EFFECT OF DIFFERENT LEVELS OF POTASSIUM AND BORON ON MORPHO-PHYSIOLOGY AND YIELD OF TOMATO

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CERTIFICATES

This is to certify that the thesis entitled **"EFFECT OF DIFFERENT LEVELS OF POTASSIUM AND BORON ON MORPHO-PHYSIOLOGY AND YIELD OF TOMATO"** submitted to the Department of Agricultural Botany, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTERS OF SCIENCE (M.S.)** in **AGRICULTURAL BOTANY**, embodies the result of a piece of bonafide research work carried out by **MD.-HAFIZUR-RAHMAN**, Registration No. **12-04804** 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, 2018
Dhaka, Bangladesh

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Dedicated to

My

Beloved Parents

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The Author

EFFECT OF DIFFERENT LEVELS OF POTASSIUM AND BORON ON MORPHO-PHYSIOLOGICAL YIELD OF TOMATO

ABSTRACT

A field experiment was carried out at the Agricultural Farm of Sher-e-Bangla Agricultural University, Dhaka, during November 2017 to April 2018 to study the effect of different levels of potassium and boron on morpho-physiology and yield of tomato. The experiment consisted of two factors: Factor-A *viz*. K_0 (0 kg K ha^{-1}), K_1 (60 kg K ha^{-1}) and K_2 (100 kg K ha^{-1}) and Factor-B *viz*. B_0 (0 kg B ha^{-1}), B_1 (0.5 kg B ha^{-1}) and B_2 (1.0 kg B ha^{-1}). The experiment was laid out in a Randomized Complete Block Design (RCBD) with four replications. The total treatment combinations were nine (9) and the planting material was BARI Tomato-14. Results revealed that potassium (K) and boron (B) individually as well as in combination showed significant variation among the treatments for most of the parameters. Different doses of K showed significant influence on the plant height and number of leaves $plant^{-1}$at 50 and 70 DAT, number of flower cluster $plant^{-1}$, fruit diameter, single fruit weight, number of fruits $cluster^{-1}$, number of fruits $plant^{-1}$, fruit weight $plant^{-1}$and fruit yield (t ha^{-1}). Boron application failed to show significant effect on plant height, number of leaves $plant^{-1}$,SPAD value, fruit length. In addition, B showed significant effects yield contributing characters such as number of fruits $plant^{-1}$, fruit diameter, fruit weight $plant^{-1}$ and fruit yield (t ha^{-1}).In terms of combination of K and B, the maximum plant height (54.60 cm) and number of leaves $plant^{-1}$ (15.35) were achieved from the treatment combination of K_2B_2. The together application of K_2 and B_2 increased the highest fruit yield of tomato which are consistent the different morphological and yield contributing characters of this study. Therefore, it is concluded that K in combination with B could increase fruit yield of tomato under the climatic and adaphic condition of Sher-e-Bangla Agricultural University (SAU).

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 (*Solanum lycopersicum*) belongs to the family Solanaceae is one of the most important and popular vegetables in Bangladesh. It ranks third in the world's vegetable production, next to potato and sweet potato, placing itself first as processing crop among the vegetables (FAO, 2002). It was originated in tropical America (Salunke *et al.*, 1987), particularly in Peru, Ecuador, Bolivia of the Andes (Kallo, 1986). It is a cheap source of vitamin-C. It is also a rich source of vitamin A and B, and calcium (Bose and Some, 2002). Hundred grams edible portion of tomato contains 0.9 g starch, 20 kilo calorie energy, 200-800 milli equivalent of vitamin A, 0.06mg niacin, 10-100 mg vitamin C, 8 mg calcium and 0.3 mg iron (Rashid, 1999).

The soil and climate conditions of winter season of Bangladesh are congenial for tomato cultivation. Among the winter vegetable crops grown in Bangladesh, tomato ranks second in respect of production to potatoes and third in respect of area (BBS, 2016). In Bangladesh, tomato has great demand throughout the year, but its production is mainly concentrated during the winter season. Recent statistics showed that tomato covered 42080 acres of land and the total production was approximately 131 thousand metric tons (BBS, 2017). Thus, the average yield is quite low as compared to that of other tomato producing countries such as India (15.14 t/ha), Japan (52.82 t/ha), USA (65.22 t/ha), China (30.39 t/ha), Egypt (34.0 t/ha),respectively (FAO, 2002). The low yield of tomato in our country is mainly due to lack of genotype and scarcity of improved cultural practices including insufficient supply of required nutrients (Ali *et al.*, 1994).

Higher production of tomato depends upon adoption of high yielding varieties, appropriate crop management techniques including precise and balanced fertilization, timely irrigation, control of diseases and insect pests. Adequate supply of nutrient can increase the yield, fruit quality, fruit size, keeping quality, colour, and taste of tomato (Shukla and Naik, 1993).

Among the different macro plant nutrients, potassium is an important nutrient. Potassium (K) is a major and essential nutrient for tomato production. Next to nitrogen, potassium is the mineral nutrient required in the largest amount by plants. The potassium requirement for optimal plant growth is in the range 2-5% of the plant dry weight of vegetative parts and fleshy fruits (Mengel and Kirkby, 1987 and Marschner, 1995). Potassium (K) fertilization is essential, for all kinds of crops especially long term vegetable crops like tomato (Sonneveld and Voogt, 1981) and according to several authors, it plays a key role in the improvement of several quality traits in tomato fruits and in almost all vegetables (Chapagain and Wiesman, 2004; Dorais *et al*., 2008; Oded and Uzi, 2003). In tomato production, potassium (K) is one of the high demand nutrients during the season and is the one where highest uptake occurs during fruit bulking (Bose *et al*., 2006). Potassium plays an important role in transporting and accumulating sugars produced in the leaf by photosynthesis to develop plant biomass and tomato fruit (Ozores-Hampton *et al*., 2012a). Adequate K nutrition has also been shown to reduce the severity of diverse physiological disorders such as uneven and blotchy ripening, irregular shape and hollow fruit, high level of internal white tissue, yellow shoulder, gray wall, and decreased lycopene (Hartz, 1999).

Micronutrient deficiencies is one of the major limiting factors for crop production in Bangladesh (Islam and Anwar, 1994). Among the micronutrients, boron plays an important role in improving the yield and quality of tomato in addition to checking various diseases and physiological disorders (Magalhaes *et al*., 1980). Demoranville and Deubert (1987) reported that fruit shape, yield, and shelf life of tomato were affected by boron deficiency. Boron is an important element and involved in division of cell, development of leaf and flower bud, glucose metabolism and hydrocarbons and their transport, growth of root, formation of cell wall and material transportation between cells in plants (Moghadam *et al*., 2012). It also improves flower production and retention, pollen tube elongation and germination, and seed and fruit development (Hanson, 1991). Application of boron increased growth and yield in plants (Ali *et al*., 2009). Dutta *et al*. (2000) reported that the application of B as boric acid improved fruit set and fruit weight over control.

Crops differ in their sensitivity to boron deficiency. Tomatos in general have a high boron requirement (Mengel and Kirkby, 1987). Fruit and seed set failure is a major reason for lower yield of rabi crops and this problem can be attributed to boron deficiency, as reported in tomato (Rahman *et al.,* 1993; Islam *et al.,* 1997). Boron deficiency may cause sterility i.e. less fruits per plant attributing lower yield (Islam and Anwar, 1994). Shoulder check crack is caused by boron deficiency and the incidence can be reduced by the application of boron (Huang and Snapp, 2004). In addition, the firmness of tomato fruits is reduced by the application of boron and the problem becomes severe during storage period (Smit and Combrink, 2004).

In Bangladesh, there is limited information on the effect of K and B on growth and yield of tomato. However, to my knowledge, little is known about the proper doses of K and B on improve the morphological, yield contributing characters and yield of tomato under the climatic and edaphic condition of SAU. In view of these limitations, a field experiment containing the treatments of K and B was conducted with the following objectives:

1. To investigate the independent effect of K and B on morpho-physiological and yield contributing characters and yield of tomato
2. To find out the best combination of K and B on morpho-physiological as well as yield contributing characters and yield of tomato.

CHAPTER II

REVIEW OF LITERATURE

Tomato is one of the most popular and widely grown vegetable of the world. It is a rich source of minerals and vitamins. The proper fertilizer management influences it s growth and yield performance. Experimental evidences showed that there is a profound effect of potassium (K) and boron (B) fertilizers on this crop. The quality of tomato fruit is largely dependent on K and B application. An attempt has been made in this chapter to present a relevant review of literature on the research works performed till to date in Bangladesh in relation to the effects of K and B on growth and yield by tomato.

2.1 Effect of potassium (K)

Abd-El-Hamied and Abd El-Hady (2018) conducted two field experiments to study the effect of three phosphors rates (0, 14 and 28 kg P fed^{-1}); five foliar treatments (0, 0.3 and 0.6% of Ca and 0.5% and 1% of K) and their interactions on tomato growth and yield. Data showed that phosphorus treatment of 14 kg P fed^{-1} gave the best results of leaf area (cm^{2}), fresh weight of tomatoes leaves, potassium content (%) in leaves, fresh weight of four fruit, fruit diameter and tomatoes yield (Mg fed^{-1}). In addition, foliar application treatments at 0.3% Ca and 0.5% K recorded the highest results of plant height, leaf area (cm^{2}), fresh weight of tomato leaves, N, P contents in leaves, chlorophyll content of leaves, weight of four fruits, fruit diameter, tomato yields (Mg fed^{-1}). The highest tomato yields (Mg fed^{-1}) values were18 and 18.06 Mg fed^{-1} recorded with 14 kg P fed^{-1} and 0.3% calcium as a foliar application followed by 14 kg P fed^{-1} and 0.5% potassium which recorded 17.36 and 17.32 Mg fed^{-1} , respectively in both seasons. Generally, it is concluded that the interaction between the treatment of 14kg P fed^{-1} and 0.3%

calcium or 0.5% potassium as a foliar application enhanced tomato yield and nutrient uptake.

Samra *et al*. (2017) concluded that, the effect of different levels of potassium (0, 60, 120 and 180 kg / ha) applied on onion cv. Swat-1 and the results indicated that maximum leaf length (32.00 cm), plant height (48.16 cm), number of leaves per plant (7.50), bulb diameter (5.20 cm) and maximum yield (24.67 t ha^{-1}) with potassium at the rate of 120 kg/ha over control.

Subba *et al*. (2017) conducted an experiment on carrot to evaluate the potassium fertilizer levels (0, 50, 75 and 100 kg/ha) with a uniform dose of nitrogen and phosphorus and reported the highest mean vegetative parameters such as plant height (36.75 cm), number of leaves per plant (9.45), fresh weight of leaves (35.12 g) and dry weight of leaves (8.78 g) with the treatment combination of 100 kg K_20 and 15 kg B. The treatment 75 kg K/ha gave the maximum yield (31.83 t/ ha).

Zhu *et al*. (2016) conducted a study to evaluate the effects of K rates on fruit yield and postharvest quality of tomato grown on a calcareous soil. Tomatoes were grown using six rates of K: 0, 60, 100, 160, 200, and 240 lb/acre of K_2O. Potassium fertilizer placement was divided into pre-plant dry fertilizer and fertigation. None of the fruit categories at the first harvest were significantly affected by K doses. For the second harvest, the response of total marketable yields was highest with critical rate of 200 lb/acre. Quadratic regression models predicted maximum extra-large fruit and total season marketable yields at 171 and 185 lb/acre, respectively.

Atanda and Olaniyi (2016) conducted a field experiment to evaluate the effect of potassium levels on onion and the results indicated that significantly highest plant height (36 cm), number of leaves (5.3), maximum average bulb weight (78.44 g), bulb diameter (5.20 cm) and yield (24.67 t ha^{-1}) was observed with potassium at the rate of 120 kg/ha.

Fouzia *et al*. (2016) studied the influence of different potassium levels (30, 50, 70, 90, 110 K kg/ha) on carrot cv. New Kuroda and reported the highest shoot height (64.88 cm), maximum number of leaves (11.45), highest shoot weight per plant (88.67 kg), highest root length (14.01 cm), maximum root diameter (4.48 cm), fresh weight (0.130 kg) and highest root yield (30.50 t/ha) were recorded with 70 kg K/ha.

Afzal *et al*. (2015) conducted a field experiment to investigate the specific contribution of potassium to yield and quality of tomato. Foliar application with varying levels (0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9 and 1.0%) of potassium solutions was applied to the plants and compared with control (without K). Exogenous application of 0.6% K significantly improved plant height, lycopene content, potassium, fruit weight and diameter. Due to positive correlation between K nutrition and fruit quality attributes, exogenous application of an appropriate K level can contribute to higher yield and better quality of tomato fruits. Among all potassium levels, 0.5–0.7% K maximally improved performance of tomato plants of both cultivars.

Ahmad *et al*. (2015) conducted a field experiment to investigate the effect of potassium and its time of application on yield and quality of tomato variety, Nagina. Treatments included three potassium levels i.e. 60, 90 and 120 kg ha^{-1} and two application timings: at transplanting as single dose, and half at transplanting + half at 40 days after transplanting in two splits, were applied along with a control (0 kg ha^{-1} K). Potassium application @ 60 kg ha^{-1} either applied in single or in two splits, significantly increased the yield and improved the quality parameters of tomato over control while higher levels of K (90 and 120 kg ha^{-1}) did not show further significant increase in the yield and quality subsequently. Results revealed that time of application/splitting of K did not affect the yield and quality. The highest yield (23.3 t ha^{-1}), firmness (8.32 kg), fruit weight (83.24 g fruit^{-1}), total invert sugars (4.11 %), dry matter (6.33 %) and mineral matter (1.95 %) were recorded with the application of 120 kg ha^{-1} potassium at transplanting. Minimum yield (17.2 t ha^{-1}), firmness (6.35 kg), fruit weight (68.11 g/fruit), mineral matter (1.80 %) and dry matter (5.26 %) were found in control.

Baloch *et al*. (2014) conducted an experiment on radish (*Raphinus sativus* L.) cv. Early Long White to evaluate the effect of potassium levels on yield parameters of radish. Phosphorus and potassium were used at constant rates of 75 and 100 kg/ha respectively and positively affected growth and yield parameters. Maximum germination (88%), plant height (32.42 cm), no of leaves per plant (17.46 leaves per plant) and leaves weight per plant (173.10 g/plant) were found when applied 100 kg K/ha. But significant increase in the root yield per plot (73.37 kg) and root yield (46.64 t /ha) per hectare was observed with the treatment 75kg K/ha.

Kumar *et al*. (2013) carried out a field experiment to study the effect of nitrogen, phosphorus and potassium fertilizers on the growth, yield and quality of tomato var. Azad T-6. Three types of fertilizers (nitrogen, phosphorus and potassium) in different combinations were tested. Tomato plants were fertilized with different rates of chemical fertilizers i.e. two doses of nitrogen fertilizers N_1 and N_2 (120 and 180 kg/ha), single dose of phosphorus P_1 (80 kg/ha) and potassium K_1 (75 kg/ha).The highest plant height, the maximum number of primary and secondary branches, number of flowers and fruits/plant as well as the greatest fruit size, fruit yield/plant and fruit yield/ha were obtained from the application of the recommended dose of nutrients *viz*., 120 kg N +80 kg P +75 kg K/ha. The results revealed that significantly the highest plant height higher yield and yield attributing characters were recorded with the application of 100% NPK i.e. 180 kg N/ha along with 80 kg P/ha and 75 kg K/ha.

Javaria *et al*. (2012) conducted a pot experiment which included six potassium fertilizer treatments (75, 150, 225, 300, 375, 450 Kg K_2O ha^{-1}) with basal doses of N and P (100 Kg and 80 Kg ha^{-1}, respectively). Pots treated with N and P alone were kept as control treatment. All potassium treatments significantly increased yield characteristics compared with untreated one (control). However, Treatment (NP+450 K_2O Kg ha^{-1}) surpassed all other treatments in terms of yield parameters. Potassium application significantly increased number of flowers $plant^{-1}$, fruit setting rate, number of clusters $plant^{-1}$, fruits $plant^{-1}$, fruits $cluster^{-1}$ and yield ha^{-1}. Therefore, when potassium was applied @ 450 Kg K_2O ha^{-1} ,it increased the yield and decreased the adverse effect on marketable yield and weight retention of tomato fruit. In conclusion 375-400 Kg K_2O ha^{-1} is recommended as it produced better quality tomatoes with longer postharvest life.

El-Nemr *et al*. (2012) carried out an experiment to study the effect of different concentrations of potassium (K) on the vegetative growth, yield and important quality traits of different tomato cultivars,. Three K levels (low, middle, and high) of 200, 300, and 350 ppm in the nutrient solution were used and two cultivars (Floridat and Super Strain B) were compared. Floridat cultivars showed higher growth and yield performance than Super Strain B. Higher yield was recorded with Floridat cultivar and high level of K concentration (350 ppm).

Akhtar *et al*. (2010) conducted a field experiment to evaluate comparative effects of sulphate and muriate of potash (SOP and MOP) application on yield, chemical composition and quality of tomato (*Lycopersicon esculentum*, L. cultivar Roma). Potassium from two sources i.e., MOP and SOP was applied @ 0, 100 and 200 kg K ha^{-1} with constant dose of 200 kg N ha^{-1} and 65 kg P ha^{-1}. A significant increase in tomato yield with K application was observed. Potassium applied @ 100 kg K ha^{-1} as MOP produced significantly higher marketable tomatoes as compared to SOP and control.

Ananthi *et al*. (2004) recorded that, among the different combinations of sources and levels of potash, application of 60 kg K_2O ha^{-1} as SOP was superior in increasing the number of fruits per plants, fruit length, fruit weight and fruit yield substantially during both the years and also the higher dry fruit yield (5.43 t/ha) fruit set per cent and harvest index over other treatment combination.

Ramakrishna (2000) concluded the application of 150:75:75 kg N, P_2O_5 and K_2O ha-1 produced significantly higher total dry matter per plant, per cent fruit set, number of fruits plant^{-1}, fruit weight per plant and ultimately higher fruit yield (1176.0 kg/plant) over other fertilizer levels and was on par with 125:62.5: 62.5 kg N, P_2O_5 and K_2O ha^{-1} (1095.3 kg/plant).

Majumdar et al. (2000) reported that increasing levels of potassium significantly influenced the fruit yield of tomato and chilli. The maximum fruit yield of tomato (525.33 q/ha) and chilli 168.20 q/ha) were observed under 90 kg ha^{-1} K treatment over no potassium (297.66 and 149.38q/ha, respectively).

2.2 Effect of boron (B)

Zamban *et al*. (2018) carried out this study to evaluate the effect of boron soil treatments and the frequency of calcium applications on the flowering, agronomic performance, and incidence of blossom end rot in two Italian tomato hybrids (San Vito and Netuno) in two growing seasons (Spring-Summer and Summer-Fall). Three boron doses (0.0, 2.0, or 4.0 g/hole), and three frequencies of calcium application (absence of application, weekly, or biweekly application). The Netuno hybrid was more productive in comparison to the San Vito hybrid. The biweekly application frequency of 0.6% $CaCl_2$ was the best option for fertilizer management, resulting in higher yields and a lower number of fruits with an incidence of blossom end rot. The increment of the boron dose defined the higher number of fruits per plant and yield increase.

Muthanna *et al*. (2017) carried out two years investigation to study the effect of boron and sulphur application on plant morphology and yield of potato. Out of thirteen treatments one control, one recommended dose of fertilizers (N-P-K: 150-80-120 kg ha^{-1}) and eleven treatment combinations along with recommended dose of fertilizers (RDF) including 3 doses of boron (1 kg, 2 kg and 3 kg/ha); 2 doses of sulphur (30 kg and 40 kg/ha) and their combinations (1 kg boron + 30 kg sulphur, 2 kg boron + 30 kg sulphur, 3 kg boron + 30 kg sulphur, 1 kg boron + 40 kg sulphur, 2 kg boron + 40 kg sulphur and 3 kg boron + 40 kg sulphur) were applied. The study indicated that plant morphology and yield of potato plant were significantly influenced by boron and sulphur application. The maximum plant height and yield of marketable tubers (17.99 t ha^{-1} and 27.00 t ha^{-1}) were recorded in the plants treated with RDF + 2 kg B + 40 kg S during both year of investigation. RDF + 2 kg B + 40 kg S was also found statistically at par with the maximum values under characters *viz*., number of sprouts per tuber, stem diameter and number of marketable tubers/hill.

Athokpam *et al*. (2016) supported that from a two year experiment that among the combination between vermicompost and boron, the application of minimum dose of boron (B_1=10 Kg/ha boron) with maximum dose of vermicompost (V_3=20q/ha) i.e. B_1V_3 application reduced the number of days taken to flowering, 50% of flowering, ripening, 50% of ripening as compared to the other treatments and found superior in increasing the available N, P_2O_5, K_2O, and Organic carbon in soil. The highest fruit yield was recorded with the combined application of 10 kg borax and 20 q vermicompost (1% N)/ha. The same treatment i.e. B_1V_3, was also found to be superior in increasing the better results regarding most of the parameters. Moreover the application B_1V_3 increased availability of N,P,K and Organic Carbon, which exerts positive effect on growth, development and yield of tomato.

Harris and Lavanya (2016) carried out a pot experiment to evaluate the influence of foliar application of boron, copper and their combinations on the quality of tomato. There were ten (10) treatments *viz*., (T_1) H_3BO_3=150 ppm; (T_2) H_3BO_3 = 250 ppm; (T_3) H_3BO_3 = 350 ppm; (T_4) $CuSO_4$ = 150 ppm; (T_5) $CuSO_4$ = 250 ppm; (T_6) $CuSO_4$ = 350 ppm; (T_7) H_3BO_3 (150 ppm) + $CuSO_4$ (150 ppm); (T_8) H_3BO_3

(250 ppm) + $CuSO_4$ (250 ppm); (T_9) H_3BO_3 (350 ppm) + $CuSO_4$ (350 ppm); (T_{10}) Control (Boron was applied as H_3BO_3 and copper is applied as $CuSO_4$). The effect of B is greater than that of Cu. The application of B increased the fresh weight of fruits (H_3BO_3 - 350 ppm), pulp weight (H_3BO_3 - 150 ppm) and TSS (H_3BO_3 - 150 ppm). It is apparent that B concentration at different levels had significant positive effect on most of the quality parameters tested.

Ali *et al*. (2015) carried out an experiment to increase the yield of BARI hybrid tomato-4, with foliar application of zinc and boron [T_0: control; T_1: 25ppm $ZnSO_4$ (Zinc Sulphate); T_2: 25ppm H_3BO_3 (Boric Acid) and T_3: 12.5ppm $ZnSO_4$ + 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).

Rab and Haq (2012) investigated the influence of CaCl2 and borax on growth, yield, and quality of tomato. Calcium chloride (0.3% and 0.6%) and borax (0.2% and 0.4%) solutions were applied as foliar sprays either alone or in combination. The application of $CaCl_2$ alone significantly increased the plant height and fruits per plant. Borax alone significantly enhanced the number of branches per plant, number of flowers per cluster, fruits per cluster, fruits per plant, fruit weight, fruit firmness, and total soluble solid content of the fruits except plant height. Foliar application of $CaCl_2$ (0.6%) + borax (0.2%) resulted in the maximum plant height

(86.60 cm), branches per plant (7.21), flowers per cluster (32.36), fruits per plant (96.37), fruit weight (96.33 g), yield (21.33 t ha^{-1}), fruit firmness (3.46 kg cm^{-2}), and total soluble solids (6.10%) and the lowest blossom end rot incidence (6.25%). However, the difference among 0.6% $CaCl_2$ + 0.2% borax, 0.3% $CaCl_2$ + 0.2% borax, and 0.6% $CaCl_2$ + 0.4% borax was non-significant.

Haque *et al*. (2011) conducted a field experiment to study the effects of nitrogen and boron on growth and yield of tomato. Four levels of each of Nitrogen (N_0=0, N_1=60, N_2=120 and N_3=180 kg N ha^{-1}) and 3 levels of Boron (B_0=0, B_1 = 0.4 and B_2= 0.6 kg B ha^{-1}) were considered as treatments. Application of B @ 0.6 kg ha^{-1} gave the highest values of the parameters (plant height, flower clusters $plant^{-1}$, flowers $cluster^{-1}$, fruits $cluster^{-1}$, fruits $plant^{-1}$, fruit weight $plant^{-1}$, fruit weight $plot^{-1}$ and fruit yield). N @ 120 kg ha^{-1} along with B @ 0.6 kg ha^{-1} produced the highest plant height (142.2 cm), flower clusters $plant^{-1}$ (12.67), flowers $cluster^{-1}$ (11.67), fruits $cluster^{-1}$ (6.33), fruits $plant^{-1}$ (67.33), fruit weight $plant^{-1}$ (1.953 kg), fruit weight $plot^{-1}$ (23.20 kg) and fruit yield (58.59 t ha^{-1}).

Salam *et al*. (2011) carried out an experiment 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*., BoZno. $B_{1.5}Zn_2$ 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 dry matter content (5.82%), lycopene content (147 ìg/100g), chlorophyll-a (42.0 μg/l00g), chlorophyll-b (61.0 μg/100g), boron content (36 μg/g), zinc content (51 μg /g) and marketable fruits at 30 days after storage (74%) were recorded with the combination of 2.5 kg B/ha + 6 kg Zn/ha, and 20 t/ha cowdung.

Salam *et al*. (2010) conducted a field research to investigate the effects of boron and zinc in presence of different levels of NPK fertilizers on quality of tomato.

There were twelve treatment combinations which comprised four levels of boron and zinc *viz*., i) B_0Zn_0= 0 kg B + 0 kg Zn/ha, ii) $B_{1.5}Zn_{2.0}$= 1.5 kg B + 2.0 kg Zn/ha, iii) $B_{2.0}Zn_{4.0}$ = 2.0 kg B + 4.0 kg Zn/ha , iv) $B_{2.5}Zn_{6.0}$, 2.5 kg B + 6.0 kg Zn/ha and three levels of NPK fertilizers *viz*., i) 50% less than the recommended NPK fertilizer dose (50% <RD), ii) Recommended NPK fertilizer dose (RD), iii) 50% more than the recommended NPK fertilizer dose (50% >RD). The highest pulp weight (88.14%), dry matter content (5.34%), TSS (4.50%), acidity (0.47%), ascorbic acid (10.95 mg/100g), lycopene content (112.00 μg/100g), chlorophyll-a (41.00μg/100g), chlorophyll-b (56.00 μg/100g) and marketable fruits at 30 days after storage (67.48%) were recorded with the combination of 2.5 kg B+ 6 kg Zn/ha and recommended dose of NPK fertilizers (N= 253, P= 90, and K= 125 kg/ha).

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. 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). Zinc, iron, copper, boron and manganese were applied at 1000 ppm each, whereas molybdenum was applied at 50 ppm. 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%), total fruit yield (266.60 kg/ha), dry matter yield of fruit (16.98 kg/ha), boron (206.58 g/ha) uptake by shoots and boron (95.23 g/ha) uptake by fruits.

Oyinlola (2004) conducted a field trial to identify the effects of 0, 1, 2, 3, 4, and 5 kg B/ha on the growth, dry matter yield and nutrient concentration of tomato cultivars Roma VF and Dandino. Application of boron significantly ($P<0.05$) increased the number of leaves and dry matter yield of the crop. Significant correlation existed between growth, yield parameters and nutrient concentrations and also among the nutrient concentrations. Plants supplied with 2 kg B/ha recorded the highest number of leaves and dry matter yield.

Oyinlola and Chude (2004) studied the effects of 0, 1, 2, 3, 4 and 5 kg B/ha on the yield and biochemical properties of tomato cultivars Roma VF and Dandino. Matured ripe fruits were analysed for biochemical properties such as ascorbic acid, reducing sugar and total soluble solid content and titratable acidity. Boron rates significantly increased the yield and yield attributes of the crop such as number of fruits and average weight of fruits, as well improved the biochemical properties of the fruits. The highest fruit yield and best fruit quality were obtained at 2 kg B/ha. Fruit yield increased by 96.5% compared to the control.

Smit and Combrink (2004) observed that insufficient fruit set of tomatoes owing to poor pollination in low cost greenhouses is a problem, 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 (*Solanum lycopersicum*) 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.

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

Davis *et al.* (2003) carried out an experiment to compare the effects of foliar and soil applied B on plant growth, fruit yield, fruit quality, and tissue nutrient levels. Boron application was associated with increased N uptake by tomato in field culture, but not under hydroponic culture. In field culture, foliar- and/or soil-applied B similarly increased fresh-market tomato plant and root dry weight, uptake, and tissue concentrations of N, Ca, K, and B, and improved fruit set, total yields, marketable yields, fruit shelf life, and fruit firmness. The similar growth and yield responses of tomato to foliar and root B application suggests that B is translocated in the phloem in tomatoes.

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

Chude *et al.* (2001) reported that plant response to soil and applied boron varies widely among species and among genotypes within a species. This assertion was verified by comparing the differential responses of Roma VF and Dandino tomato (*Lycopersicon lycopersicum*) cultivars to a range of boron levels in a field trials. Boron levels were 0, 0.5, 1.0, 1.50, 2.0 and 2.5 kg/ha. There was a highly significant (P=0.01) interaction between B rates and cultivars, with Dandino producing higher yields than Roma VF. Total soluble solids, titratable acidity and reducing sugar contents of the two cultivars differed significantly (P=0.05). Generally, Dandino contained higher amounts of these indexes than Roma VF. This cultivar seems to be more B efficient than Roma VF even at low external B level.

Yadav *et al.* (2001) conducted a 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.

Singaram and Prabha (1999) carried out an experiment to study the method of application of boron on tomato. They observed that the B concentration of the fruit was influenced by the treatments. The application of borax generally increased the dry weight of tomato shoots at both the flowering and harvest stages.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at the Agricultural farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from November 2017 to April 2018 to study the effect of different levels of potassium and boron on morpho-physiology and yield of tomato.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 Soil

The soil of the experimental area belongs to the Modhupur 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 II.

3.3 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 III.

3.4 Plant materials BARI Tomto-14

Seeds of BARI tomato-14 were collected from Bangladesh Agricultural Research Institute (BARI), Joydevpur, Gazipur. After multilocation trials BARI released this variety for general cultivation with a popular name BARI Tomato-14. This variety is tolerant to bacterial wilt. Fruit is large, round with attractive red flesh color. Average number of fruits per plant is 30-35, single fruit weight is 90-95 g and prolonged harvesting period is 40-60 days. Storage quality is high and crop life time is 110-120 days. Under proper management practices it may give 90-95 t ha^{-1} fruit yield.

3.5 Experimental details

3.5.1 Treatments

The experiment comprised of two factors.

Factor A: Potassium (K) application - three levels

1. K_0 = 0 kg ha^{-1} (Control)
2. K_1 = 60 kg ha^{-1}
3. K_2 = 100 kg ha^{-1}

Factor B: Boron (B) application - three levels

1. B_0 = 0 kg ha^{-1} (Control)
2. B_1 = 0.5 kg ha^{-1}
3. B_2 = 1.0 kg ha^{-1}

Treatment combinations – Nine (9) treatment combinations

K_0B_0, K_1B_0, K_2B_0, K_0B_1, K_1B_1, K_2B_1, K_0B_2, K_1B_2 and K_2B_2.

3.5.2 Experimental design and layout

The experiment was laid out in Randomized Complete Block Design (RCBD) with four replications. The layout of the experiment was prepared for distributing the combination of doses of potassium (K) and boron (B). The 9 treatment combinations of the experiment were assigned at random into 36 plots. The size of each unit plot was 1.6 m × 1.5 m (= 2.40 m^2). The distance between blocks and plots were 0.5 m and 0.50 m respectively. The layout of the experiment field is presented in Appendix IV.

3.6 Variety used and seed collection

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

3.6.2 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. Each seed bed size was 3m × 1m raised above the ground level maintaining a spacing of 50cm between the beds. Two seed beds were prepared for raising the seedlings. Ten (10) grams of seeds were sown in each seed bed on 5 November, 2017. 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.

3.7 Preparation of the main field

The plot selected for the experiment was opened in the last week of November, 2017 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 3 December 2017. The individual plots were made by making ridges (20 cm high) around each plot to restrict lateral runoff of irrigation water.

3.8 Fertilizers and manure application

The N, P, S and Zn fertilizer were applied according to Fertilizer Recommended Guide, BARC, 2015 through urea, Triple super phosphate (TSP), Gypsum and Zinc oxide, respectively. Potassium (K) and Boron (B) were applied through Muriate of Potash (MOP) and boric acid ,respectively as per treatment. One third (⅓) of whole amount of urea and ½ amount of MP, and whole amount of TSP, Gypsum, Zinc oxide and boric acid were applied at the time of final land preparation. The remaining urea was top dressed in two equal installments- at 25 days after transplanting (DAT) and 50 DAT, respectively. The remaining MOP was top dressed in two equal installment with urea at 25 and 50 DAT.

3.9 Transplanting and watering of seedlings

Healthy and uniform sized 30 days old seedlings were taken separately from the seed bed and were transplanted in the experimental field on 4 December 2017 maintaining a spacing of 50 cm × 40 cm. The seed bed was watered before uprooting the seedlings so as to minimize the damage of the roots. This operation was carried out during late hours in the evening. 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. Ground water was applied in the field until the establishment of seedlings.

3.10 Intercultural Operation

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

3.10.1 Gap filling and weeding

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

3.10.2 Irrigation

Irrigation was done three times. The first irrigation was given in the field at 20 days after transplanting (DAT) through irrigation channel. The second irrigation was given at the stage of maximum vegetative growth stage (35 DAT). The final irrigation was given as per requirement.

3.10.3 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.

3.11 Harvesting, threshing and cleaning

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 10 March 2018 and completed by 4 April 2018.

3.12 Data Collection and Recording

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

1. Plant height (cm)
2. Number of leaves plant^{-1}
3. SPAD value
4. Number of flower cluster plant^{-1}
5. Number of fruits cluster^{-1}
6. Fruit length (cm)
7. Fruit diameter (cm)
8. Number of fruits plant^{-1}
9. Fruit weight plant^{-1} (g)
10. Single fruit weight (g)
11. Fruit weight plot^{-1} (kg)
12. Fruit weight ha^{-1} (t)

3.13 Procedure of recording data

3.13.1 Plant height (cm)

The height of plant was recorded in centimeter (cm) at different days after sowing of crop duration. Data were recorded as the average of 5 plants selected at random from the inner rows of each plot. The height was measured from the ground level to the tip of the leaves.

3.13.2 Number of leaves plant^{-1}

Number of leaves plant^{-1} was counted at different days after sowing of crop duration. Leaves number plant^{-1} was recorded from pre selected 5 plants by counting all leaves from each plot and mean was calculated.

3.13.3 SPAD value

SPAD value was measured at 50 days after transplanting (DAT) with the help of SPAD meter.

3.13.4 Number of cluster plant^{-1}

The number of clusters was counted from the randomly selected 5 plants and the average number of clusters produced per plant was calculated.

3.13.5 Number of fruits cluster^{-1}

The number of fruits and clusters was recorded from the five sample plants, and the average number of fruits cluster^{-1} was recorded as number of fruits cluster^{-1}.

3.13.6 Fruit length (cm)

The length of fruit was measured with a slide calipers from the neck of the fruit to the bottom of 20 selected marketable fruits from each plot and their average was calculated in centimeter.

3.13.7 Fruit diameter (cm)

Diameter or fruit was measured at the middle portion of 20 selected marketable fruits from each plot with a slide calipers and their average was calculated in centimeter.

3.13.8 Number of fruits plant^{-1}

Total fruit number was counted from 5 selected plants and average value was calculated as number of fruits per plant.

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

Total fruit weight was counted from 5 selected plants and average value was calculated as fruit weight per plant and was expressed in gram.

3.13.10 Single fruit weight (g)

From first harvest to last harvest total fruit number and weight was counted from 5 plants to determine single fruit weight. The average value was recorded as single fruit weight and expressed in gram.

3.13.11 Fruit weight plot^{-1} (kg)

A pan scale balance was used to take the weight or fruits per plot. It was measured by totaling of fruit yield from each unit plot during the period from first to final harvest and was recorded in kilogram.

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

After collection of per plot yield, it was converted to ton per hectare by the following formula

$$\text{Fruit yield per hectare (ton)} = \frac{\text{Fruit yield per plot (kg)} \times 10000\ \text{m}^2}{\text{Plot size (m}^2) \times 1\,000\ \text{kg}}$$

3.14 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

Individual and interaction effects of K and B on different growth and morphology and yield and yield contributing parameters of tomato are shown in the Tables 1-5. The results presented in tables are discussed character wise under the following heads.

4.1 Growth and morphological parameters

4.1.1 Plant height (cm)

Effect of potassium (K)

Significant variation was not observed on plant height of tomato at 30 DAT but significant was found on plant height at 50 DAT and70 DAT,respectively on effect by K (Fig. 1 and Appendix V). Results revealed that the highest plant height at 30 DAT (19.51 cm) was found from the treatment K_2 (100 kg K ha^{-1}) where the lowest plant height at 30 DAT (16.66 cm) was observed from the control treatment K_0 (0 kg K ha^{-1}) similarly the highest plant height at 50 DAT (33.51 cm) was achieved from the treatment K_2 (100 kg K ha^{-1}) where the lowest plant height at 50 DAT (32.98 cm) was found from the control treatment K_0 (0 kg K ha^{-1}). Again, at 70 DAT, the highest plant height (52.15 cm) was obtained from the treatment of K_2 (100 kg K ha^{-1}) where the lowest plant height (50.23 cm a) was obtained from the Control treatment K_0 (0 kg K ha^{-1}) which was statistically identical with the treatment K_1 (60 kg K ha^{-1}). So, in brief, it was observed that the highest plant height (19.51 cm,33.51cm, 52.15 cm at 30,50 and 70 DAT and at harvest, respectively) was obtained from the treatment of K_2 (100 kg K ha^{-1}) whereas the lowest plant height (16.66 cm,32.98cm, 50.23 cm at 30,50 and 70 DAT respectively) was obtained from the control treatment K_0 (0 kg K ha^{-1}). Abd El-Hamied and Abd El-Hady (2018) also observed foliar application of K contributed to increase plant height which supported the present study.

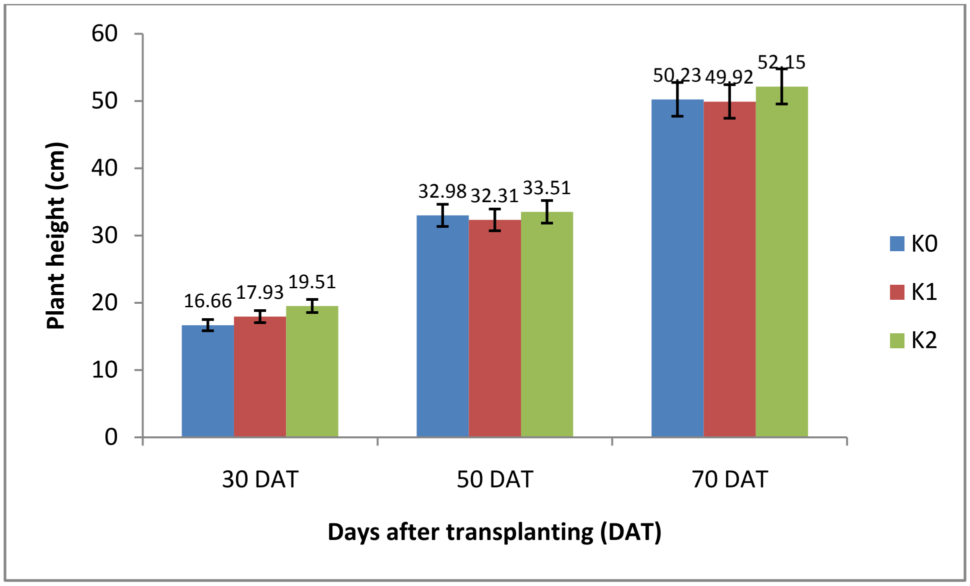

Fig. 1. Plant height of tomato as affected by different doses of potassium(K)

K_0 = Control (0 kg K ha^{-1}), K_1 = 60 kg K ha^{-1}, K_2 = 100 kg K ha^{-1}

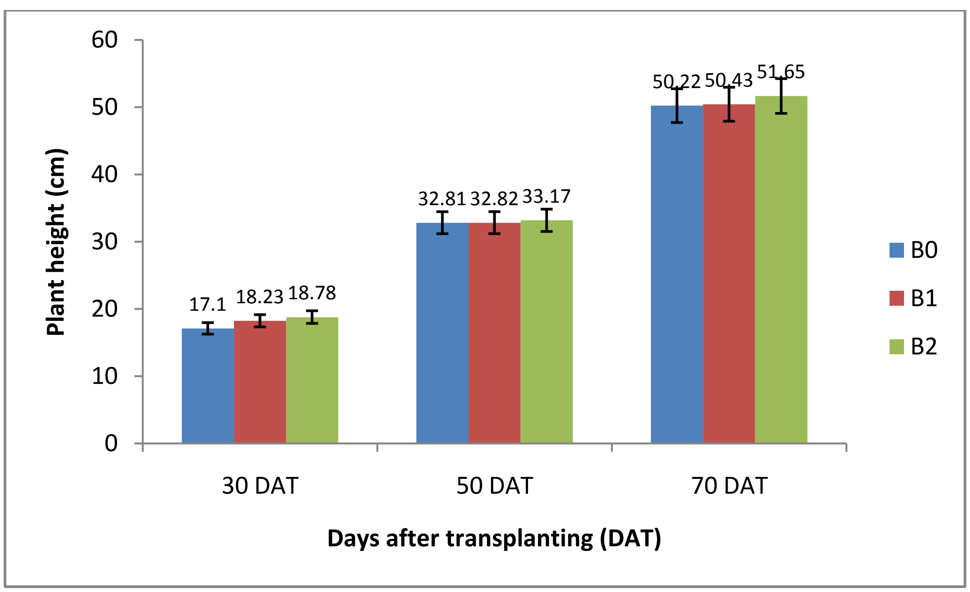

Fig. 2. Plant height of tomato as affected by different doses of boron(B)

B_0 = Control (0 kg B ha^{-1}), B_1 = 0.5 kg B ha^{-1}, B_2 = 1.0 kg B ha^{-1}

Effect of boron (B)

There was no significant variation on plant height of tomato influenced by different levels of B application at different growth stages (Fig. 2 and Appendix V). But the highest plant height (18.78, 33.17 and 51.65 cm at 30, 50 and 70 DAT, respectively) was achieved from the treatment of B_2 (1.0 kg B ha^{-1}) where the lowest plant height (17.10, 32.81 and 50.22 cm at 30, 50 and 70 DAT, respectively) was achieved from the control treatment B_0 (0 kg B ha^{-1}). Rab and Haq (2012) also found similar result with the present study. They also found non-significant relation on plant height with B application.

Combination effect of K and B

Plant height of tomato was significantly varied due to interaction effect ofK and B at different growth stages (Table 1 and Appendix V). Results indicated that the highest plant height at 30 DAT (21.32 cm) was obtained from the treatment combination of K_2B_2 where the lowest plant height at 30 DAT (15.17 cm) was found from the treatment combination of K_0B_0. Similar trend was also found at 50 and 70 DAT. At 50 and 70 DAT, the highest plant height (35.22 and 54.60 cm, respectively) was found from the treatment combination of K_2B_2 where the lowest plant height (30.58 and 49.05 cm at 50 70 DAT, respectively) was found from the treatment combination of K_0B_0. In a nut shell, it was stated that the highest plant height (21.32, 35.22 and 54.60 cm at 30, 50, and 70 DAT, respectively) was found from the treatment combination of K_2B_2 where the lowest plant height (15.17, 30.58 and 49.05 cm at 30, 50 and 70 DAT, respectively) was found from the treatment combination of K_0B_0

Table 1. Combination effect of potassium (K) and boron (B) on plant height of tomato at different growth stages

Treatments	Plant height (cm)		
	30 DAT	50 DAT	70 DAT
K_0B_0	15.17 f	30.58 g	49.05 d
K_1B_0	19.88 b	33.34 cd	51.35 b
K_2B_0	18.20 cd	33.56 c	50.90 b
K_0B_1	17.72 de	32.16 ef	50.70 bc
K_1B_1	16.85 e	31.57 f	49.22 d
K_2B_1	18.74 c	32.78 de	49.65 cd
K_0B_2	17.10 e	34.56 b	50.95 b
K_1B_2	17.33 de	32.64 e	50.50 bc
K_2B_2	21.32 a	35.22 a	54.60 a
$LSD_{0.05}$	0.90	0.65	1.10
Level of significance	*	*	*
CV (%)	8.76	6.25	8.71

B_0 = Control (0 kg B ha^{-1}), B_1 = 0.5 kg B ha^{-1}, B_2 = 1.0 kg B ha^{-1}

K_0 = Control (0 kg K ha^{-1}), K_1 = 60 kg K ha^{-1}, K_2 = 100 kg K ha^{-1}

* Significant at 5% level

4.1.2 Number of leaves plant^{-1}

Effect of potassium (K)

Significant variation was not found on number of leaves plant^{-1} at 30 DAT affected by different levels of K application.On the other hand variation was found at 50 DAT and 70 DAT (Fig. 3 and Appendix VI). At 30 DAT, the highest number of leaves plant^{-1} (9.07) was achieved from the treatment of K_2 (100 kg K ha^{-1}) which was statistically identical with K_1 (60 kg K ha^{-1}) where the lowest number of leaves plant^{-1} (7.60) was achieved from the Control treatment K_0 (0 kg K ha^{-1}). Similarly, at 50 DAT the highest number of leaves plant^{-1} (12.00) was achieved from the treatment of K_2 (100 kg K ha^{-1}) which was also statistically identical with K_1 (60 kg K ha^{-1}) where the lowest number of leaves plant^{-1} (9.77) was achieved from the control treatment K_0 (0 kg K ha^{-1}). At 70 DAT, the highest number of leaves plant^{-1} (14.32) was achieved from the treatment of K_2 (100 kg K ha^{-1}) where the lowest number of leaves plant^{-1} (12.58) was achieved from the control treatment K_0 (0 kg K ha^{-1}). So, it can be said that in brief, the highest number of leaves plant^{-1} (9.07, 12.00 and 14.32 at 30, 50 and 70 DAT, respectively) was achieved from the treatment of K_2 (100 kg K ha^{-1}) and the lowest number of leaves plant^{-1} (7.60, 9.77 and 12.58 at 30, 50 and 70 DAT, respectively) was achieved from the Control treatment K_0 (0 kg K ha^{-1}). Samra *et al*. (2017), Subba *et al*. (2017) and Atanda and Olaniyi (2016) also found similar results.

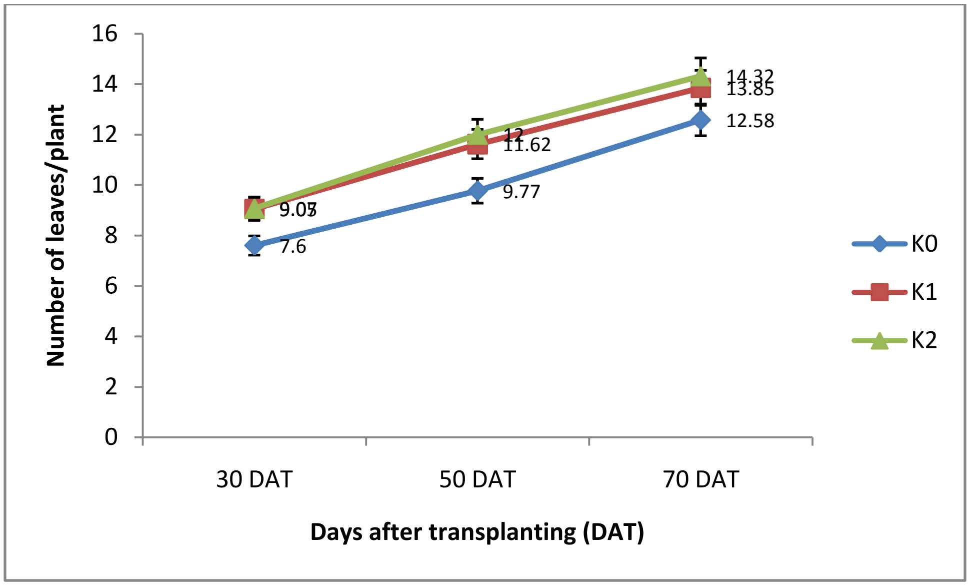

Fig. 3. Number of leaves plant^{-1} of tomato as affected by different doses of K

K_0 = Control (0 kg K ha^{-1}), K_1 = 60 kg K ha^{-1}, K_2 = 100 kg K ha^{-1}

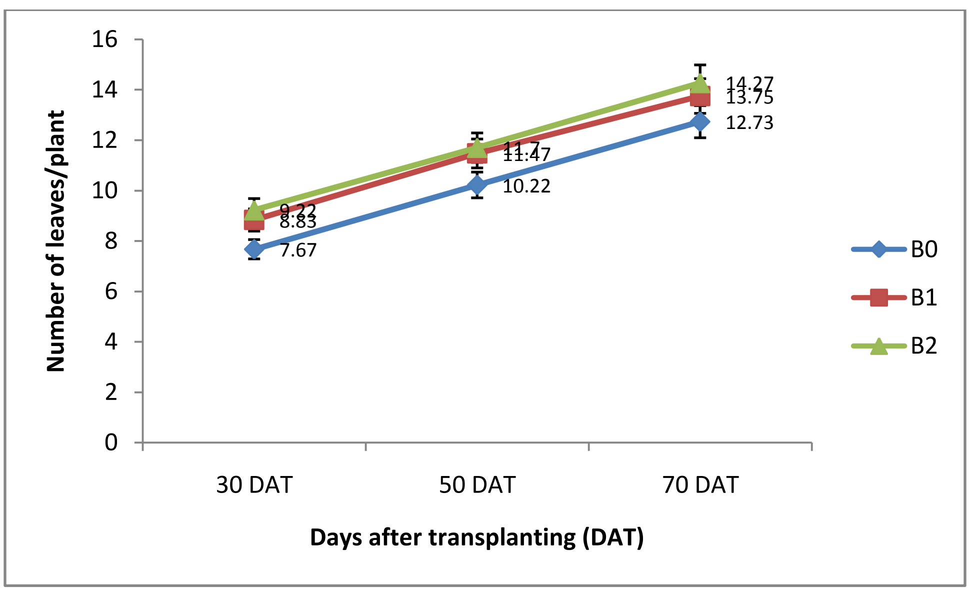

Fig. 4. Number of leaves plant^{-1} of tomato as effected by different doses of boron (B)

B_0 = Control (0 kg B ha^{-1}), B_1 = 0.5 kg B ha^{-1}, B_2 = 1.0 kg B ha^{-1}

Effect of boron (B)

Significant variation was not observed on number of leaves plant^{-1} as affected by different levels of B application at different growth stages (Fig. 4 and Appendix VI). But at 30 DAT, the highest number of leaves plant^{-1} (9.22) was obtained from the treatment of B_2 (1.0 kg B ha^{-1}) where the lowest number of leaves plant^{-1} (7.67) was observed from the control treatment B_0 (0 kg Bha^{-1}). Similarly, at 50 DAT, the highest number of leaves plant^{-1} (11.70) was recorded from the treatment of B_2 (1.0 kg B ha^{-1}) which was identical with B_1 (0.5 kg B ha^{-1}) where the lowest number of leaves plant^{-1} (10.22) was founded from the control treatment B_0 (0 kg Bha^{-1}). At 70 DAT, treatment B_2 (1.0 kg B ha^{-1}) also gave the highest number of leaves plant^{-1} (14.27) followed by B_1 (0.5 kg B ha^{-1}) where the lowest number of leaves plant^{-1} (12.73) was also found from the control treatment B_0 (0 kg Bha^{-1}). As a result, in brief, the highest number of leaves plant^{-1} (9.22, 11.70 and 14.27 at 30, 50 and 70 DAT, respectively) was recorded from the treatment of B_2 (1.0 kg B ha^{-1}) and the lowest number of leaves plant^{-1} (7.67, 10.22 and 12.73 at 30, 50 and 70 DAT, respectively) was achieved from the control treatment B_0 (0 kg Bha^{-1}). Oyinlola (2004) also found application of boron significantly increased the number of leaves of the crop which supported the present findings of the study.

Combination effect of K and B

Number of leaves plant^{-1} was not varied significantly at different growth stages at 30 DAT but variation was found 50 and 70 DAT due to interaction effect between K and B application (Table 2 and Appendix VI). Results showed that the highest number of leaves plant^{-1} (10.10) at 30 DAT was obtained from the treatment combination of K_2B_2 followed by K_1 B_2. The lowest number of leaves plant^{-1} (7.25) at 30 DAT was recorded from the treatment combination of K_0B_0 which was statistically similar with K_2B_0, K_0B_1 and K_0B_2. At 50 DAT, the highest number of leaves plant^{-1} (13.10) was achieved from the treatment combination of K_2B_2 which was statistically similar with K_1B_2. The lowest number of leaves plant^{-1} (9.45) at 50 DAT was achieved from the treatment combination of K_0B_0 which was closely followed by K_0B_1 and K_0B_2. The highest number of leaves plant^{-1} (15.35) at 70 DAT was achieved from the treatment combination of K_2B_2 which was statistically similar with K_1B_2. The lowest number of leaves plant^{-1} (12.05) at 70 DAT was found from the treatment combination of K_0B_0 which was statistically similar with K_0B_1. It was also summarized that the highest number of leaves plant^{-1} (10.10, 13.10 and 15.35 at 30, 50 and 70 DAT, respectively) was achieved from the treatment combination of K_2B_2 and the lowest number of leaves plant^{-1} (7.25, 9.45 and 12.05 at 30, 50 and 70 DAT, respectively) was achieved from the treatment combination of K_0B_0.

Table 2.Combination effect of potassium (K) and boron (B) on number of leaves plant^{-1}of tomato

Treatments	Number of leaves plant^{-1}		
	30 DAT	50 DAT	70 DAT
K_0B_0	7.25	9.45 f	12.05 f
K_1B_0	8.15	10.50 de	12.95 de
K_2B_0	7.60	10.70 d	12.95 de
K_0B_1	7.75	9.90 f	12.30 ef
K_1B_1	9.30	12.40 b	14.65 b
K_2B_1	9.45	11.40 c	13.85 c
K_0B_2	7.80	9.95 ef	13.40 cd
K_1B_2	9.75	12.75 ab	14.75 ab
K_2B_2	10.1	13.10 a	15.35 a
$LSD_{0.05}$	0.54	0.56	0.65
Level of significance	NS	*	*
CV (%)	8.22	7.19	10.02

B_0 = Control (0 kg B ha^{-1}), B_1 = 0.5 kg B ha^{-1}, B_2 = 1.0 kg B ha^{-1}

K_0 = Control (0 kg K ha^{-1}), K_1 = 60 kg K ha^{-1}, K_2 = 100 kg K ha^{-1}

4.1.3 SPAD value

Effect of potassium (K)

SPAD value at 50 DAT was significantly varied due to different levels of K application (Fig. 5 and Appendix VII). However, the highest SPAD value (54.67) was recorded from the treatment of K_2 (100 kgK ha^{-1}) and the lowest SPAD value (51.42) was obtained from the control treatment K_0 (0 kg K ha^{-1}). Abd-El-Hamied and Abd El-Hady (2018) also found similar result with the present study.

Effect of boron (B)

Significant variation was observed on SPAD value at different levels of B application (Fig. 6 and Appendix VII). But results showed that the highest SPAD value (53.26) was achieved from the treatment of B_2 (1.0 kg B ha^{-1}) and the lowest SPAD value (52.57) was achieved from the control treatment B_0 (0 kg B ha^{-1}). Salam *et al*. (2011) and Yadav *et al.* (2001) also found similar results which supported the present finding.

Combination effect of K and B

Significan variation was not observed on SPAD value due to different levels of K and B application (Table 3 and Appendix VII). However, results indicated that the highest SPAD value (55.22) was achieved from the treatment combination of K_2B_2 and the lowest SPAD value (50.67) was achieved from the treatment combination of K_0B_0.

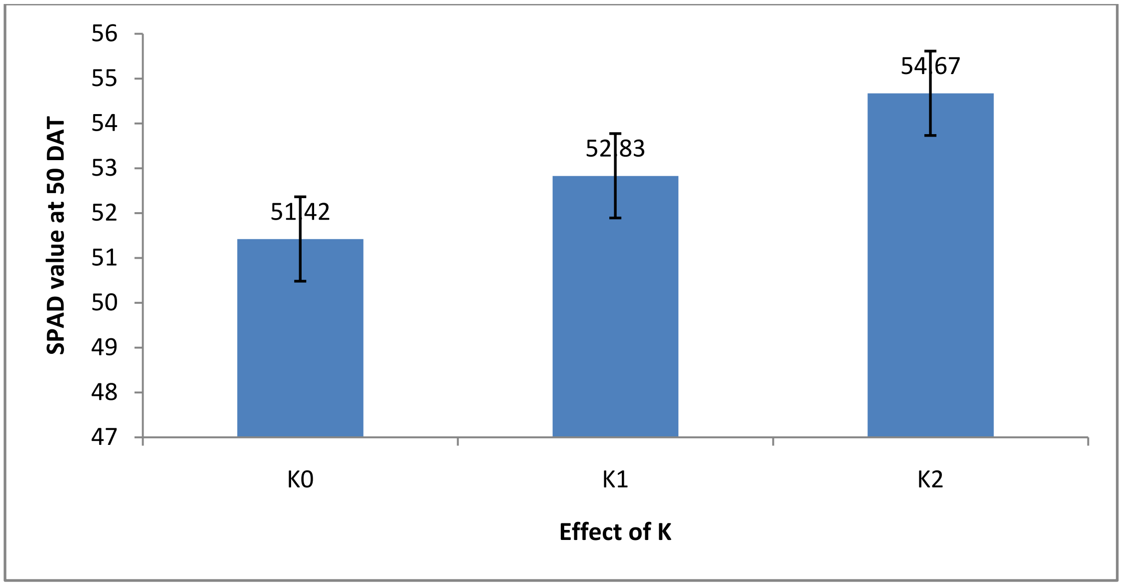

Fig. 5. SPAD value of tomato leaves as affected by different doses potassium (K)

K_0 = Control (0 kg K ha^{-1}), K_1 = 60 kg K ha^{-1}, K_2 = 100 kg K ha^{-1}

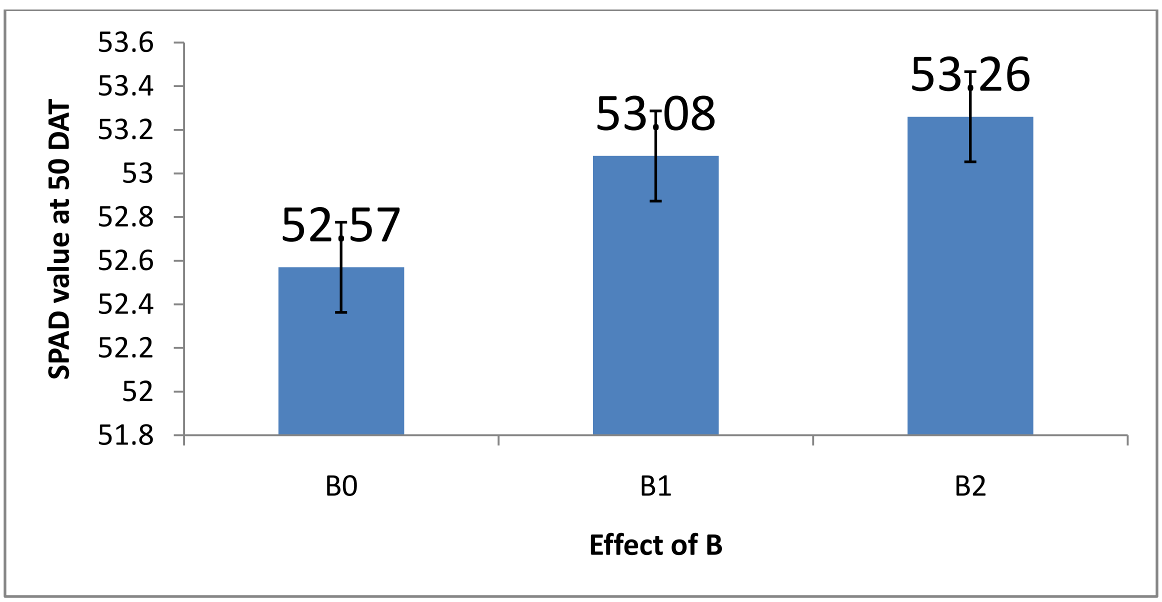

Fig. 6. SPAD value of tomato leaves as affected by different doses of boron (B)

B_0 = Control (0 kg B ha^{-1}), B_1 = 0.5 kg B ha^{-1}, B_2 = 1.0 kg B ha^{-1}

Table 3. Combination effect of potassium (K) and boron (B) on SPAD value of tomato leaves

Treatment	SPAD value at 50 DAT
K_0B_0	50.69
K_1B_0	54.63
K_2B_0	53.96
K_0B_1	51.21
K_1B_1	51.79
K_2B_1	54.82
K_0B_2	52.36
K_1B_2	52.06
K_2B_2	55.22
$LSD_{0.05}$	0.58
Level of significance	*
CV (%)	10.02

B_0 = Control (0 kg B ha^{-1}), B_1 = 0.5 kg B ha^{-1}, B_2 = 1.0 kg B ha^{-1}

K_0 = Control (0 kg K ha^{-1}), K_1 = 60 kg K ha^{-1}, K_2 = 100 kg K ha^{-1}

4.2 Yield contributing parameters

4.2.1 Number of flower cluster plant^{-1}

Effect of potassium (K)

Application of K had significant effect on number of flower clusters plant^{-1} influenced by different levels of K application (Table 4 and Appendix VIII). The highest number of flower cluster plant^{-1} (4.42) was recorded from the treatment of K_2 (100 kg K ha^{-1}) followed by K_1 (60 kg K ha^{-1}) and the lowest number of flower cluster plant^{-1} (3.75) was obtained from the control treatment K_0 (0 kg K ha^{-1}). Similar result was also observed by Javaria *et al*. (2012).

Effect of boron (B)

Number of flower clusters plant^{-1} was significantly affected by different levels of B application (Table 4 and Appendix VIII). The highest number of flower clusters plant^{-1} (4.30) was recorded from the treatment B_2 (1.0 kg B ha^{-1}) which was identical with B_1 (0.5 kg B ha^{-1}) where the lowest number of flower cluster plant^{-1} (3.80) was achieved from the control treatment B_0 (0 kg Bha^{-1}). Similar result was also observed by Ali *et al*. (2015) and found that number of flower clusters plant^{-1} increased significantly with B application which supported the present study.

Combination effect of K and B

Number of flower clusters plant^{-1} was significantly influenced by interaction effect of K and B application (Table 4 and Appendix VIII). The highest number of flower cluster plant^{-1} (4.65) was recorded from the treatment combination of K_2B_2 which was immediate higher than the treatment combination of K_2B_1(4.45). The lowest number of flower cluster plant^{-1} (3.20) was recorded from the treatment combination of K_0B.

4.2.2 Number of fruits cluster^{-1}

Effect of potassium (K)

Considerable influence was found on number of fruits cluster^{-1} persuaded by different levels of K application (Table 4 and Appendix VIII). The highest number of fruits cluster^{-1} (6.64) was obtained from the treatment of K_2 (100 kg K ha^{-1}) and the lowest number of fruits cluster^{-1} (6.26) was obtained from the control treatment K_0 (0 kg K ha^{-1}). Similar results was also observed by Javaria *et al*. (2012).

Effect of boron (B)

Number of fruits cluster^{-1} was significant with the application of different levels of B (Table 4 and Appendix VIII). The highest number of fruits cluster^{-1} (6.75) was obtained from the treatment of B_2 (1.0 kg B ha^{-1}) and the lowest number of fruits cluster^{-1} (6.20) was obtained from the Control treatment B_0 (0 kg Bha^{-1}). Similar result was also observed by Rab and Haq (2012) and Haque *et al*. (2011) which supported the present study.

Combination effect of K and B

Remarkable variation was founded on number of fruits cluster^{-1} due to the interaction effect of K and B application (Table 4 and Appendix VIII). The highest number of fruits cluster^{-1} (6.85) was obtained from the treatment combination of K_2B_2 which was statistically similar with the treatment combination of K_0B_2. The lowest number of fruits cluster^{-1} (5.67) was obtained from the treatment combination of K_0B_0 which was significantly different from treatment combinations ofK_2B_0, K_0B_1 and K_1B_2.

4.2.3 Fruit length (cm)

Effect of potassium (K)

Non-significant variation was found on fruit length as influenced by different levels of K application (Table 4 and Appendix VIII). However the highest fruit length (5.49 cm) was achieved from the treatment of K_2 (100 kg K ha^{-1}) and the lowest fruit length (5.22 cm) was achieved from the control treatment K_0 (0 kg K ha^{-1}). Ananthi *et al*. (2004) and Fouzia *et al*. (2016) also found similar result as found inthe present study.

Effect of boron (B)

Significant variation was not observed on fruit length affected by different levels of B application (Table 4 and Appendix VIII). However, the highest fruit length (5.44 cm) was obtained from the treatment of B_2 (1.0 kg B ha^{-1}) and the lowest fruit length (5.24 cm) was obtained from the control treatment B_0 (0 kg Bha^{-1}). The result obtained from the present study was similar with the findings of Ali *et al*. (2015) and Yadav *et al.* (2001).

Combination effect of K and B

Significant variation on fruit length was not observed by interaction effect of K and B application (Table 4 and Appendix VIII). However, the highest fruit length (5.60 cm) was obtained from the treatment combination of K_2B_2 and the lowest fruit length (5.06 cm) was obtained from the treatment combination of K_0B_0 .

4.2.4 Fruit diameter (cm)

Effect of potassium (K)

Significant variation was observed on fruit diameter influenced by different levels of K application (Table 4 and Appendix VIII). The highest fruit diameter (6.21 cm) was obtained from the treatment K_2 (100 kg K ha^{-1}) and the lowest fruit diameter (5.84 cm) was achieved from the Control treatment K_0 (0 kg K ha^{-1}) which was identical with K_1 (60 kg K ha^{-1}). Abd-El-Hamied and Abd El-Hady (2018), Zhu *et al*. (2016) and Afzal *et al*. (2015) also found similar result.

Effect of boron (B)

Significant variation was observed on fruit diameter at different growth stages influenced by different levels of B application (Table 4 and Appendix VIII). Among the three B treatment, B_2 (1.0 kg B ha^{-1}) showed the highest fruit diameter (6.12cm) followed by B_1 (0.5 kg B ha^{-1}) and the lowest fruit diameter (5.84 cm) was obtained from the control treatment B_0 (0 kg B ha^{-1}). Similar result was also observed by Ali *et al*. (2015).

Combination effect of K and B

Significant variation was observed on fruit diameter influenced by interaction effect of K and B application (Table 4 and Appendix VIII). The highest fruit diameter (6.37 cm) was recorded from the treatment combination of K_2B_2 which was statistically identical with the treatment combination of K_2B_1. The lowest fruit diameter (5.67 cm) was obtained from the treatment combination K_0B_0 which was statistically similar with the treatment combinations K_0B_1 and K_1B_1.

4.2.5 Number of fruits plant^{-1}

Effect of potassium (K)

Considerable influence was observed on number of fruits plant^{-1} persuaded by different levels of K application (Table 4 and Appendix VIII). The highest number of fruits plant^{-1} (27.65) was recorded from the treatment of K_2 (100 kgK ha^{-1}) which was statistically identical with K_1 (60 kg K ha^{-1}) and the lowest number of fruits plant^{-1} (22.88) was obtained from the control treatment K_0 (0 kg K ha^{-1}). Similar results was also observed by Kumar *et al*. (2013) and Javaria *et al*. (2012).

Effect of boron (B)

Number of fruits plant^{-1} was found significant with the application of different levels of B (Table 4 and Appendix VIII). The highest number of fruits plant^{-1} (27.70) was achieved from the treatment of B_2 (1.0 kg B ha^{-1}) which was statistically similar with B_1 (0.5 kg B ha^{-1}) and the lowest number of fruits plant^{-1} (23.23) was obtained from the control treatment B_0 (0 kg Bha^{-1}). The results obtained from the present study was similar with the findings of Rab and Haq (2012) and Haque *et al*. (2011).

Combination effect of K and B

Significant variation was found on number of fruits plant^{-1} due to the interaction effect of K and B application (Table 4 and Appendix VIII). The highest number of fruits plant^{-1} (29.10) was recorded from the treatment combination of K_2B_2 which was statistically similar with the treatment combination of K_2B_1. The lowest number of fruits plant^{-1} (18.15) was obtained from the treatment combination of K_0B_0 which was significantly different from all other treatment combinations followed by K_2B_0 and K_0B_1.

Table 4. Effect of potassium (K) and boron (B) on yield contributing parameters of tomato

Treatments	**Yield contributing parameters**				
	Number of flower cluster plant^{-1}	Number of fruits cluster^{-1}	Fruit length (cm)	Fruit diameter (cm)	Number of fruits plant^{-1}
Effect of potassium (K)					
K_0	3.75 c	6.26	5.22	5.84 b	22.88 b
K_1	4.20 b	6.44	5.37	5.89 b	27.40 a
K_2	4.42 a	6.64	5.49	6.21 a	27.65 a
$LSD_{0.05}$	0.17	0.15	0.13	0.13	0.45
Level of significance	*	*	NS	*	*
CV (%)	7.11	6.29	4.06	6.27	9.12
Effect of boron (B)					
B_0	3.80 b	6.20	5.27	5.84 c	23.23 b
B_1	4.27 a	6.38	5.41	5.98 b	27.00 a
B_2	4.30 a	6.75	5.44	6.12 a	27.70 a
$LSD_{0.05}$	0.17	0.29	0.14	0.10	1.09
Level of significance	*	*	NS	*	*
CV (%)	7.11	6.29	4.06	6.27	9.12
Interaction effect between K and B					
K_0B_0	3.20 e	5.67 e	5.06	5.67 d	18.15 f
K_1B_0	4.05 d	6.60 bc	5.32	5.91 bc	26.50 d
K_2B_0	4.15 cd	6.32 d	5.33	6.05 b	25.05 e
K_0B_1	4.00 d	6.36 d	5.27	5.80 cd	24.50 e
K_1B_1	4.25 c	6.47 cd	5.35	5.81 cd	27.40 c
K_2B_1	4.45 b	6.67 b	5.55	6.22 a	28.80 ab
K_0B_2	4.05 d	6.74 ab	5.32	6.05 b	26.00 d
K_1B_2	4.30 bc	6.32 d	5.44	5.95 bc	28.30 b
K_2B_2	4.65 a	6.85 a	5.60	6.37 a	29.10 a
$LSD_{0.05}$	0.17	0.16	0.15	0.15	0.75
Level of significance	*	*	NS	*	*
CV (%)	7.11	6.29	4.06	6.27	9.12

B_0 = Control (0 kg B ha^{-1}), B_1 = 0.5 kg B ha^{-1}, B_2 = 1.0 kg B ha^{-1}

K_0 = Control (0 kg K ha^{-1}), K_1 = 60 kg K ha^{-1}, K_2 = 100 kg K ha^{-1}

4.3 Yield parameters

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

Effect of potassium (K)

Significant variation was observed on fruit weight plant^{-1} influenced by different levels of K application (Table 5 and Appendix IX). The highest fruit weight plant^{-1} (1691.00 g) was recorded from the treatment K_2 (100 kg K ha^{-1}) which was significantly different from other treatments where the lowest fruit weight plant^{-1} (1280.00 g) was obtained from the control treatment K_0 (0 kg K ha^{-1}). Abd-El-Hamied and Abd El-Hady (2018) and Afzal *et al*. (2015) also found similar result.

Effect of boron (B)

Application of boron had significant effect on fruit weight plant^{-1} (Table 5 and Appendix IX). The highest fruit weight plant^{-1} (1624.00 g) was obtained from the treatment B_2 (1.0 kg B ha^{-1}) which was statistically identical with B_1 (0.5 kg B ha^{-1}) and the lowest fruit weight plant^{-1} (1346.00 g) was obtained from the control treatment B_0 (0 kg Bha^{-1}). Harris and Lavanya (2016) observed that the application of B increased the fresh weight of fruits (H_3BO_3 - 350 ppm) which supported the present study. Similar result was also observed by Haque *et al*. (2011).

Combination effect of K and B

Fruit weight plant^{-1} was significantly influenced by interaction effect of K and B application (Table 5 and Appendix IX). The highest fruit weight plant^{-1} (1807.00 g) was obtained from the treatment combination of K_2B_2 which was significantly different from all other treatment combinations followed by the treatment combination of K_2B_1. The lowest fruit weight plant^{-1} (1057.00 g) was obtained from the treatment combination of K_0B_0 which was also significantly different from all other treatment combinations .

4.3.2 Single fruit weight (g)

Effect of potassium (K)

Considerable influence was observed on single fruit weight persuaded by different levels of K application (Table 5 and Appendix IX). Among the three K treatments, the highest single fruit weight (61.70 g) was obtained from the treatment of K_2 (100 kg K ha^{-1}) and the lowest single fruit weight (58.25 g) was obtained from the control treatment K_0 (0 kg K ha^{-1}). Similar result on single fruit weight was also observed by Abd-El-Hamied and Abd El-Hady (2018) and Afzal *et al*. (2015).

Effect of boron (B)

The recorded data on single fruit weight was found significant with the application of different levels of B (Table 5 and Appendix IX). Among the three B treatments, the highest single fruit weight (61.19 g) was obtained from the treatment of B_2 (1.0 kg B ha^{-1}) and the lowest single fruit weight (58.46 g) was obtained from the control treatment B_0 (0 kg Bha^{-1}). Harris and Lavanya (2016) and Haque *et al*. (2011) also found similar with the present study.

Combination effect of K and B

Significant variation was found on single fruit weight due to the interaction effect of K and B application (Table 5 and Appendix IX). The highest single fruit weight (62.91 g) was obtained from the treatment combination of K_2B_2 which was statistically similar with the treatment combination of K_2B_1 and K_1B_2 and statistically similar with K_1B_1. The lowest single fruit weight (55.44 g) was recorded from the treatment combination of K_0B_0 which was statistically similar with the treatment combination of K_0B_1.

4.3.3 Fruit weight plot^{-1} (kg)

Effect of potassium (K)

Fruit weight plot^{-1} was significally influenced by different levels of K application (Table 5 and Appendix IX). The highest fruit weight plot^{-1} (15.22 kg) was recorded from the treatment K_2 (100 kgK ha^{-1}) which was identical with the treatment K_1 (60 kg K ha^{-1}) and the lowest fruit weight plot^{-1} (11.52 kg) was obtained from the control treatment K_0 (0 kg K ha^{-1}).

Effect of boron (B)

Boron application had significant effect on fruit weight plot^{-1} (Table 5 and Appendix IX). The highest fruit weight plot^{-1} (14.61 kg) was achieved from the treatment of B_2 (1.0 kg B ha^{-1}) which was identical with the treatment B_1 (0.5 kg B ha^{-1}). The lowest fruit weight plot^{-1} (12.11 kg) was obtained from the control treatment B_0 (0 kg Bha^{-1}). Haque *et al*. (2011) and Yadav *et al.* (2006) also observed similar result.

Combination effect of K and B

Fruit weight plot^{-1} was significally influenced by interaction effect of K and B application (Table 5 and Appendix IX). The highest fruit weight plot^{-1} (16.26 kg) was obtained from the treatment combination of K_2B_2 which was identical with the treatment combination of K_2B_1. The lowest fruit weight plot^{-1} (9.51 kg) was obtained from the treatment combination of K_0B_0 which was significantly different from all other treatment combinations.

4.3.4 Fruit Yield ha^{-1} (t)

Effect of potassium (K)

Significant variation was found on fruit yield t ha^{-1} due to the effect of different levels of K application (Table 5 and Appendix IX). The highest fruit yield (63.43 t ha^{-1}) was obtained from the treatment K_2 (100 kg K ha^{-1}) which was significantly different from K_1 (60 kg K ha^{-1}) and control treatment K_0 (0 kg K ha^{-1}). The lowest fruit yield (48.00 t ha^{-1}) was obtained from the control treatment K_0 (0 kg K ha^{-1}). The results obtained from the present study was similar with the findings of Abd-El-Hamied and Abd El-Hady (2018), Zhu *et al*. (2016) and Afzal *et al*. (2015).

Effect of boron (B)

Significant variation was observed on fruit yield t ha^{-1} at different growth stages due to the effect of different levels of B application (Table 5 and Appendix IX). The highest fruit yield t ha^{-1} (60.58 t) was achieved from the treatment of B_2 (1.0 kg B ha^{-1}) which was statistically identical with the treatment B_1 (0.5 kg B ha^{-1}) and the lowest fruit yield t ha^{-1} (50.46 t) was achieved from the control treatment B_0 (0 kg B ha^{-1}). The results obtained from the present study was in conformity with the findings of Harris and Lavanya (2016), Haque *et al*. (2011) and Yadav *et al.* (2006).

Combination effect of K and B

Fruit yield t ha^{-1} was significally influenced by interaction effect of K and B application (Table 5 and Appendix IX). The highest fruit yield t ha^{-1} (67.78 t) was found from the treatment combination of K_2B_2 which was statistically similar with the treatment combination of K_2B_1. The lowest fruit yield t ha^{-1} (39.62 t) was found from the treatment combination of K_0B_0 which was significantly different from all other treatment combinations. This results are consistant with morphological and yield contributing characters of this study

Table 5. Combined effect of potassium (K) and boron (B) on yield attributes and yield of tomato

Treatments	Yield parameters			
	Fruit weight plant^{-1} (g)	Single fruit weight (g)	Fruit weight plot^{-1} (kg)	Fruit yield ha^{-1} (t)
Effect of potassium (K)				
K_0	1280.00 c	58.25 c	11.52 b	48.00 c
K_1	1620.00 b	59.92 b	14.58 a	60.75 b
K_2	1691.00 a	61.70 a	15.22 a	63.43 a
$LSD_{0.05}$	3.46	0.45	1.08	0.57
Level of significance	*	*	*	*
CV (%)	10.77	8.14	11.76	13.77
Effect of boron (B)				
B_0	1346.00 b	58.46 c	12.11 b	50.46 b
B_1	1622.00 a	60.22 b	14.60 a	60.54 a
B_2	1624.00 a	61.19 a	14.61 a	60.58 a
$LSD_{0.05}$	3.39	0.58	1.08	1.48
Level of significance	*	*	*	*
CV (%)	10.77	8.14	11.76	13.77
Interaction effect between K and B				
K_0B_0	1057.00 h	55.44 d	9.507 f	39.62 f
K_1B_0	1475.00 f	59.79 b	13.27 d	55.30 d
K_2B_0	1506.00 e	60.14 b	13.55 d	56.46 d
K_0B_1	1391.00 g	57.04 cd	12.52 e	52.15 e
K_1B_1	1669.00 d	61.42 ab	15.02 c	62.59 c
K_2B_1	1761.00 b	62.19 a	15.85 ab	66.04 ab
K_0B_2	1393.00 g	57.91 c	12.54 e	52.24 e
K_1B_2	1717.00 c	62.75 a	15.45 bc	64.37 bc
K_2B_2	1807.00 a	62.91 a	16.26 a	67.78 a
$LSD_{0.05}$	5.62	1.66	0.53	2.10
Level of significance	*	*	*	*
CV (%)	10.77	8.14	11.76	13.77

B_0 = Control (0 kg B ha^{-1}), B_1 = 0.5 kg B ha^{-1}, B_2 = 1.0 kg B ha^{-1}

K_0 = Control (0 kg K ha^{-1}), K_1 = 60 kg K ha^{-1}, K_2 = 100 kg K ha^{-1}

Plot area: 2.40 m^2

CHAPTER V

SUMMARY AND CONCLUSION

A field experiment was conducted at the Agricultural Farm of Sher-e-Bangla Agricultural University, Dhaka, during November 2017 to April 2018 to study the effect of different levels of potassium and boron on morpho-physiology and yield of tomato.The experiment was laid out in a Randomized Complete Block Design (RCBD) with four replications. The unit plot size was 1.6 m × 1.5 m (= 2.4 m^2). There were 9 treatments combinations in the experiment comprising 3 levels of K *viz*. K_0 (0 kg K ha^{-1}), K_1 (60 kg K ha^{-1}) and K_2 (100 kgK ha^{-1}) and 3 levels of B *viz*. B_0 (0 kg Bha^{-1}), B_1 (0.5 kg B ha^{-1}) and B_2 (1.0 kg B ha^{-1})

The individual and combined effects of potassium (K) and boron (B) on growth yield and yield contributing parameters in tomato plants were studied. Potassium (K) and Boron (B) fertilization at different levels individually influenced plant characters. The individual and combinatiom effect of K and B on growth, yield and yield contributing parameters was found positive.

Application of potassium (K) significantly influenced all growth, yield attributes and yield parameters of tomato. Considering potassium (K) application, the highest plant height (19.51, 33.51, 52.15 cm at 30, 50 and 70 DAT, and at harvest, respectively), number of leaves $plant^{-1}$ (9.07, 12.00 and 14.32 at 30, 50 and 70 DAT, respectively) was recorded from K_2. The highest number of flower cluster $plant^{-1}$ (4.42), number of fruits $cluster^{-1}$ (6.64), fruit length (5.49 cm), fruit diameter (6.21 cm), number of fruits $plant^{-1}$ (27.65), fruit weight $plant^{-1}$ (1691.00 g), single fruit weight (61.70 g), fruit weight $plot^{-1}$ (15.22 kg) and fruit yield ha^{-1} (63.43 t) were obtained from the treatment of K_2 (100 kg K ha^{-1}). Similarly, the lowest number of flower cluster $plant^{-1}$ (3.75), lowest number of fruits $cluster^{-1}$ (6.26), lowest fruit diameter (5.84cm), lowest number of fruits $plant^{-1}$ (22.88), lowest fruit weight $plant^{-1}$ (1280.00 g), lowest single fruit weight (58.25 g), lowest fruit weight plot^{-1} (11.52 kg) and lowest fruit yield ha^{-1} (48.00 t) were obtained from the control treatment K_0 (0 kg K ha^{-1}).

Different doses of boron (B) application showed significant influence on different growth, yield and yield contributing parameters except plant height, SPAD value and fruit length. The highest plant height (18.78, 33.17 and 51.65 cm at 30, 50 and 70 DAT, respectively) was obtained from the treatment of B_2 (1.0 kg B ha^{-1}) and the lowest plant height (17.10, 32.81 and 50.22 cm at 30, 50 and 70 DAT, respectively) was obtained from the control treatment B_0 (0 kg Bha^{-1}). Again, the highest number of leaves plant^{-1} (9.22, 11.70 and 14.27 at 30, 50 and 70 DAT, respectively) was recorded from the treatment of B_2 (1.0 kg B ha^{-1}) whereas the lowest number of leaves plant^{-1} (7.67, 10.22 and 12.73 at 30, 50 and 70 DAT, respectively) was obtained from the control treatment B_0 (0 kg Bha^{-1}). Similarly, the highest SPAD value (53.26) was achieved from the treatment of B_2 (1.0 kg B ha^{-1}) where the lowest SPAD value (52.57) was obtained from the control treatment B_0 (0 kg B ha^{-1}). The highest number of flower cluster plant^{-1} (4.30), fruit diameter (5.84 cm), single fruit weight (61.19 g), number of fruits cluster^{-1} (6.75), fruit length (5.44 cm), number of fruits plant^{-1} (27.70), fruit weight plant^{-1} (1624.00 g), fruit weight plot^{-1} (14.61 kg) and fruit yield ha^{-1} (60.88 t) were obtained from the treatment of B_2 (1.0 kg B ha^{-1}) whereas the lowest number of flower cluster plant^{-1} (3.80), lowest number of fruits cluster^{-1} (6.20), lowest fruit length (5.24 cm), lowest fruit diameter (6.12 cm), lowest number of fruits plant^{-1} (23.23), lowest fruit weight plant^{-1} (1346.00 g), lowest single fruit weight (58.46 g), lowest fruit weight plot^{-1} (12.11 kg) and lowest fruit yield ha^{-1} (50.46 t) were achieved from the control treatment B_0 (0 kg B ha^{-1}).

Different combination of K and B showed significant influence on growth, yield and yield contributing parameters. Results revealed that the highest plant height (21.32, 35.22 and 54.60 cm at 30, 50, and 70 DAT, respectively), number of leaves plant^{-1} (10.10, 13.10 and 15.35 at 30, 50 and 70 DAT, respectively) and

SPAD value (55.22) at 50 DAT was obtained from the treatment combination of K_2B_2 whereas the lowest plant height (15.17, 30.58 and 49.05 cm at 30, 50 and 70 DAT, respectively), number of leaves plant^{-1} (7.25, 9.45 and 12.05 at 30, 50 and 70 DAT, respectively) and the lowest SPAD value (50.67) at 50 DAT were from obtained the treatment combination of K_0B_0. The highest number of flower cluster plant^{-1} (4.65), fruit diameter (6.37 cm), single fruit weight (62.91 g), number of fruits cluster^{-1} (6.85), fruit length (5.60 cm), number of fruits plant^{-1} (29.10), fruit weight plant^{-1} (1807.00 g), fruit weight plot^{-1} (16.26 kg) and fruit weight ha^{-1} (67.78 t) were found from the treatment combination of K_2B_2. Similarly, the lowest number of flower cluster plant^{-1} (3.20), number of fruits cluster^{-1} (5.67), fruit length (5.06 cm), fruit diameter (5.67 cm), number of fruits plant^{-1} (18.15), fruit weight plant^{-1} (1057.00 g), single fruit weight (59.79 g), fruit weight plot^{-1} (9.51 kg) and fruit yield ha^{-1} (39.62 t) were found from the treatment combination of K_0B_0.

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

- Individual effect of K and B on growth and yield of tomato was found positive and significant.
- The combination effect of K and B enhanced growth, yield and yield attributes of tomato.
- Combination of K_2 (100 kg K ha^{-1}) and B_2 (1.0 kg B ha^{-1}) was the most suitable combination to give the highest yield of tomato.

Similar research works at different AEZ of Bangladesh are needed to be carried out for the confirmation of the present findings.

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APPENDICES

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

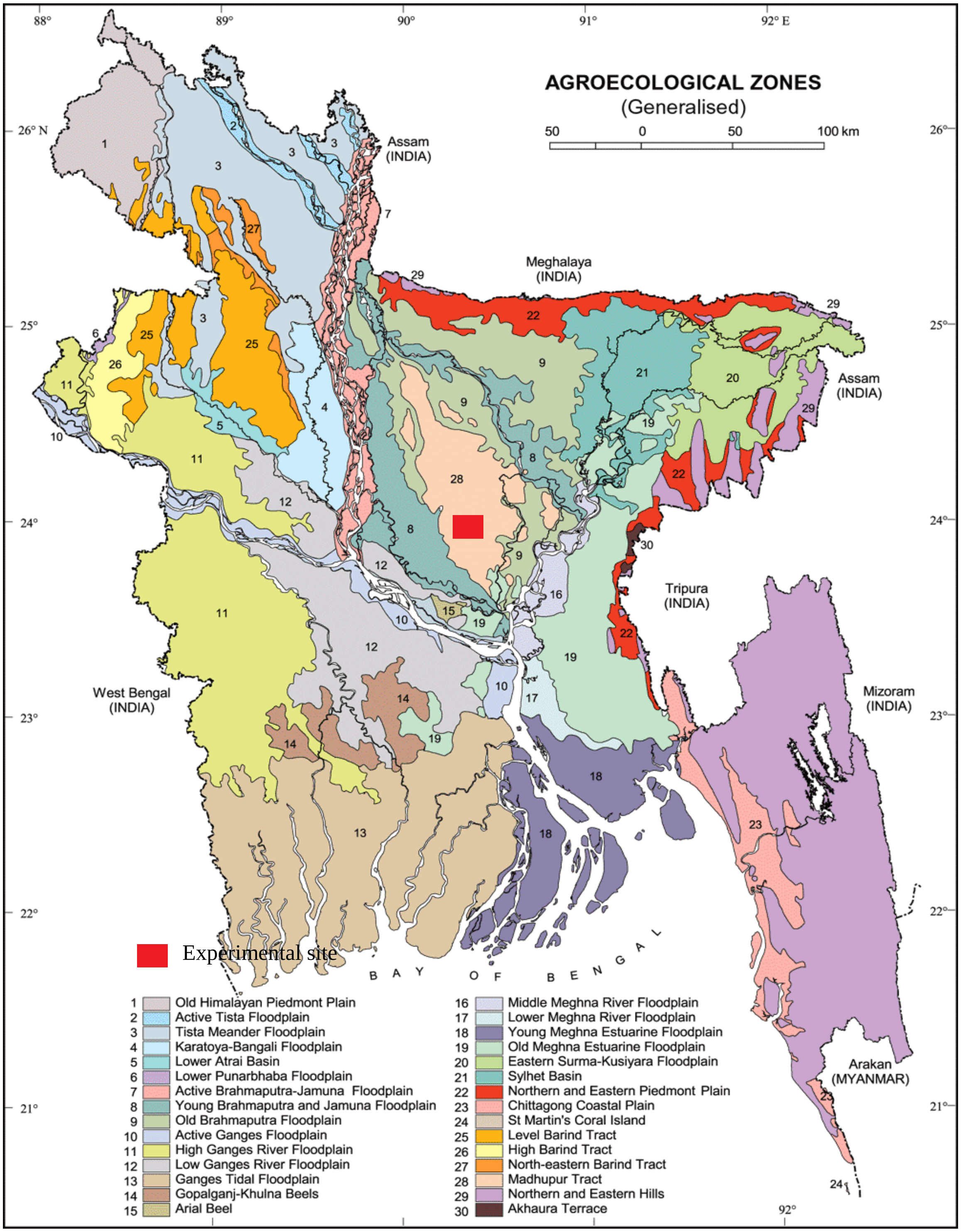

Fig. 7. Experimental site

Appendix II. Monthly records of air temperature, relative humidity and rainfall during the period from November 2017 to April 2018.

Year	Month	Air temperature (°C)			Relative humidity (%)	Rainfall (mm)
		Max	*Min*	*Mean*		
2017	November	28.60	8.52	18.56	56.75	14.40
2017	December	25.50	6.70	16.10	54.80	0.0
2018	January	23.80	11.70	17.75	46.20	0.0
2018	February	22.75	14.26	18.51	37.90	0.0
2018	March	35.20	21.00	28.10	52.44	20.4
2018	April	34.70	24.60	29.65	65.40	165.0

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**
Partical size analysis % Sand	27
%Silt	43
% Clay	30
Textural class	Silty Clay Loam (ISSS)
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

Source: Soil Resource Development Institute (SRDI)

Appendix IV. Layout of the experiment field

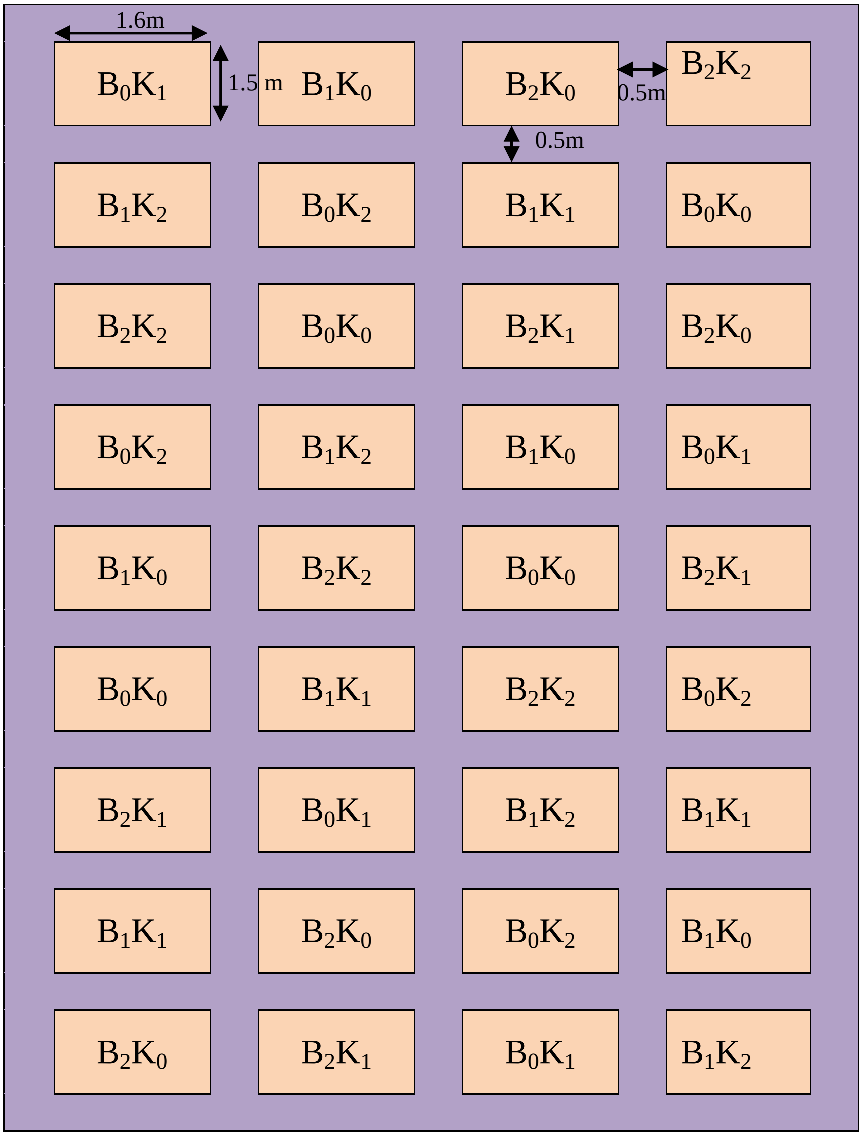

Fig. 8. Layout of the experimental plot

Appendix V. Combined effect of potassium (K) and boron (B) on plant height of tomato

Source	Degrees of Freedom	Mean square of plant height (cm)		
		30 DAT	50 DAT	70 DAT
Replication	3	1.56	3.57	3.41
Factor A	2	NS	4.39*	17.44*
Factor B	2	NS	NS	NS
AB	4	9.17*	14.11*	9.46*
Error	24	8.08	0.01	19.57

Appendix VI. Combined effect of potassium (K) and boron (B) on number of leaves plant^{-1} of tomato

Source	Degrees of Freedom	Mean square of number of leaves plant^{-1}		
		30 DAT	50 DAT	70 DAT
Replication	3	0.59	2.75	2.17
Factor A	2	NS	17.11*	9.65*
Factor B	2	NS	NS	NS
AB	4	NS	2.13*	2.05*
Error	24	0.34	0.65	0.95

Appendix VII. Combined effect of potassium (K) and boron (B) on SPAD value of tomato leaves

Source	Degrees of Freedom	Mean square of SPAD value at 50 DAT
Replication	3	1.08
Factor A	2	31.81
Factor B	2	1.56
AB	4	6.41
Error	24	2.16

Appendix VIII. Combined effect of potassium (K) and boron (B) on yield contributing parameters of tomato

Source	Degrees of Freedom	Mean square of yield contributing parameters				
		Number of flower cluster plant^{-1}	Number of fruits cluster^{-1}	Fruit length (cm)	Fruit diameter (cm)	Number of fruits plant^{-1}
Replication	3	2.15	4.73	0.15	0.26	3.90
Factor A	2	1.39*	0.44*	NS	0.49*	86.37*
Factor B	2	0.99*	0.97*	NS	0.24*	69.26*
AB	4	0.15*	0.26*	0.02**	0.02*	11.91*
Error	24	0.44*	2.87*	NS	0.14*	4.68*

Table IX. Combined effect of potassium (K) and boron (B) on yield parameters of tomato

Source	Degrees of Freedom	Mean square of yield parameters			
		Fruit weight plant^{-1} (g)	Single fruit weight (g)	Fruit weight plot^{-1} (kg)	Fruit yield ha^{-1} (t)
Replication	3	20.212	4.80	1.95	3.74
Factor A	2	702.76*	35.65*	46.94*	815.12*
Factor B	2	807.36*	23.02*	24.93*	432.96*
AB	4	70.26*	27.51*	0.55*	9.53*
Error	24	67.85	7.29	1.63	2.08