foliar spray of zinc on fruit yield of chilli **(**Capsicum annuum L.). Life Sci. Int. J. **8**(1, 2, 3 & 4): 2944-2949.

Naga-Sivaiah, K., Swain, S. K., Raju, B. and Sandeep, V. V. (2013). Effect of micronutrient foliar application on seed yield in tomato. Int. J. of plant Anim. sci. **1**(7): 70-72.

Nataraja, T.H., A.S. Halepyati, B.T. Pujari and B.K. Desai. 2006. Influence of phosphorus levels and micronutrients on the physiological parameters of wheat. *Karnataka J. Agri. Sci*. **19**: 685–687

Naz, R.M.M., Muhammad, S., Hamid, A. and Bibi, F. (2012). Effect of boron on the flowering andfruiting of tomato. *Sarhad J. Agric*. **28**(1): 37-40

Olsen, S. R., Cole, C. V., Watanabe, F. S., & Dean, L. A. (1954). Estimation of available phosphorus in soils by extraction with sodium bicarbonate. Circular, Washington, DC: US Department of Agriculture. **939**: 19.

Osman, I.M. (2019). Effect of boron and zinc on the growth, yield and yield contributing traits of tomato. *IOSR J. Agric. Vet. Sci. (IOSR-JAVS)*. **12**(2): 25-37.

Page, A.L., Miller, R.H. and Keeney, D.R. (1982). Methods of analysis part 2, Chemical and Microbiological Properties, Second Edition American Society of Agronomy, Inc., Soil Science Society of American Inc. Madson, Wisconsin, USA. pp. 403-430.

Patil, B. C., Hosamani., R. M., Ajjappalavara, P. S., Naik, B. H., Smitha R. P. and Ukkund K. C. (2008). Effect of Foliar Application of Micronutrients on Growth and Yield components of Tomato **(***Lycopersicon esculentum* Mill.). *Karnataka J. Agric. Sci*. **21**(3): 428-430.

Patil, V.K., Yadlod, S. S., Pawar., V. B. and Narsude, P. B. (2010). Effect of foliar application of micronutrients on growth and quality of tomato (*Lycopersicon esculentum* MILL.). *Asian J. Hort*. **4**(2): 370- 372.

Patnaik, M. C., Raj, G. B. and Reddy, I. P. (2001). Response of tomato to zinc and iron. *Veg. Sci*. **28**(1): 78-79.

Phillips, M. (2004). Economic benefit from using micronutrients for the farmer and the fertilizer producer. IFA. International Symposium on Micronutrients. Feb. 23–25, 2004. New Delhi, India.

Prasad, K.K.; Chowdhary, B.M. and Amrendra, K. (1997). Response of tomato to boron application in Chotanagpur region. *J. Res. Birsa Agric. Univ*. **9**(2) 145-147.

Prasad, P.N.S., Subbarayappa, C.T., Sathish, A. and Ramamurthy, V. (2021). Impact of Zinc Fertilization on Tomato ***(Solanum lycopersicum*** L.) Yield, Zinc use Efficiency, Growth and Quality Parameters in Eastern Dry Zone (EDZ) Soils of Karnataka, India. *Int. J. Plant Soil Sci***.** **33**(7): 20-38.

Prasad, V. M. and Saravanan, S. (2014). Effect of zinc and boron on growth, yield and quality of tomato (*Lycopersicon esculentum* MILL.) under protected cultivation. *European Academic Res.* **2**(3): 4572-4597.

Rashid, M.M. 1983. Sabjeer Chash, 1stEdn., Begum Shahla RashidPublishers, Joydebpur, Gazipur, 86-87.

Riaz, A. and Muhammad, I. (2011). Effect of boron application time on yield of wheat, rice and cotton crop in Pakistan. *Soil Environ*. **30**(1): 50-57.

Rizwan, U., Gohar, A., Mohammad, I., Manzoor, A., Muhammad, U., Samia, M. and Saquib, F. (2015). Growth and yield of Tomato *(Lycopersicum esculentum*) as influenced by different levels of zinc and boron as foliar application. *Ameri-Euras. J. Agric. Environ.* **15**(12): 2495-2498.

Roy, A.C. and Monir, M.R. (2020). Effect of Foliar Spray of Boron on the Growth and Quality of Exotic Tomato (*Lycopersicon esculentum* Mill) in Bangladesh. *Asian Plant Res. J*. **4**(4): 17-24.

Sajid, A., Hafiz, U.I., Rana-Naveed, U.R.R., IRFAN, A.S., Muhammad, S.N., Muhammad, Z.S., Dawood, A.S. and Muhammad, A.N. (2013). Foliar application of some macro and micronutrients improves tomato growth, flowering and yield. *Int. J. Bio. sci.* **3**(10): 280-287.

Salam, M.A., Siddique, M.A. and Rahim, M.A. (2011). Quality of tomato as influenced by boron and zinc in presence of different doses of cowdung. *Bangladesh J. Agril. Res*. **36**(1): 151-163.

Salunkhe, D.K., Desai, B.B. and Bhat, N.R. 1987. Vegetables and flower seed production. 1st Edn. Agricola Publishing Academi, New Delhi, India. pp. 118-119.

Sanjida, M., Howlader, J., Akon, M.R. and Ahmed, T. (2020). Effects of varieties and boron on growth and yield of summer tomato. *Asian J. Crop Soil Sci. Plant Nutr*. **4**(1): 141-149.

Saravaiya, S.N., Wakchaure, S.S., Jadhav, P.B., Tekale, G.S., Patil, N.B. and Dekhane, S.S. (2014). Effect of foliar application of micronutrients in tomato (*Lycopersicon esculentum* Mill.). *Asian J. Hort. Sci*. **9**(2): 297-300.

Sathya, S., Mani, S., Mahendran, P.P. and Arulmozhiselvan, K. (2010). Effect of application of boron on growth, quality and fruit yield of PKM 1 tomato. *Indian J. Agric. Res*. **44**: 274-280.

Shil, N.C., Naser, H.M., Brahma, S., Yousuf, M.N. and Rashid, M.H. (2013). Response of chilli (*Capsium annuum* L.) to zinc and boron application. Bangladesh J. Agril. Res. **38**(1): 49-59.

Shkolnik, M. J. 1974. Micronutrients in Plant Life of Nauka, Leningard. 323.

Shoba, N., Natarajan, S., Veeraragavathatham, D. and Amarnath, V. (2005). Effect of calcium, boron and ethrel on fruit cracking in tomato. *Res. Crops*. **6**(2): 369-370.

Smit, J.N. and Combrink, N.J. (2004). The effect of boron levels in nutrient solutions on fruit production and quality of greenhouse tomatoes South *African J. Plant Soil*. **21**(3): 188-191.

Soomro, Z. H., Baloch, P. A. and Gandhai, A. W. (2011). comparative effects of foliar and soil applied boron on growth and fodder yield of Maize. *Pak. J. Agri. Agril. Engg. Vet. Sci.* ***27****(1): 18-26*.

Srividya, S., S.S. Reddy, V. Sudhavani and R. Reddy. (2014). Effect of post-harvest chemicals on fruit physiology and shelf Life of tomato under ambient conditions. *Int. J. Agric. Food Sci. Technol*. **5**(2): 99-104.

Sturiao, W.P., Lucena, J.J., Martinez, H.E.P. and Lapez-Rayo, S. (2020). Effects of boron foliar sprays on tomato cultivation. *Acta Hort*. **1273**: 207-216.

Sultan, S., Naser, H.M,, Akther, S. and Begum, R.A. (2016). Effectiveness of soil and foliar application of zinc and boron on the yield of tomato. *Bangladesh J. Agril. Res*. **41**(3): 411-418.

Syed. I., Hyder, M.A., Ali, A. and Imdad, A.M. (2012). Effect of boron nutrition on paddy yield under salinesodic soils. *Pakistan J. Agric. Res*. **25**(4): 27-31**.**

Ullah, R., Ayub, G. and Ilyas, M. (2015). Growth and Yield of Tomato *(Lycopersicon esculentum* L.) As Influenced By Different Levels of Zinc and Boron as Foliar Application. *American-Eurasian J. Agric. Environ. Sci*. **15**(12): 2495-2498.

UNDP. (1988). Land Resource Apprisal of Bangladesh for Agricultural Development Report 2: Agro-ecological Regions of Bangladesh, FAO, Rome, Italy. p. 577.

USDA National Nutrient Database for Standard Reference Release 28 (2016). Basic Report 11529, Tomatoes, red, ripe, raw, year round average Report Date: January 03, 2016. Nutrient values and weights are for edible portion. Software v.2.3.2. The National Agricultural Library.

Xu, W., Wang, P. and Yuan, L. (2021). Effects of Application Methods of Boron on Tomato Growth, Fruit Quality and Flavor. Horticulturae. **7**: 223.

Yadav, M., Singh, D.B., Chaudhary, R. and Reshi, T.A. (2006). Effect of boron on yield of tomato *(Lycopersicon esculentum* Mill) cv. DVRT-1. *Plant Archives*. **6**(1): 383-384.

Yadav, P. V. S., Singh, N. and Tikkoo, A. (1999). Effect of zinc and boron application on yield of tomato. *Haryana J. Hort. Sci.* **28**(3&4): 241-243.

Yadav, P.V.S.; Abha, T.; Sharma, N.K. and Tikkoo, A. (2001). Effect of zinc and boron application on growth, flowering and fruiting of tomato *(Lycopersicon esculentum* Mill). *Haryana J. Hort. Sci.* **30**(1-2): 105107.

APPENDICES

Appendix I. Agro-Ecological Zone of Bangladesh showing the experimental location

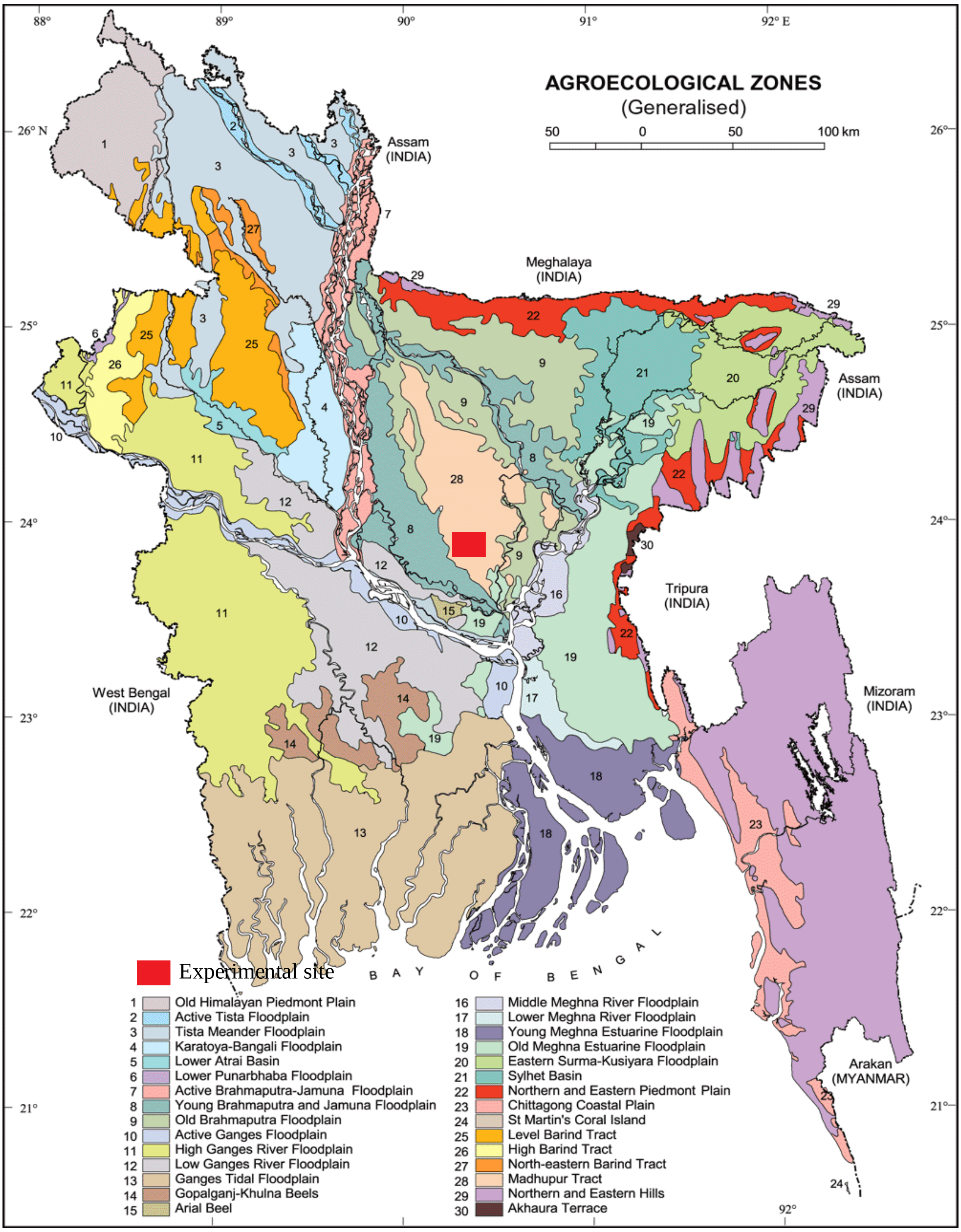


Figure 8. Experimental site

Appendix II. Monthly records of air temperature, relative humidity and rainfall during the period from October 2020 to February 2021

Year	Month	Air temperature (°C)			Relative humidity (%)	Rainfall (mm)
		Max	*Min*	*Mean*		
2020	October	30.42	16.24	23.33	68.48	52.60
2020	November	28.60	8.52	18.56	56.75	14.40
2020	December	25.50	6.70	16.10	54.80	0.0
2021	January	23.80	11.70	17.75	46.20	0.0
2021	February	22.75	14.26	18.51	37.90	0.0

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

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

A. Morphological characteristics of the experimental field

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

Source: Soil Resource Development Institute (SRDI)

B. Physical and chemical properties of the initial soil

Characteristics	**Value**
Particle size analysis % Sand	27
%Silt	43
% Clay	30
Textural class	Silty Clay Loam (USDD)
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20
Exchangeable K (me/100 g soil)	0.1
Available S (ppm)	45
Available B (ppm)	0.363
Available Zn (ppm)	0.201

Source: Soil Resource Development Institute (SRDI)

Appendix IV. Mean square of plant height of tomato at different growth stages

Sources of variation	Degrees of freedom	Mean square of plant height		
		30 DAT	60 DAT	90 DAT
Replication	2	0.076	1.720	3.103
Factor A	2	92.748*	256.68*	368.48*
Factor B	2	137.89*	358.32*	561.08*
AB	4	6.581**	15.567*	25.866*
Error	16	1.951	2.026	3.587

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

Appendix V. Mean square of number of leaves plant^{-1} of tomato at different growth stages

Sources of variation	Degrees of freedom	Mean square of number of leaves plant^{-1}		
		30 DAT	60 DAT	90 DAT
Replication	2	0.112	0.259	1.861
Factor A	2	19.37*	97.333*	136.92*
Factor B	2	50.70*	130.11*	225.03*
AB	4	4.926**	10.778**	16.981*
Error	16	0.521	1.160	2.126

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

Appendix VI. Mean square of number of branches plant^{-1} of tomato at different growth stages

Sources of variation	Degrees of freedom	Mean square of number of branches plant^{-1}	
		60 DAT	90 DAT
Replication	2	0.162	0.086
Factor A	2	12.04*	4.778**
Factor B	2	18.02*	19.00*
AB	4	0.479**	1.444**
Error	16	0.082	0.113

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

Appendix VII. Mean square of yield contributing parameters of tomato

Sources of variation	Degrees of freedom	Mean square of yield contributing parameters						
		No. of flower clusters plant^{-1}	No. of flowers plant^{-1}	No. of fruits cluster^{-1}	No. of fruits plant^{-1}			% fruit dry matter
Replication	2	0.513	22.09	0.074	0.401			0.026
Factor A	2	0.352**	43.23*	0.266*	23.65*			2.960*
Factor B	2	4.486*	122.8*	0.011^{NS}	58.50*			12.89*
AB	4	0.156**	3.995*	0.034**	3.181*			0.211**
Error	16	0.080	1.027	0.011	1.149			0.121

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

Appendix VIII. Mean square of yield parameters of tomato

Sources of variation	Degrees of freedom	Mean square of yield parameters		
		Fruit weigh plant^{-1}	Fruit yield plot^{-1}	Fruit yield ha^{-1}
Replication	2	0.003	0.840	6.526
Factor A	2	0.152**	33.88*	261.30*
Factor B	2	0.370**	82.50*	636.64*
AB	4	0.023**	4.914*	37.870*
Error	16	0.007	0.305	7.373

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