INFLUENCE OF POTASSIUM AND BORON ON QUALITY AND YIELD OF TOMATO

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CERTIFICATE

*This is to certify that the thesis entitled **"INFLUENCE OF POTASSIUM AND BORON ON QUALITY AND YIELD OF TOMATO"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE** in **HORTICULTURE,** embodies the result of a piece of bonafide research work carried out by **KAZI ABDUL BATEN,** Registration No. **13-05356**, under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma.*

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

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The Author

INFLUENCE OF POTASSIUM AND BORON ON QUALITY AND YIELD OF TOMATO

Abstract

The field experiment was therefore conducted to investigate the influence of potassium and boron on the quality and yield of tomato at the Horticulture farm of the Sher-e-Bangla Agricultural University, Dhaka, during the rabi season (October 2019 to March 2020). The experiment consisted of two factors, Factor A: four different levels of potassium (K_2O) viz., 0, 80, 120, 140 kg/ha, Factor B: four different levels of boron (B) viz., 0, 0.6, 1.2, 1.8 kg/ha. The experiment was comprised of 16 treatment combinations and laid out in Randomized Complete Block Design (RCBD) with three replications. The influence of different levels of potassium, boron and their combined effect showed significant variations in quality and yield of tomato. Plant grown with 120 kg /ha K_2O gave the highest result in number of leaves per plant (40.52), number of flower clusters per plant (8.32), number of flowers per cluster (6.59), number of fruits per cluster (4.54) , number of mature fruits per plant (37.93), weight of fruits per plant (0.95 kg), weight of fruits per plot (5.68 kg), yield per hectare (63.19 ton/ha) as well as quality parameter total soluble solids % (7.84), β -Carotene mg per 100g (0.36) and Vitamin-C mg per 100g (112.6). Among the different levels of boron maximum results were obtained from 1.2 kg B/h in all yield and quality parameters except plant height. In combine treatments the maximum plant height (119.2 cm), number of leaves per plant (42.92), number of flower clusters per plant (8.93), number of flowers per cluster (7.44), number of fruits per cluster (4.79), weight of fruits per plant (1.07 kg) were produced from the treatment combination of 120 kg K/ha with 1.2 kg B/ha. The highest fruit yields per plot (6.42 kg), per hectare (71.33 t) as well as quality were achieved from the treatment combination of 120 kg K_2O/ha with 1.2 kg B/ha. So, optimum use of potassium with the combination of micro nutrient boron could influence quality and yield of tomato significantly.

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ABBREVIATIONS AND ACRONYMS	
ABBREVIATION	**ELABORATIONS**
AEZ	Agro-Ecological Zone
Anon.	Anonymous
ANOVA	Analysis of Variance
@	at the rate of
a.i	Active ingredient
Adv.	Advanced
Agric.	Agriculture
Agril	Agricultural
Hort.	Horticulture
BARI	Bangladesh Agricultural Research Institute
SAU	Sher-e-Bangla Agricultural University
BAU	Bangladesh Agricultural University
BBS	Bangladesh Bureau of Statistics
RCBD	Randomized Complete Block Design
CV	Coefficient of Variation
cv.	Cultivar
EC	Emulsifiable Concentrate
cm	Centimeter
df	Degrees of Freedom
DAT	Days After Trasplanting
Mo	Molybdenum
B	Boron
LSD	Least significance difference
et al.	and others
etc.	etcetera
FAO	Food and Agricultural Organization
ns	Non-Significant

GA_3	Gibberellic Acid
J.	Journal
pp.	Pages
cv.	Cultiver
comms	Communication
gm	Gram
t	ton
ha^{-1}	Per hectare
$plant^{-1}$	Per plant
%	Percent
kg	Kilogram
^{0}C	Degree Celsiu
Res.	Research
RH	Relative humidity
Sci	Science ’s
Vol.	Volume

CHAPTER I

INTRODUCTION

Tomato (*Lycopersicon esculentum* L.) belongs to family Solanaceae is the second largest vegetable crop, widely cultivated all over the world and grown in approximately 4.8 million hectares with annual production in 2014 reached to 170 million tonnes (FAO, 2014). It originated in tropical America (Salunkhe *et al.*, 1987), mainly in the region of the Andes Mountain in Peru and Bolivia (McCollum, 1992). Due to the excellent adaptability to wider range of soil and climatic conditions it is widely grown in any parts of the world (Ahmed, 1976). The leading tomato producing countries of the world are China (50,000,000 tons), India (17,500,000 tons), United States (13,206,950 tons), Turkey (11,350,000 tons) Egypt (8,625,219 tons (FAO, 2013).

It is one of the popular, important and high nutritious vegetables grown and cultivated in Bangladesh in both winter and summer season around all parts of the country. The climatic condition of Bangladesh favors tomato to grow in winter season and it can be cultivated in all parts of the country (Haque *et al.,* 1999). In Bangladesh, it is cultivated in total area of 75602 acres with annual production reaches to 413610 metric tons in 2014-15, (BBS, 2015).

Tomato fruit can be consumed either fresh as raw salad or cooked or in the form of processed products such as jam, jelly, sauce etc. It is considered as 'poor man's apple' because of its attractive appearance and very high nutritive value, containing vitamin A, vitamin C and minerals like calcium, potassium etc. Nutritional value of red tomatoes (raw) per 100 g contains 18 kcal energy, 2.6 g sugars, 4.0 g carbohydrates, 1.0 g dietary fiber, 0.25 g fat, 13 mg vitamin C and 1.0 g protein, 96 g water, (Zhang et al., 2009).Tomato also have medicinal value as tomato is a rich source of lycopene and vitamins. Lycopene may help counteract the harmful effects of substances called free radicals, which are thought to contribute to age-related processes and a number of types of cancer, including, but not limited to, those of prostate, lung, stomach, pancreas, breast, cervex, colorectum, mouth and oesophagus. Masroor*et al.*, (1988).

Fertilizer management practices is most crucial cultural practices especially in tomato due to the intensive cropping and gradual decline in soil nutrients. This problem can be managed by proper fertilizer management practices (Tindall, 1983). So, judicial use of fertilizers is helpful for obtaining sustainable production as well as improvement of the quality of produce. For the successful and economic production of tomato, it is necessary to give emphasis on the use of macronutrients as well as micronutrients. Improving the quality and appearance of fruit is the foundation for success in producing market tomatoes. Tomato fruit quality and appearance are determined by nutritional doctors like Potassium (K), calcium (Ca), and boron (B) are the key nutritional factors controlling fruit development and maturation (Marschner, 1995).

Potassium is a vital macronutrient for all the plants as well as tomatoes for balancing physiological activities. Potassium has significant effect on quantity and quality of tomato yield because of its vital roles in photosynthesis, favoring high energy status and appropriate nutrient translocation and water uptake in plants. Potassium is especially important in a multi nutrient fertilizer application (Brady, 1995). The recommended K application rate for tomato grown in a drip irrigation system was 205 kg/ha (Olson *et al.*, 2004). The most important functions of K in plant metabolism are enzyme activation. In addition, K status has a marked influence on photosynthetic activity and thus on the accumulation of carbohydrates and organic acids that support plant growth and function. Potassium application positively influence the the peduncle length, flower number, the fruit set and the number of fruit (Besford and Maw, 1975). It has marked effect on the quality of tomato fruits particularly on color (Wall,1940 and Ozbunet al., (1967).

Boron has a pronounced effect on the production and quality of tomato. Tomatos in general have a high boron requirement (Mengel and Kirkby, 1987).Boron is known to reduce the cracking of fruits in tomato. The quality of crops is also influenced due to boron and the timely application of boron helps in increasing the size of fruits as well as firmness which is very important for market. Boron plays an important role in flowering and fruit formation (Nonnecke, 1989). A positive correlation was observed between boron and flower bud, number of flowers and weight of fruit in tomato (Bose *et al.*, 2002). In boron deficient plants the youngest leaves become pale green, losing more color at the base then at the tip. Boron deficiency symptoms will often appear in the form of thickened wilted, or curled leaves, a thickened, cracked, or water soaked condition of petioles and stems, and discoloration, cracking or rotting of fruit, tubers or roots. (Tisdale et al., 1985).

In fertilizer schedule, an inclusion of B often decides the success and failure of the crops (Dwivedi *et al.,* 1990). It is reported that the ranges between deficiency and toxicity of B are quite narrow and that an application of B can be extremely toxic to plants at concentrations only slightly above the optimum rate (Gupta *et al*., 1985).

Sequel to the above an attempt was made to study the Influence of potassium and boron on quality and yield of tomato with the following objectives:

1. To investigate the effect of potassium on quality and yield of tomato.
2. To investigate the effect of boron on quality and yield of tomato.
3. To find out the suitable combination of potassium and boron concentrations on quality and yield of tomato.

CHAPTER II

REVIEW OF LITERATURE

Tomato is an important vegetable crop and received much attention of the researchers throughout the world to develop its suitable production technique among various research works. Investigations have been made in various parts of the world to determine the different levels of potassium and boron for its successful cultivation. However, the combined effects of these production practices have not been defined clearly. In Bangladesh, there have not many studies on the influence of different levels of potassium and boron on the quality and yield of tomato. Relevant available literature in this connection has been described in this chapter.

2.1 Influencet of potassium on quality and yield of tomato

Sofonias *et al.* (2018) conducted a research work to investigate the effect of potassium levels on productivity and fruit quality of tomato at Hamelmalo, Eritrea. The experiment was conducted in Randomized Complete Block Design with nine potassium levels (0, 50, 100, 150, 200, 250, 300, 350 and 400 kg K_2O/ha) replicated thrice. Data was collected on yield and fruit quality parameters and they were subjected to one-way analysis of variance (1-way ANOVA). The results of this study revealed that potassium had significant effect in all yield and quality parameters studied. Fruit diameter, fruit weight per plant, total yield, total soluble solids, specific gravity and fruit dry matter content showed significant increase with an increase in potassium level from 0 to 150 kg K_2O/ha and thereafter decreased while fruit moisture content was increased in the range of 150 - 400 kg K_2O/ha. As a result, highest fruit weight (1.39 kg/plant), fruit yield (15.45 t/ha), total soluble solids (3.84 Brix), specific gravity, (1.46) and fruit dry matter (5.68%) were recorded from 150 kg K_2O/ha. Therefore it is recommended that potassium fertilizers should be used and balanced NPK fertilizers should be applied to improve yield and quality of tomato produced.

Al-Moshileh *et. al.* (2017). Conducted a study to evaluate the Effect of potassium fertilization on tomato and cucumber plants under greenhouse conditions. Four levels of K fertilizer as potassium sulphate (100, 150, 200 and 250 ppm) were applied in fertigation method to both tomato and cucumber plants grown the in greenhouses to evaluate their agronomic performance in response to various levels of K fertilizer. Results revealed that increasing potassium levels resulted in a significant increase in leaf K concentration and chlorophyll content. Both tomato and cucumber fruits produced from plants received high level of K (250 ppm) showed superiority over those produced from plants received low level of K (100 ppm) regarding percentage of total soluble solids contents and firmness. Moreover, there was a direct proportional relationship between the level of applied K fertilizer and studied fruit quality parameters (percentage of total soluble solids, firmness). In addition, our data in the present study revealed that under the suggested K regimes investigated, the marketable yield increased linearly with increasing K levels. In conclusion, increasing K rate to 250 ppm statistically increased leaf K concentration and chlorophyll contents of tomato and cucumber plants. While increasing K rates did not affect TSS% and firmness of tomato and cucumber fruits.

Afzal *et al.* (2015) conducted an experiment to investigate the Specific contribution of potassium to yield and quality of tomato, a field experiment was conducted on two tomato cultivars, Nagina and Roma. 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 0.5, 0.6 and 0.7% K maximally improved ascorbic acid contents of both tomato cultivars whereas 0.4 and 0.8% did not improve ascorbic acid contents. Positive relation between K 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 mostly improved performance of tomato plants of both cultivars.

Zelelew *et al.* (2016) designed an experiment to assess the response of potato varieties to different levels of potassium application five potassium levels (0, 75, 150, 225 and 300 kg K2O/ha) along with all possible interactions were used. Tuber number, tuber diameter, tuber weight per plant, total yield, total soluble solids, specific gravity and tuber moisture content showed significant differences due to the application of potassium. As a result, the highest tuber weight (1.14 kg/plant) and yield (49.38 tones/ha) were recorded from Ajiba treated with 300 kg K2O/ha. The result further revealed that there is a promising profit return by investing more on potassium application upto 300 kg K2O/ha. It is, thus, recommended that potassium fertilizers should be introduced to optimize productivity in Hamelmalo area, Eritrea.

Zia-ul-Hassan *et al.* (2016) conducted a study to assess the effect of soil applied potassium sulphate (K_2SO_4) fertilizer on growth, biomass production and K accumulation of plants of tomato variety Roma. The study was executed in a net-house under natural conditions following completely randomized design. There were six treatments (0, 50, 100, 150, 200 and 250 kg K2O per ha), each repeated thrice. A recommended blanket dose of 150 kg nitrogen and 75 kg phosphorus (per ha) was also given to the crop. Tomato plants were raised in five kg plastic pots filled with a K-deficient soil (119 mg per kg). Results of the study indicated that K nutrition significantly enhanced growth, biomass production and K accumulation of tomato plants. K nutrition augmented different plant height (49%), shoot diameter (103%), fresh biomass (134%), dry biomass (182%), number of leaves (75%)

and K concentration (3.1 fold). It is concluded that a dose of 100 kg K_2O (per ha) was the most optimum for tomato plants at early growth stage. These results need to be verified under field conditions at maturity level of tomatoes.

Ahmad *et al.* (2015) was found total invert sugars (4.11 %), the highest yield (23.3 t ha-1), fruit weight (83.24 g fruit-1), firmness (8.32 kg), mineral matter and dry matter (6.33 %) (1.95 %) were recorded with the application of 120 kg ha-1 potassium at transplanting while the highest values of ascorbic acid (30.33 mg 100 g-1), TSS (7.03 %) and acidity (0.81%) were observed in treatment where potassium was applied @ 60 kg ha-1 in two splits.

A pot experiment which included six K fertilizer treatments (75, 150, 225, 300, 375, 450 Kg K2O ha-1) with basal doses of N and P (100 Kg and 80 Kg ha-1, respectively) was conducted by Javaria *et al*. (2012). All K treatments significantly increased yield characteristics of tomato fruit compared with untreated one (control). However, Treatment (NP+450 K2O Kg ha-1) surpassed all the other treatments in term of yield parameters. Potassium application significantly increased number of flowers plant-1, fruit setting rate, number of truss plant-1, fruits plant-1 and yield ha -1.

Javaria *et al.* (2012) conducted a pot experiment which included six potassium fertilizer treatments (75, 150, 225, 300, 375, 450 Kg K2O ha-1) with basal doses of N and P (100 Kg and 80 Kg ha-1, respectively). All potassium treatments significantly increased yield characteristics as well as post-harvest quality of tomato fruit compared with untreated one (control). However, Treatment (NP+450 K2O Kg ha-1) surpassed all the other treatments in term of yield parameters. Potassium application significantly increased number of flowers plant-1, fruit setting rate, number of truss plant-1, fruits plant-1 and yield ha -1. Moreover, increased potassium levels also had positive effect on post-harvest life attributes of tomato fruit. In addition, the Shelf life, quality of general appearance and taste were significantly influenced as potassium levels increased to 375 kg K2O ha-1 but decreased at 450 Kg K2O ha-1. On the other hand, while increased potassium levels decreased all the undesired parameters, wilting and drying of calyx, physiological weight loss %, and % non-marketable yield .Therefore, when potassium was applied @ 450 Kg K2O ha-1 it increased the yield had decreased the adverse effect on marketable yield, wilting and drying of calyx and weight retention of tomato fruit. In conclusion 375-400 Kg K2O ha-1 is recommended as it produced better quality tomatoes with longer postharvest life.

Clarke (2004) found little effect of potassium application on flower production, although the proportion of flowers that matured into marketable fruit and hence the yield, increased with potassium level.

Iqbal *et al.* (2011) conducted an experiment to study the effect of N and K doses (60, 90 and 120kg ha -1 N and 90 kg, 110kg, 130kg of K) on growth, economical yield and yield components of tomato under the agro climatic conditions of Swat. The maximum days to flowering (52) in 0 kg N and 110 kg of K, maximum days to maturity (85.67) were observed with the application of 120 kg N and130 kg ha -1 of K . Maximum fruit length (5.96cm) was observed in 0kg of N and 130kg/N of K, whereas maximum fruit diameter (5.08cm) was recorded when plants applied 120kg N and 90kg K. in treatment 14 (120kg N and 90kg ha -1 of K) was obtained with the application 60 kgN and 130kg ha -1 of potassium.

Ehsan *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* M. cultivar Roma) i.e., MOP and SOP was applied @ 0, 100 and 200kg 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 Potassium application was recorded. Potassium applied @100 kg K ha-1 as MOP produced significantly higher marketable tomatoes ascompared to SOP and control. Vitamin C contents in tomato fruits increasedwith K application in the form of MOP. The K use as MOP significantly reduced incidence of leaf blight disease and insect pest attack in tomato plant as compared to SOP and control treatments.

A study named the effect of nitrogen and potassium application on the growth, yield and quality of spring crop of tomato cv. Punjab Upma (Harneet *et al.* 2004). Treatments consisted of 16 combinations of 4 levels each of N (100, 140, 180, 220 kg/ha) and K (40, 60, 80, 100 kg/ha). Increasing the N level from 100 to 140 kg/ha and the K level from 40 to 60 kg/ha significantly increased marketable and total yields. Significant increase in ascorbic acid content, N and K concentrations in leaves and juice content was recorded when the N level increased from 100 to 140 kg/ha. There was also a significant variation shown in the concentration of K in leaves when K level was increased from 40 to 60 kg/ha.

Gent (2004) determined if the yield of greenhouse tomato benefit from supplemental nitrogen (N) and potassium (K) supplied in amounts greater than that taken up by the plants, the yield and fruit and leaf tissue composition were compared for tomato plants grown in rock wool medium and supplied with sufficient N and K, or with N and/or K supply increased by approximately 30% over the control. In 1999, supplemental N in the form of NH_4NO_3 decreased yield, a trend that became more obvious as the season progressed. The K supply had no significant effect.

Liu *et al.* (2004) conducted in a solar greenhouse using tomato cv. Zhongza 9 to investigate the light and temperature in the greenhouse, and the distribution of N, P and K in soil culture in winter-spring and autumn-winter crops. The distribution of total N, P and K was affected by light and temperature condition in the greenhouse. Both in winter-spring and autumn-winter crops, the distribution trend of total N, P and K was the same as that of dry material: mainly distributed in the stem and leaves before fruit formation stage, and in the fruits during fruit formation stage. In autumn-winter crop, because of the abominable light and temperature condition, the distributing proportion of N, P and K in early and middle stages of picking was higher than that in winterspring crop. The total proportion changed with different elements and growth stages.

Khalil *et al.* (2001) had undertaken a study to determine the appropriate nitrogen fertilizer for maximum tomato (cv. Peshawar Local) yield and its effects on various agronomic characters of tomato. Treatments comprised: untreated control; 150 kg ammonium nitrate/ha + 100 kg P/ha + 50 kg K/ha; 150 kg ammonium nitrate/ha; 150 kg ammonium nitrate/ha + 100 kg P/ha + 50 kg K/ha; 150 kg ammonium sulfate; 150 kg urea/ha + 100 kg P/ha + 50 kg K/ha; 150 kg ammonium sulfate/ha + 100 kg P/ha + 50 kg K/ha and 150 kg urea/ha. The ammonium sulfate + P + K treatment was the best among all treatments with respect to days to flower initiation (57 days), weight of individual fruit (50.8 g), weight of total fruits per plant (1990 g) and yield (21865 kg/ha). The control treatment showed lowest response with respect to different chracteristics.

Sun-Hong Mei *et al.* (2001) conducted a research work on the effect of K deficiency on the incidence of brown blotches in ripening fruits of tomatoes .K deficiency was caused by the occurrence of brown blotches, longer periods of K deficiency caused more blotches in plants. Yield was reduced in K-deficient plants.

Hartz *et al.* (1999) A survey of 140 processing tomato fields in central California was conducted in 1996-97 to examine the relationship between K nutrition and fruit quality for processing. Quality parameters evaluated were soluble solids (SS), pH, colour of a blended juice sample, and the percentage of fruits affected by the colour disorders yellow shoulder (YS) or internal white tissue (IWT). Juice colour and pH were not correlated with soil K availability or plant K status. SS was correlated with both soil exchangeable K and midseason leaf K concentration, but the regression relationships suggested that the impact of soil or plant K status on fruit SS was minor.

A fertilizer trail was conducted by Pansare *et al*. (1994) to find out the effect of different N, P and K on yield and quality of tomato. They found that the maximum yield of high quality tomatoes were obtained when straight fertilizers was added in the N, P, K ratio of 3:1:2 (150 kg N/ha, 50 kg P2O5/ha, 100 kg K2O/ha).

Cerne and Briski (1993) conducted field trials on the fertilizer and irrigation requirement of tomato cv. Rutgers plants where 250 kg N and 72 kg P2O5/haplants 200 or 400 kg K2O/ha in the first year, 0 or 200 kg K20/ha in the second year, 0 or 40 t ; stable manure/ha were applied in all treatments. The combination of 400 kg K2O/ha stable manure and irrigation gave the highest total yield in the 1st and 2^{nd} years (1.03and 2.25 kg/plant respectively).

Silva and Vizzotto (1990) conducted field trail with the cultivar Angela Gigante 1-5, 100, the plants received N: P2O5: K2O at 30-180; 75-450:30-180 kg/ha plus poultry manure at 0, 10 or 20 t/ha. The largest fruits and the highest yields (53 t/ha) were obtained by applying N: P2O5: K2O at 104:259:140 kg/ha plus poultry manure at 20 t/ha.

Mehta and Saini (1986) conducted, two year fertilizer trails and found the plants received basal FYM (20 t/ha) and N at 75-125, P2O5 at 60-90 or K2O at 30- 60 kg/ha, significant yield increases were obtained with the highest N and K rates.

On a sandy loam soil Murphy (1964) found that applications of potassium increased plant height by up to 65%, but the responses are correspondingly smaller on soils with greater reserves of potassium. Increasing levels of potassium to improve all aspects of fruit quality eg.by reducing the incidence of hollow fruit, and of ripening disorders, by improving fruit shape and firmness.

2.2. Influence of boron (B) on quality and yield of Tomato:

Sathya *et al.* (2010) conducted a field experiment was conducted during 2006 at Agricultural College and Research Institute, Madurai to investigate the effect of application of boron on growth, quality and fruit yield of PKM 1 tomato. 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 per cent borax spray produced taller plants with more no. of branches. The quality parameters of PKM 1 tomato fruit such as ascorbic acid 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 per cent and 9.20° brix respectively. 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 per cent increase over control and was found to be significantly superior to rest of the treatments.

Dipti *et al.* (2008) observed effect of application of boron through solubor and borax as foliar spray and soil application of borax was studied on boron deficient alkaline calcareous soil by conducting a field experiment on tomato. It was observed that foliar application of boron through both solubor and borax @ 140 mg kg-1 recorded significant increase in yield over control. The soil application of borax was also found equally beneficial. However, application of boron through solubor and borax @ 280 mg kg-1 was found to significantly improve the quality of tomato suggesting that foliar application of solubor or borax @ 280 mg kg-1 is beneficial for increasing yield as well as enhancing quality of tomato grown on alkaline calcareous soils.

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. 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 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.

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.

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

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

Naresh (2002) carried out an investigation in Nagaland, India during 1998-2000 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. 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. B also had positive effects on number of branches, plant height, flowers and number of fruit set per plant, resulting in an increase in the number of fruits per plant and total yield. 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 [Lycopersicon esculentum]) cultivars to a range of boron levels in field trials at Kadawa (11° 39' N, 8° 2' E) and Samaru (11° 12', 7° 37' E) in Sudan and northern Guinea savanna, respectively, in Nigeria. Boron levels were 0, 0.5, 1.0, 1.50, 2.0 and 2.5 kg/ha replicated three times in a randomized complete block design. Treatment effects were evaluated on fruit yield and nutritional qualities of the two tomato cultivars at harvest. There was a highly significant (P=0.01) interaction between B rates and cultivars, with Dandino producing higher yields than Roma VF in both years and locations. 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 during 1990 and 1991, in Hisar, Haryana, India, to evaluate the effect of different concentrations of zinc and boron on the vegetative growth, flowering and fruiting of tomato. The treatments comprised five levels of zinc (0, 2.5, 5.0, 7.50 and 10.0 ppm) and four levels of boron (0, 0.50, 0.75 and 1.00 ppm) as soil application, as well as 0.5% zinc and 0.3% boron as foliar application. The highest values for secondary branches, leaf area, total chlorophyll content, fresh weight, fruit length, fruit breadth and fruit number were obtained with the application of 7.5 ppm zinc and 1.0 ppm boron.

A greenhouse experiment involving 4 rates of B (0, 5, 10 and 20 mg B/kg) and 3 rates of Zn (0, 10 and 20 mg Zn/kg) was conducted by Gunes *et al.* (2000) 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.

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

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

Prasad *et al.* (1997) carried out a field experiments in rabi [winter] 1991-94 on an acidic red loam soil at Ranchi, India, tomato cv. Pusa Ruby plants were given a soil boron application (0.00, 4.54, 9.09, 13.63 or 18.18 kg borax/ha) at final field preparation or a foliar boron application (0.0, 1.0, 1.5, 2.0 or 2.5 kg borax/ha) at 25 days after transplanting. Boron application significantly increased tomato yield compared to the control treatment, with the highest yields produced on plots given a foliar application of 2.5 kg borax/ha (48.74, 152.61 and 227.67 q/ha in 1991-92, 1992-93 and 1993-94, respectively). Foliar application of borax at 2.5 kg/ha also gave the highest average yield (143.06 q/ha) and the highest net additional income (Rs 7324).

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

Sarker *et al.* (1996) carried out an experiment at Gangachara Series of Mithapukur, Rangpur indicated that the highest tuber yield of 28.72 t/ha was produced by combined effect of 150 kg N + 60 kg P + 120 kg K + 20 kg S + 20 kg Zn + 2 kg B + 15 kg Mg + 5 t cowdung per hectare.

Efkar *et al.* (1995) carried out an experiment to study the response of potato cv. Desiree to the application of boron fertilizer in Pakistan using 4 levels of boron (0, 1, 1.5 and 2 kg/ha). The crop also received a basal dressing of NPK fertilizers and FYM (5 t/ha). Application of 1.5 kg B/ha gave the highest tuber yield of 10.9 t/ha compared with the control yield of 7.9 t/ha.

Pregno and Arour (1992) conducted an experiment to find out boron deficiency and toxicity in potato cv. Sebago on an oxisol of the Atherton Tablelands at North Queensland, Australia. In this field trial 5 doses of boron (0, 2, 4, 8 and 12 kg

B/ha) were used. It was observed that total tuber yield was the highest when 2 kg B/ha was applied and it was followed by 4 kg/ha. Plant height was not increased by low rates of boron but was reduced by 8 and 12 kg B/ha compared with no B.

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

Palkovics and Gyori (1984) conducted a field research to determine the effect of boron on the growth and yield of potato cv. Somogy on rusty forest soil. It was observed that the application of boron contributed to yield increments and to the improvement of tuber quality. The critical level of B was 60 mg/kg of foliage and above this, B content depressed yield.

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

Grewal and Trehan (1981) studied the effect of trace elements on potato and observed that some cultivers showed a marked response to Zn and B application while others showed little response.

Awasthi and Grewal (1977) worked with potatoes on slightly acidic soils at Shillong, India, using soil application of 25 kg ZnSo4/ha or foliar application of 0.1% boron solution. The authors observed that both Zn and B application increased tuber yield by 100-150 kg/ha.

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.

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

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

CHAPTER 3
MATERIALS AND METHODS

This chapter presents the materials and method used in conducting the experiment. It consists of a short description of location of' the experimental plot, characteristics of soil, climate, material used, treatments, land preparation, manuring, and fertilization, transplanting and gap filling, staking and pruning, after cares, harvesting, and collection of data. These are described below:

3.1 Experimental site

The experiment was conducted during the rabi season (October 2019 to March 2020) at the main experimental field of department of horticulture, Sher-e-Bangla Agricultural University (SAU), Dhaka-1207, Bangladesh to study the influence of potassium and Boron quality and yield of Tomato. The location of the experimental site was at 23^0 75 minute North latitude and 90^0 34 minute East longitude with an elevation of 8.45 meter from sea level.

3.2 Soil

The soil of the experimental field belongs to the Tejgaon series under the Agroecological Zone, Madhupur Tract (AEZ-28) and the General Soil Type is Deep Red Brown Terrace Soils. A composite sample was made by collecting soil from several spots of the field at a depth of 0-15 cm before the initiation of the study. The collected soil was air-dried, grind and passed through 2 mm sieve and analyzed at Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka for some important physical and chemical properties. The soil was having a texture of sandy loam with pH and organic matter capacity 5.6 and 0.78%, respectively and the the soil composed of 27% sand, 43% silt, 30% clay. Details descriptions of the characteristics of soil are presented in Appendix III.

3.3 Climatic condition

Experimental site was located in the subtropical monsoon climatic zone, set aparted by heavy rainfall during the months from April to September (Kharif season) and scant of rainfall during the rest of the year (Rabi season). Plenty of sunshine and moderately low temperature prevails during October to March (Rabi season) which is generally preferred for vegetable cultivation. Details of the meteorological data during the period of the experiment was collected from the Bangladesh Meteorological Department, Agargoan, Dhaka-1212 and presented in Appendix II.

3.4 Plant materials used

The tomato variety used in the experiment was “BARI Tomato 16”. This is a high yielding determinate type. The seeds were obtained from Bangladesh Agriculture Research Institute, Gazipur.

3.5 Seedbed preparation

Seedbed preparation for raising healthy seedlings was an important task before starting the field research work. In the farm a suitable place was selected for the seedbed and the size of the seedbed was 3 m×1 m. For making seedbed, the soil was well ploughed and converted into loose friable and dried masses to obtain good tilt. Weeds, stubbles and dead roots were removed from the seedbed. The soil of seedbed was treated by Sevin 50WP @ 5 kg/ha to protect the young plants from the attack of mole crickets, ants and cutworms.

3.6 Treatment of seed

Before sowing seeds in the seedbed Sevin 50WP @ 3g/1kg seeds was applied to treat the seeds to protect some seed borne diseases such as leaf spot, blight, anthracnose, etc.

3.7 Seed sowing

Sowing of seeds was done on 16 th October, 2019 in the seedbed. It was done thinly in lines spaced at 5 cm distance. Seeds were sown at a depth of 2 cm and covered with a fine layer of soil and then light irrigation was done by water can. Then the beds were covered with dry straw to maintain required temperature and moisture. The cover of dry straw was removed immediately after emergence of seed sprout. To protect the young seedlings from scorching sunshine and rain, a bamboo mat was provided to shade when the seeds were germinated. Seeds were completely germinated within 5-6 days after sowing.

3.8 Raising of seedlings

Watering and weeding were done several times. No chemical fertilizers were applied for rising of seedlings. Seedlings were not attacked by any kind of insect or disease. Healthy and 30 days old seedlings were transplanted into the experimental field on 16^{th} November 2019.

3.9 Layout and design

The field experiment was conducted by Randomized Complete Block Design (RCBD) with three replications. Two factors were used in the experiment viz. four levels of Potassium and four levels of Boron. The experimental plot was first divided into three blocks. Each block consisted of 16 plots. Thus, the total number of plots was 48. Different combinations of Potassium and Boron were assigned randomly to each plot as per design of the experiment. The size of a unit plot was 1.2 m × 1.2 m. A distance of 0.5 m between the plots and 0.75 m between the blocks were kept. Thus the total area of the experiment was 182.82 m

3.10 Treatment of the experiment

The experiment consisted of two factors. Details were presented below:

Factor A: Potassium as K

1. K_0 = 0 kg K ha^{-1} (control)
2. K_1= 80 kg K ha^{-1} = 134 kg MoP/ha = 20 g/plot
3. K_2 = 120 kg K ha^{-1} = 200 kg MoP/ha = 29 g/plot
4. K_3 = 140 kg K ha^{-1} = 233 kg MoP/ha = 34 g/plot

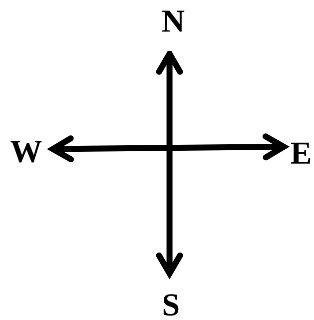
Factor B: Boron as B

1. B_0 = 0 kg B ha^{-1} (control)
2. B_1 = 0.6 kg B ha^{-1} = 3.5 kg boric acid/ha = 0.5 g/plot
3. B_2 = 1.2 kg B ha^{-1} = 7.02 kg boric acid/ha = 1.02 g/plot
4. B_3 = 1.8 kg B ha^{-1} = 10.5 kg boric acid/ha = 1.90 g/plot

There were 16 treatments combinations such as: K_0B_0, K_0B_1, K_0B_2, K_0B_3, K_1B_0, K_1B_1, K_1B_2, K_1B_3, K_2B_0, K_2B_1, K_2B_2, K_2B_3, K_3B_0, K_3B_1, K_3B_2, K_3B_3 .

R1 R2 R3

N



Factors A: Potassium (kg/ha)
K_O = 0 (Control),
K_1= 80 kg/ha,
27.7m K_2 = 120 kg/ha,
K_3 = 140 kg/ha,

Factors B: Boron (kg/ha)
B_O = 0(Control),
B_1 = 0.6 kg B/ha,
B_2 = 1.2 kg B/ha,
B_3 = 1.8 kg B/ha

Plot size: 1.2 m × 1.2 m
Spacing: 60 cm × 40 cm
Spacing between replication: 0.75 cm
Spacing between plots: 0.5 cm

Fig 1. Layout of experiment

3.11 Cultivation procedure

3.11.1 Land preparation

The selected plot of the experiment was opened in the 1st week of November 2019 with a power tiller, and left exposed to the sun for a week. Subsequently cross ploughing was done five times with a country plough followed by laddering to make the land suitable for transplanting the seedlings. All weeds, stubbles and residues were eliminated from the field. Finally, a good tilt was achieved. The experimental plot was partitioned into the unit plots in accordance with the experimental design mentioned in Figure 1. The soil was treated with insecticides (cinocarb 3G @ 4 kg/ha) at the time of final land preparation to protect young plants from the attack of soil inhibiting insects such as cutworm and mole cricket.

3.11.2 Application of manure and fertilizer

Manure and fertilizers that were applied presented in Table 1. The total amount of cow dung and TSP was applied to the plot during final land preparation as basal dose. Boron was applied as boric acid (16% B) as basal treatment. Urea and MP was applied in three equal installments at 20, 40 and 60 days after transplanting in ring method.

Table 1. Dose and Date of fertilizer and manure applications

Fertilizer and manure	Dose per hectare	Application (%)			
		Basal	15 DAT	30 DAT	45 DAT
Cow dung	10 ton	10 ton			
Urea	550		200	200	150
TSP	450	450			
MOP	As per treatment				
Boric acid	As per treatment				

Source: BARC fertilizer recommendation Guide 2017

3.11.3 Transplanting

The entire seedbed was irrigated before uprooting the seedlings to minimize the damage of roots. During the uprooting, care was taken so that root damage became minimum and some soil remained with the roots. Thirty days old healthy seedlings were transplanted at the spacing of 60 cm × 40 cm in the experimental plots on 15th November 2019. Thus the 6 plants were accommodated in each unit plot. In the afternoon, planting was done. Light irrigation was given immediately after transplanting around each seedling for their better establishment. To protect the transplanted seedlings from scorching sunlight, shading was done for five days with the help of transparent polythene, watering was done up to five days until they became capable of establishing on their own root system.

3.12 Intercultural operations

3.12.1 Gap filling

Some seedlings were damaged after transplanting and gap filling was carried out with new seedlings from the seed bed.

3.12.2 Weeding

The plants were kept under careful observation. Significant number of weed were found in the control treatment. Weeding was done three times in these plots. At 15, 30 and 40 DAT weeding was done followed by irrigation in the plots considering the optimum time for removal weed.

3.12.3 Spading

For proper growth and development, soils of each plot were pulverized by spade for easy aeration and it was done after each irrigation.

3.12.4 Staking and pruning

When the plants were well established, staking was given to each plant by bamboo sticks to keep them erect. As Tomato is a heavy bearing type staking is must for within a few days of staking, as the plants grew up, the plants were lightly pruned.

3.12.5 Irrigation

Just after transplanting of seedlings light irrigation was done. A week after transplanting the requirement of irrigation was realized through visual estimation. When the plants of a plot had shown the wilting symptoms the plots were irrigated on the same day with a hosepipe until the entire plot was properly wet.

3.12.6 Earthing up

Earthing up was done by taking the soil from the space between the rows for better vegetative growth,weed control and irrigation facilities.

3.12.7 Insects and disease control

Insect pests: Spraying of Diazinon 60EC @ 2ml/L as preventive measure against the insect pests like cutworms, leaf hoppers, aphids and fruit borers. The insecticide applications were done fortnightly as a routine work from a week after transplanting to a week before first harvesting. Furadan 5G was also applied during the final land preparation as soil insecticide.

Diseases:

The precautionary measures against disease infections especially late blight and foot rot were taken by spraying of Dithane M-45 @ 2g/l at the early vegetative stages as well as the period of foggy weather. Ridomil was also applied @ 2 g/1 against late blight disease of tomato. Tomato Mossaic virus was observed in the field and infected plant was uprooted immediately after observation and for the protection of further attack of Virus precautionary measure was also taken by controlling insect pest.

a

b

c

d

Plate 1. Pictorial presentation of transplanting, irrigation, stalking and flower initiation (a) Seedling transplanting, (b) Irrigation seedbed, (c) stalking tomato plants, (d) flower initiation

3.13 Harvesting

According to maturity indices fruits were harvested at 4 to 5 days intervals during early ripe stage when they attained slightly red color. Harvesting was started from 1st March, 2015 and was continued up to end of March 2020.

3.14 Data collection

The data of the following characters were recorded from five plants randomly selected from each plot, except yield of curds, which was recorded plot wise.

3.14.1 Growth and Yield contributing parameters

3.14.1.1 Plant height

Plant height was measured from the sample plants from the ground level to the tip of the longest stem and mean value was calculated. Data were recorded at 30 days interval starting from 30 days of planting and it was recorded upto 90 DAT.

3.14.1.2 Number of Leaf per plant

Number of Leaf per plant was measured from the sample plants and mean value was calculated. Data were recorded at 30 days interval starting from 30 days of planting and it was recorded upto 90 DAT.

3.14.1.3 Number of flower clusters per plant

The numbers of flower clusters were counted periodically from the sample plants and average number of flower clusters produced per plant was recorded at the time of final harvest.

3.14.1.4 Number of flowers per cluster The number of flowers per cluster was calculated by the following formula:

Number of flowers per cluster= $\frac{\text{Total number of flowers in sample plants}}{\text{Total number of flower clusters in sample plants}}$

3.14.1.5 Number of flowers per plant

The number of flowers per plant was calculated by the following formula:

Number of flowers per plant= Number of flower clusters per plant × Number of flowers per cluster.

3.14.1.6 Number of fruit clusters per plant

The number of clusters bearing fruits was counted from the sample plants and the average number of fruit clusters produced per plant was recorded and calculated at the final harvest.

3.14.1.7 Number of fruits per plant

All the mature and marketable fruits for an individual plants were calculated carefuly. For calculation of number of fruits per plant following formula was used:

Number of fruits per plant= $\frac{\textbf{Total number of fruits from 5 sample plants after harvest}}{\textbf{5}}$

3.14.2 Yield parameters

3.14.2.1 Weight of fruit per plant

All the mature and marketable fruits for an individual plants were calculated carefully. For measuring weight of fruits a pan scale balance was used to take the weight of fruits per plant and for the calculation of weight of fruits per plant following formula was used:

Weight of fruits per plant (kg)=$\frac{\textbf{Totala weight of fruits from 5 sample plants}}{\textbf{5}}$

3.14.2.2 Fruit yield per plot

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

3.14.2.3 Fruit yield per hectare

It was measured by the following formula:

Fruit yield per hectare (t) $= \frac{\text{Fruit yield per plot (kg)} \times 10000}{\text{Area of plot (m2)} \times 1000}$

3.14.3 Quality parameters

3.14.3.1 TSS %

Data on total Soluble Solids (TSS) were determined from 100 sample fruits for each treatment by adopting weight in air/weight in water method**.**

3.14.3.2 β-Carotene (mg per 100g)

Fruit analysis was carried out for quality parameters. About half kg of uniform ripened fruits collected from each treatment at intermediate stage were washed and cleaned, crushed and juice was extracted and used for estimating quality parameters as β-Carotene (mg per 100g) by using standard methods of analysis.

3.14.3.3 Vitamin-C (mg per 100g)

Fruit analysis was carried out for quality parameters. About half kg of uniform ripened fruits collected from each treatment at intermediate stage were washed and cleaned, crushed and juice was extracted and used for estimating quality parameters as Vitamin-C **(**ascorbic acid) by using standard methods of analysis.

3.15 Statistical analysis

The data obtained for different characters were statistically analyzed by using MSTAT-C computer package programme to find out the significance of the difference for potassium and boron quality and yield contributing characters of tomato. The mean values of all the recorded characters were evaluated and analysis of variance was performed by the ‘F’ (variance ratio) test. Difference between treatments was assessed by Least Significant Difference (LSD) test at 0.05% level of significance (Gomez and Gomez, 1984).

3.16 Economic analysis

The cost of production was analyzed in order to find out the most economic combination different level of planting time and organic nutrient sources. All input cost included the cost for lease of land and interests on running capital in computing the cost of production. The interests were calculated @ 14% in simple rate. Analyses were done according to the procedure of Alam *et al.* (1989). The benefit cost ratio (BCR) was calculated as follows:

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

a

b

c

d

Plate 2. Pictorial presentation of different activity (a) fruit development, (b) Ripen fruit harvesting, (c) Sample preparation for quality analysis (d) Titration for vitamin C level calculation

CHAPTER 4

RESULTS AND DISCUSSION

This chapter comprises the presentation and discussion of the results obtained from the effect of potassium and boron on the quality and yield of tomato. The results of the present Study were presented in Tables 2-7 and Figures 2-15.

4.1 Growth Parameter

4.1.1. Plant height

There was significant variation among different doses of Potassium in respect of plant height at different stages of growth (Table 2 & Fig. 2). Plant height was increased gradually with the passing of time up to final harvest in all doses of Potassium. Effect of different doses of potassium on plant height at 90 DAT was found to be statistically significant (Table 1). The plant height at 90 DAT varied from 101.1 to 113.9 cm with the regarding treatment variations. The maximum plant height at 30 DAT, 60 DAT and 90 DAT was (24.14 cm, 104.4 cm and 113.9 cm) was recorded in plant grown with K_3 (140 kg K ha^{-1}) and the minimum (113.9 cm, 94.29 cm and 101.1 cm) was found at 0 kg K/ha (control) respectively. So. It is easily calculated that with the increasing rate of potassium show positive increase in plant height of tomato. Harneet *et al*., (2004) stated that K_2O increased plant height up to maximum doses with an increasing trend and Probably, K2O ensured the availability of other essential nutrients as a result, maximum growth was occurred and the ultimate results are the maximum plant height. Chandra *et al*., (2003) recorded the significant increase in the plant height (95 cm) with K application at flower initiation stage in tomato. Liu *et al*., (2004) reported that spraying of K_2O at 100 kg/ha increased the plant height.

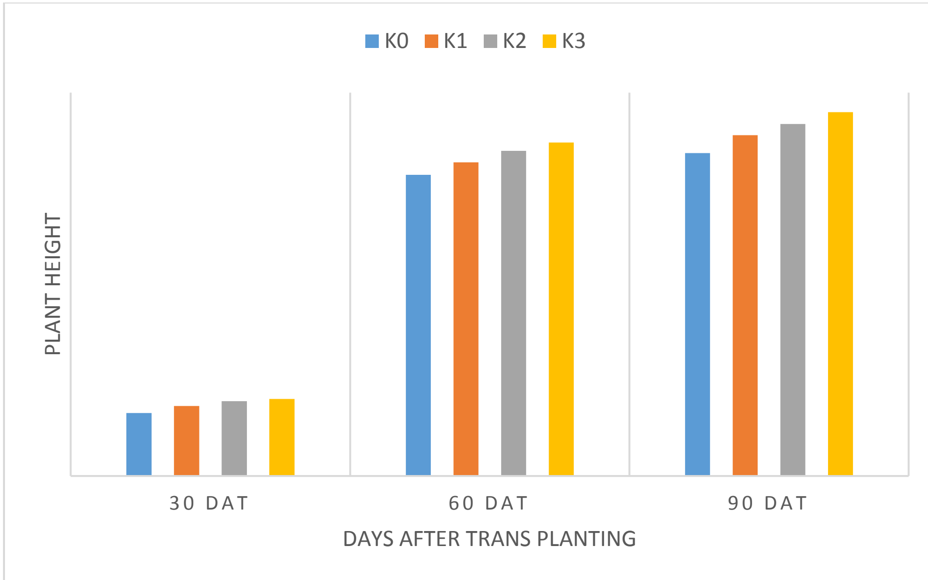


Figure 2. Plant height of tomato as influenced by potassium (K)

Here, K_0 = 0 kg K ha^{-1} K_1= 80 kg K ha^{-1} K_2 = 120 kg K ha^{-1} K_3 = 140 kg K ha^{-1}

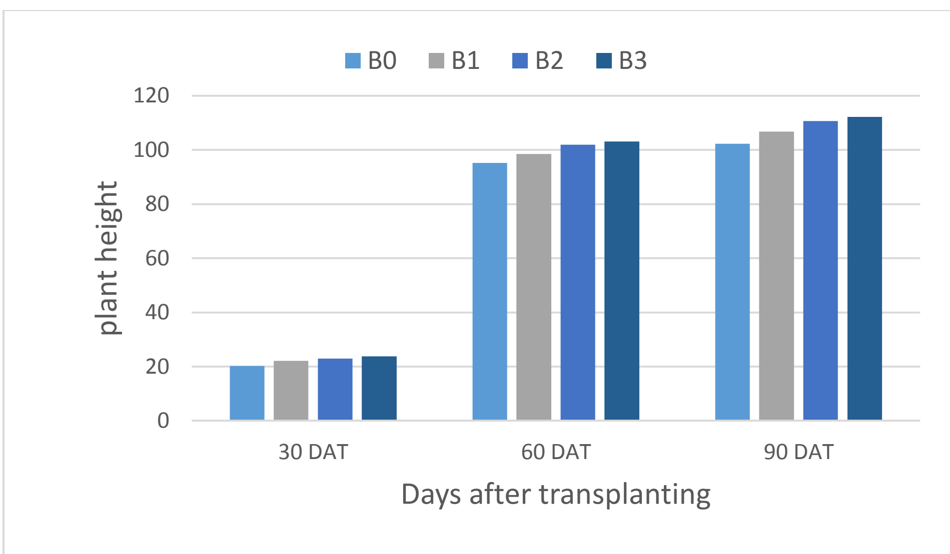


Figure 3. Plant height of tomato as influenced by boron (B)

Here, B_0 = 0 kg B ha^{-1} (control), B_1 = 0.6 kg B ha^{-1}, B_2 = 1.2 kg B ha^{-1}, B_3 = 1.8 kg B ha^{-}

1

Significance difference was observed due to application of different levels of boron on plant height at different days after transplanting (Table 2 & Fig. 3). It was observed that in case of all the boron doses plant height was increased gradually with the passing of time and it was continued up to the last data record at 90 DAT. Among the different levels of boron treatments on plant height at final harvest was found to be statistically significant. At final harvest the plant height varied from 102.3 cm to 112.2 cm (Table 1). The maximum plant height at 30 DAT, 60 DAT and 90 DAT was (23.78 cm, 103.1 cm and 112.2 cm) was recorded in plant grown with B_3 (1.8 kg B ha-1) and the minimum (20.24 cm, 95.21 cm and 102.3 cm) was found at 0 kg B/ha (control) respectively. At 60 DAT B2 (1.2 kg B ha-1) was statistically similar to the B3 (1.8 kg B ha-1).The maximum plant height (112.2 cm) was recorded in plant grown with 1.8 kg B ha-1 and the minimum (102.3 cm) was recorded from the 0 kg B ha-1. Gupta and Shukla (1977) reported that application of potassium increased plant height.

The variations in plant height at different days after planting due to combined effect of potassium and boron were found to be statistically significant at 30 DAT, 60 DAT and 90 DAT (Table 2 and Appendix IV). Plant height was gradually increased with the age of plant up to 90 DAT due to indeterminate type of variety. The plant height at 90 DAT ranged from 96.92 cm to 119.2 cm. The highest plant height was recorded (119.2 cm) from the treatment combination of 140 kg K ha-1 with 1.8 kg B ha-1 and the shortest plant (96.92 cm) was found from the treatment combination of zero potassium with 0 kg B/ha. Similar result was observed from Gupta and Shukla (1977).

Table 2. Plant height of tomato as influenced by potassium (K) and boron (B)

Treatment	Plant height (cm)		
	30 DAT	60 DAT	90 DAT
Effect of potassium (K)			
K_0	19.69 d	94.29 d	101.1 d
K_1	21.94 c	98.20 c	106.7 c
K_2	23.36 b	101.8 b	110.2 b
K_3	24.14 a	104.4 a	113.9 a
$LSD_{0.05}$	0.7381	0.8393	1.339
CV(%)	6.93	6.49	9.58
Effect of boron (B)			
B_0	20.24 d	95.21 c	102.3 d
B_1	22.16 c	98.46 b	106.7 c
B_2	22.95 b	101.9 a	110.7 b
B_3	23.78 a	103.1 a	112.2 a
$LSD_{0.05}$	0.7378	1.322	1.339
CV(%)	6.93	6.49	9.58
Combined effect of K and B			
K_0B_0	18.64 k	91.47 j	96.92 k
K_0B_1	18.75 k	91.71 j	97.36 k
K_0B_2	19.52 j	95.85 h	103.7 i
K_0B_3	21.84 h	98.14 fg	106.3 h
K_1B_0	19.32 j	93.48 i	100.5 j
K_1B_1	22.53 fg	98.94 f	107.9 fg
K_1B_2	22.72 f	100.1 e	108.7 ef
K_1B_3	23.18 e	100.3 e	109.7 e
K_2B_0	20.78 i	97.22 g	104.4 i
K_2B_1	23.48 e	101.3 d	109.9 e
K_2B_2	24.43 c	104.0 c	112.8 cd
K_2B_3	24.77 bc	104.5 c	113.7 c
K_3B_0	22.24 g	98.67 f	107.3 gh
K_3B_1	23.88 d	101.8 d	111.8 d
K_3B_2	25.12 ab	107.7 b	117.4 b
K_3B_3	25.33 a	109.4 a	119.2 a
$LSD_{0.05}$	0.3839	0.9879	1.102
CV(%)	6.93	6.49	9.58

Here,

K_0 = 0 kg K ha^{-1} (control), K_1= 80 kg K ha^{-1}, K_2 = 120 kg K ha^{-1}, K_3 = 140 kg K ha^{-1}

B_0 = 0 kg B ha^{-1} (control), B_1 = 0.6 kg B ha^{-1}, B_2 = 1.2 kg B ha^{-1}, B_3 = 1.8 kg B ha^{-1}

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

4.1.2 Number of leaves per plant

The significant variation was found at 30, 60, and 90 DAT due to the application of different levels of potassium except (Table 3 & Fig. 4). At 30 DAT, the highest number of leaves per plant (14.39) was found from K_2 (120 kg/ha K) which was statistically similar to K3 (14.06) while the lowest number of leaves per plant (11.56) was observed from K_0 (control). At 60 DAT, the maximum number of leaves per plant (31.22) was recorded from K2 (120 kg/ha K) which was statistically similar to K3 (30.36) while the lowest number of leaves per plant (25.56) was obtained from K_0 (control). At 90 DAT, the maximum number of leaves per plant (40.52) was recorded from K2 (120 kg/ha K) which was statistically similar to K3 (39.89) while the lowest number of leaves per plant (36.04) was obtained from K_0 (control). It may concluded that 120 kg/ha K will be the most competent dose of tomato for maximum leaf number and character related to leaf number. Similar observation was found from Cerne and Briski (1993) study they reported that K enhanced the effect of on vegetative growth in tomato. Chandra et al., (2003) also reported the effect of potassium for improving the tomato cv. Alicante and mentioned that the application of potassium increased the number of leaves per plant.

Significance difference was observed due to application of different levels of boron on number of leaves per plant at different days after planting (Table 3 & Fig. 5). It was observed that in case of all the boron doses number of leaves per plant was increased gradually with the passing of time and it was continued up to the last data record at 90 DAT. Among the different levels of boron treatments on number of leaves per plant at 90 DAT was found to be maximum number of leaves per plant. At 90 DAT the number of leaves per plant varied from 39.26 to 36.72 (Table 2). At 30 DAT, the highest number of leaves per plant (14.42) was found from B_2 (1.2 kg/ha B) while the lowest number of leaves per plant (12.00) was observed from K_0 (control). At 60 DAT, the maximum number of leaves per plant (30.92) was

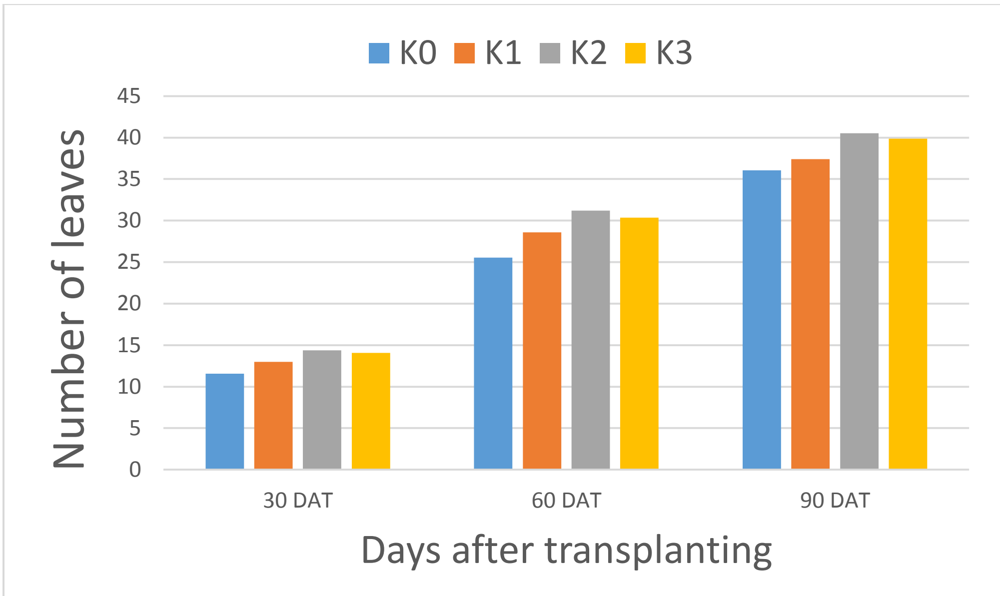


Figure 4. Number of leaves per plant of tomato as influenced by Potassium (K)

Here, K_0: 0 kg K ha^{-1} K_1: 80 kg K ha^{-1} K_2: 120 kg K ha^{-1} K_3: 140 kg K ha^{-1}

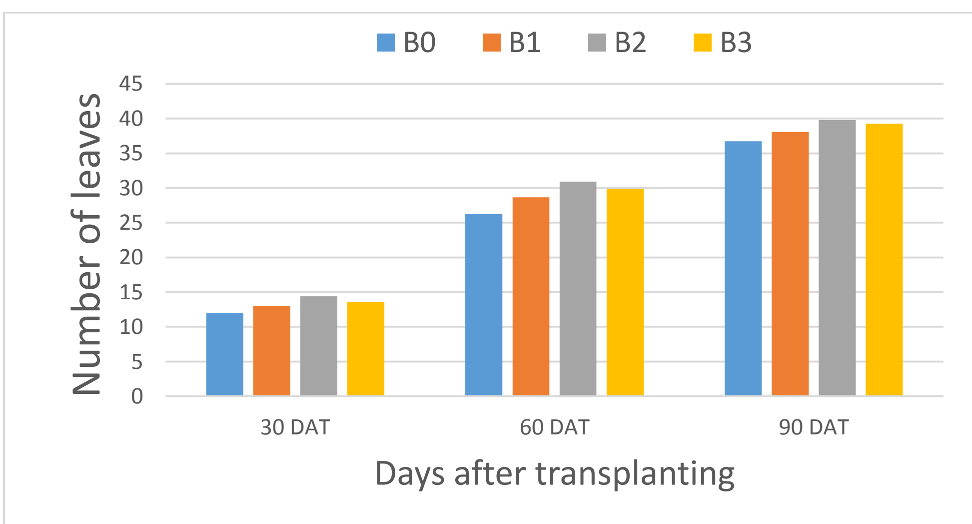


Figure 5. Number of leaves per plant of tomato as influenced by boron (B)

Here, B_0: 0 kg B ha^{-1}, B_1: 0.6 kg B ha^{-1}, B_2: 1.2 kg B ha^{-1}, B_3: 1.8 kg B ha^{-1}

recorded from B_2 (1.2 kg/ha B) while the lowest number of leaves per plant (26.28) was obtained from B_0 (control). At 90 DAT, the maximum number of leaves per plant (39.78) was recorded from B_2 (1.2 kg/ha B) which was statistically similar to B3 (39.26) while the lowest number of leaves per plant (36.72) was obtained from B_0 (control). Similar result was found from Yadav *et al.* (2001) and they reported that number of leaves were significantly influenced by the increase of boron up to 1.5 kg/ha. Oyewole and Aduayi (1992) observed that application of B at 2 p.p.m. increased leaf number, stem diameter, number of flowers and fruit yield, and reduced per cent flower abortion

Interaction effect of K and B on the number of leaves per plant was also significant at 30 DAT, 60 DAT and 90 DAT (Table 3). At 30 DAT the maximum number of leaves per plant (15.48) was recorded from K_3B_2 (140 kg/ha of K + 1.2 kg B per ha) and the minimum number of leaves per plant (11.05) was found from K_0B_0 (no K+no B) which was similar to K_0B_1, K_1B_0, $K_0B_{3.}$ At 60 DAT the maximum number of leaves per plant (33.75) was found from K_2B_2 (120 kg/ha of K + 1.2 kg B per ha) the minimum number of leaves per plant (24.48) was obtained from K_0B_0 (no K+no B) which was similar to K_0B_1, K_1B_0, $K_0B_{3.}$ At 90 DAT the maximum number of leaves per plant (42.92) was found from K_2B_2 (120 kg/ha of K + 1.2 kg B per ha) which was statistically similar to K_3B_2 where the minimum number of leaves per plant (35.23) was obtained from K_0B_0 (no K+no B) which was similar to K_0B_1, K_1B_{0}..

Table 3. Number of leaves plant-1t of tomato as influenced by potassium (K) and boron (B)

Treatment	Number of leaves plant^{-1}		
	30 DAT	60 DAT	90 DAT
Effect of potassium (K)			
K_0	11.56 c	25.56 c	36.04 c
K_1	12.97 b	28.58 b	37.39 b
K_2	14.39 a	31.22 a	40.52 a
K_3	14.06 a	30.36 a	39.89 a
$LSD_{0.05}$	0.7793	1.026	1.174
CV(%)	6.93	6.49	9.58
Effect of boron (B)			
B_0	12.00 c	26.28 d	36.72 c
B_1	13.01 b	28.66 c	38.08 b
B_2	14.42 a	30.92 a	39.78 a
B_3	13.56 b	29.86 b	39.26 a
$LSD_{0.05}$	0.7451	1.026	0.9261
CV(%)	6.93	6.49	9.58
Combined effect of K and B			
K_0B_0	11.05 k	24.48 j	35.23 j
K_0B_1	11.12 k	24.66 j	35.32 j
K_0B_2	12.44 i	27.14 h	37.18 h
K_0B_3	11.64 j	25.95 i	36.44 i
K_1B_0	11.48 jk	24.78 j	36.36 i
K_1B_1	13.07 gh	28.77 g	38.14 fg
K_1B_2	13.92 de	30.60 ef	36.45 i
K_1B_3	13.42 fg	30.18 f	38.62 ef
K_2B_0	12.88 hi	28.36 g	37.77 gh
K_2B_1	14.18 cd	30.93 de	39.63 cd
K_2B_2	15.84 a	33.75 a	42.92 a
K_2B_3	14.67 b	31.84 bc	41.75 b
K_3B_0	12.58 i	27.52 h	37.52 gh
K_3B_1	13.67 ef	30.27 f	39.24 de
K_3B_2	15.48 a	32.18 b	42.56 a
K_3B_3	14.52 bc	31.48 cd	40.24 c
$LSD_{0.05}$	0.4251	0.5776	0.6350
CV(%)	6.93	6.49	9.58

K_0: 0 kg K ha^{-1} (control), K_1: 80 kg K ha^{-1}, K_2: 120 kg K ha^{-1}, K_3:140 kg K ha^{-1}

B_0: 0 kg B ha^{-1} (control), B_1: 0.6 kg B ha^{-1}, B_2: 1.2 kg B ha^{-1}, B_3: 1.8 kg B ha^{-1}

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

4.2 Yield Contributing Parameter

4.2.1 Number of flower clusters per plant

The significant variation was found due to the application of different levels of potassium except (Table 4 & Fig. 6). The maximum number of flower clusters per plant (8.320) was recorded from K2 (120 kg/ha K) which was statistically similar to K3 (8.097) while the lowest number of flower clusters (6.648) was obtained from K_0 (no potassium was applied). It may concluded that 120 kg/ha K will be the most competent dose of tomato for maximum number of flower clusters per plant. Similar observation was found from Cerne and Briski (1993), they reported that K enhanced vegetative growth in tomato. Chandra et al., (2003) also reported the effect of potassium for improving the tomato cv. Alicante and mentioned that the application of potassium increased the number of flower clusters per plant.

Significance difference was observed due to application of different levels of boron on number of flower clusters per plant. The number of flower clusters per plant varied from 6.852 to 8.243 (Table 4 & Fig. 7). The maximum number of flower clusters per plant (8.24) was recorded from B_2 (1.2 kg/ha B) which was statistically similar to B_3 (1.2 kg/ha B) and mean value was 7.98 while the lowest number of flower clusters (6.85) was obtained from B_0 (no boron was applied).

In case of combined effect of potassium and boron on number of flower clusters per plant was observed significant effect. The maximum number of flower clusters per plant (8.93) was found from K_2B_2 (120 kg/ha of K + 1.2 kg B per ha) which was statistically similar to K_3B_2 and K_2B_3 where the minimum number of flower clusters per plant (6.26) was obtained from K_0B_0 (no K+no B) which was similar to K_0B_1.

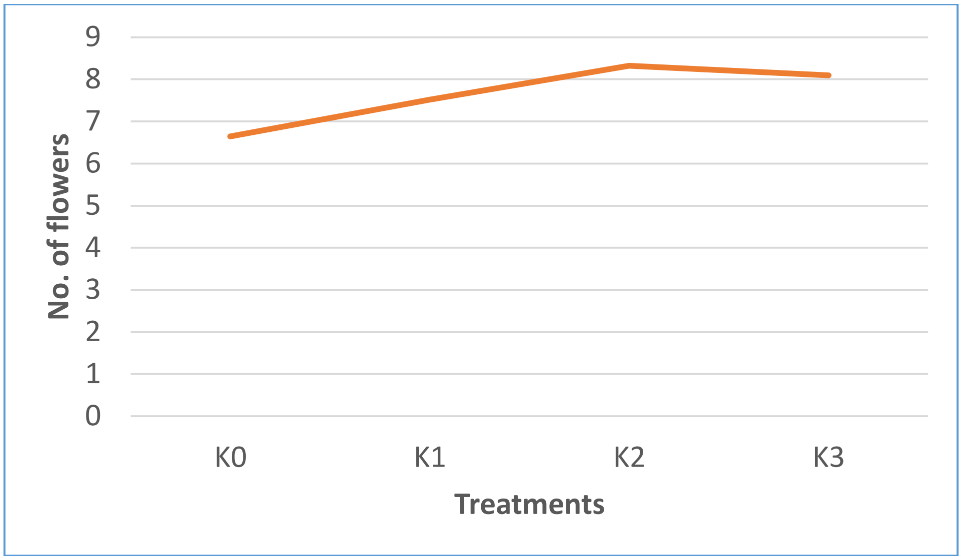


Figure 6. No. of flower clusters per plant of tomato plant as influenced by potassium (K)

K_0: 0 kg K ha^{-1} K_1: 80 kg K ha^{-1} K_2: 120 kg K ha^{-1} K_3: 140 kg K ha^{-1}

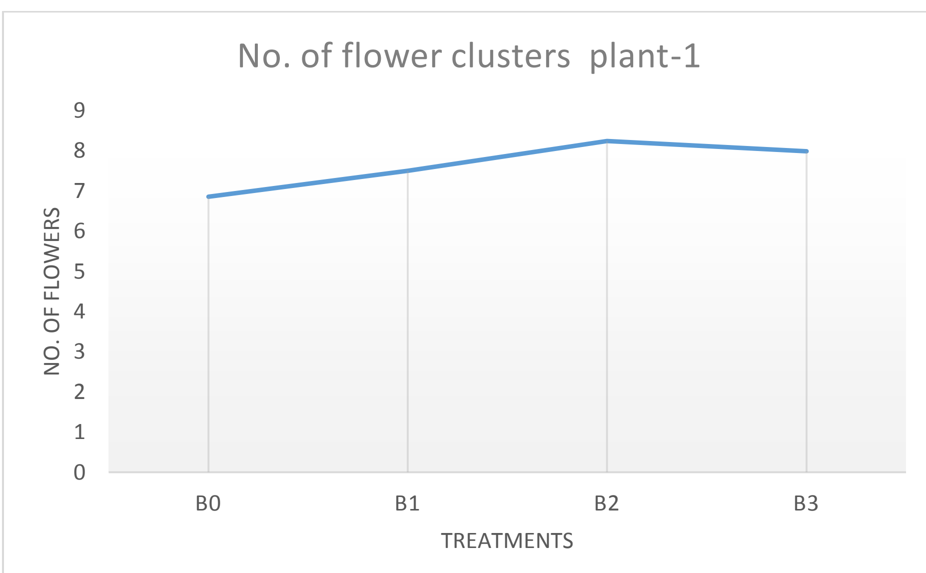


Figure 7. No. of flower clusters per plant of tomato plant as influenced by

Boron (K)

B_0: 0 kg B ha^{-1}, B_1: 0.6 kg B ha^{-1}, B_2: 1.2 kg B ha^{-1}, B_3: 1.8 kg B ha^{-1}

4.2.2 Number of flowers per cluster

The significant variation was found due to the application of different levels of potassium on number of flowers per cluster in tomato plants (Table 4). The maximum number of flowers per cluster (6.59) was recorded from K2 (120 kg/ha K) Which was statistically similar to K3 (6.41) while the lowest number of flowers per cluster (4.94) was obtained from K_0 (no potassium was applied). It may concluded that 120 kg/ha K will be the most functional recommendation of tomato plants for obtaining maximum number of flowers per cluster. Liu *et al.,* (2004) observed that the effect of 150 kg/ha K increased the number of flower per cluster of Dhananshree tomato cultivar. Silva and Vizzotto (1990) observed that the application of K (150 kg/ha K) at 50 percent flowering increased fruit set and total yield of tomato. On other hand, Chandra *et al.,* (2003) reported that K was very crucial for the development of the fertile flowers at the medium and the lower concentration respectively.

Significance difference was observed due to application of different levels of boron on number of flowers per cluster. The number of flowers per cluster varied from 5.04 to 6.59 (Table 4). The maximum number of flowers per cluster (6.59) was recorded from B_2 (1.2 kg/ha B) which was statistically similar to B_3 (1.2 kg/ha B) and mean value was 6.26 while the lowest number of flowers per cluster (5.04) was obtained from B_0 (no boron was applied). The data raveled that maximum number of flowers per cluster was obtain from the treatment of B_2 (1.2 kg/ha B) and control treatment showed lowest result. Oyewole and Aduayi (1992) observed that Application of B at 2 p.p.m. increased leaf number, stem diameter, number of flowers and fruit yield, and reduced per cent flower abortion.

Table 4. Yield contributing parameters of tomato as influenced by potassium (K) and boron (B)

Treatment	Yield contributing parameters			
	Number of flower clusters per plant	Number of flowers per cluster	Number of fruits per cluster	Number of fruits per plant
Effect of potassium (K)				
K_0	6.648 c	4.945 c	3.933 c	26.19 d
K_1	7.515 b	5.655 b	4.213 b	31.75 c
K_2	8.320 a	6.590 a	4.547 a	37.93 a
K_3	8.097 a	6.410 a	4.478 a	36.40 b
$LSD_{0.05}$	0.2306	0.5494	0.07573	0.7264
CV(%)	5.59	10.30	6.02	7.34
Effect of boron (B)				
B_0	6.852 c	5.040 c	4.069 c	27.97 d
B_1	7.503 b	5.705 b	4.282 b	32.32 c
B_2	8.243 a	6.593 a	4.503 a	37.31 a
B_3	7.983 a	6.262 a	4.317 b	34.67 b
$LSD_{0.05}$	0.3968	0.5494	0.08843	1.024
CV(%)	5.59	10.30	6.02	7.34
Combined effect of K and B				
K_0B_0	6.260 i	4.640 i	3.853 g	24.14 j
K_0B_1	6.330 i	4.720 i	3.867 g	24.48 ij
K_0B_2	7.120 fg	5.300 fg	4.103 f	29.24 g
K_0B_3	6.880 gh	5.120 gh	3.910 g	26.92 h
K_1B_0	6.640 h	4.900 hi	3.947 g	26.22 hi
K_1B_1	7.420 e	5.520 f	4.337 e	32.20 f
K_1B_2	8.120 cd	6.270 d	4.397 de	35.70 e
K_1B_3	7.880 d	5.930 e	4.170 f	32.88 f
K_2B_0	7.330 ef	5.400 fg	4.317 e	31.64 f
K_2B_1	8.300 bc	6.400 d	4.513 cd	37.48 d
K_2B_2	8.930 a	7.440 a	4.793 a	42.82 a
K_2B_3	8.720 a	7.120 bc	4.563 c	39.78 bc
K_3B_0	7.180 ef	5.220 fg	4.160 f	29.87 g
K_3B_1	7.960 d	6.180 de	4.413 de	35.12 e
K_3B_2	8.800 a	7.360 ab	4.717 ab	41.50 ab
K_3B_3	8.450 b	6.880 c	4.623 bc	39.10 cd
$LSD_{0.05}$	0.2583	0.2983	0.1395	1.750
CV(%)	5.59	10.30	6.02	7.34

K_0 = 0 kg K ha^{-1} (control), K_1= 80 kg K ha^{-1}, K_2 = 120 kg K ha^{-1}, K_3 = 140 kg K ha^{-1}

B_0 = 0 kg B ha^{-1} (control), B_1 = 0.6 kg B ha^{-1}, B_2 = 1.2 kg B ha^{-1}, B_3 = 1.8 kg B ha^{-1}
In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Interaction effect of K and B on the number of flower per cluster was significant (Table 4). The maximum number of flowers per cluster (7.44) was found from K_2B_2 (120 kg/ha of K + 1.2 kg B per ha) which was statistically similar to K_3B_2 where the minimum number of flowers per cluster (4.64) was obtained from K_0B_0 (no K+no B) which was similar to K_0B_1.

4.2.3 Number of fruits per cluster

The significant variation was found due to the application of different levels of potassium on number of fruits per cluster in tomato plants (Table 4 and Fig. 8). The maximum number of fruits per cluster (4.54) was recorded from K2 (120 kg/ha K) which was statistically similar to K3 (4.47) while the lowest number of fruits per cluster (3.93) was obtained from K_0 (no potassium was applied). It may concluded that 120 kg/ha K will be the most functional recommendation of tomato plants for obtaining maximum number of fruits per cluster. Liu *et al.*, (2004) observed that the effect of 150 kg/ha K increased the number of flower per cluster of Dhananshree tomato cultivar.Silva and Vizzotto (1990) observed that the application of K (150 kg/ha K) at 50 percent flowering increased fruit set and total yield of tomato. On other hand, Chandra *et al.*, (2003) reported that K wasvery crucial for the development of the fertile flowers at the medium and the lower concentration respectively.

Significance difference was observed due to application of different levels of boron on number of fruits per cluster. The number of fruits per cluster varied from 4.06 to 4.50 (Table 4 and Fig. 9). The maximum number of fruits per cluster (4.50) was recorded from B_2 (1.2 kg/ha B) while the lowest number of fruits per cluster (4.06) was obtained from B_0 (no boron was applied). These results indicated that higher dose of boron favored the higher number of flower per cluster. Naresh

(2002) reported that B also had positive effects on flowers and number of fruit set per plant, resulting in an increase in the number of fruits per plant and total yield.

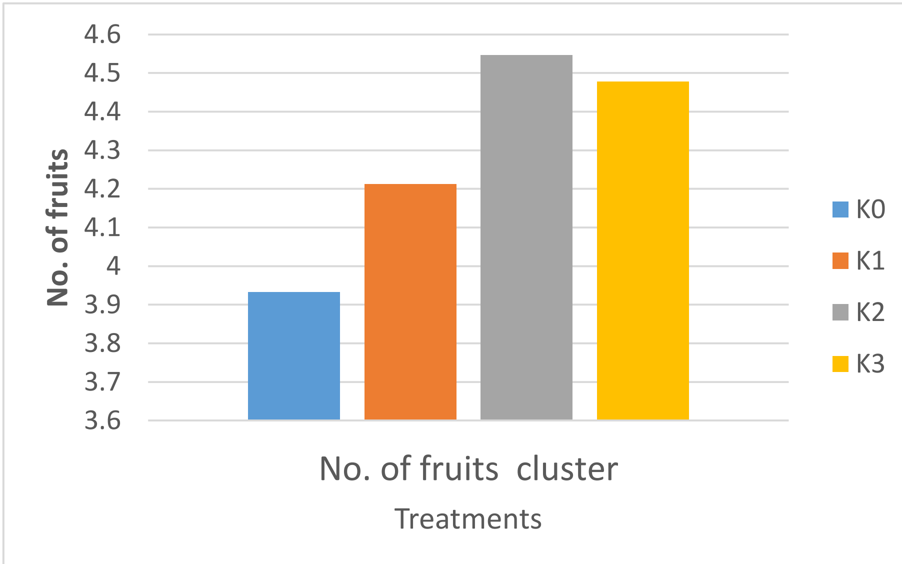


Figure 8. No. of fruits per cluster and no. of fruits per plant of tomato as influenced by potassium (K)

Here, K_0: 0 kg K ha^{-1} K_1: 80 kg K ha^{-1} K_2: 120 kg K ha^{-1} K_3: 140 kg K ha^{-1}

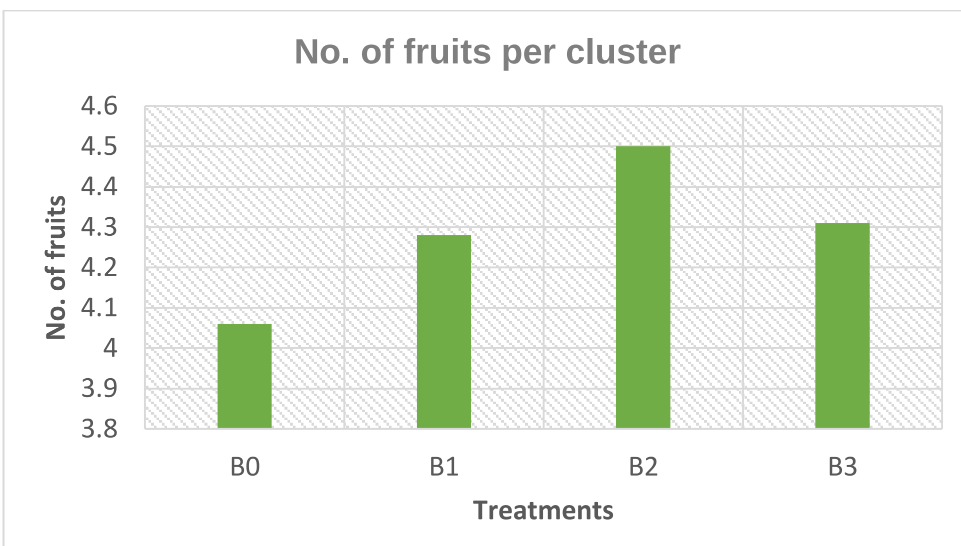


Figure 9. No. of fruits per cluster of tomato as influenced by boron (B)

Here, B_0: 0 kg B ha^{-1}, B_1: 0.6 kg B ha^{-1}, B_2: 1.2 kg B ha^{-1}, B_3: 1.8 kg B ha^{-1}

Interaction effect of K and B on the number of fruits per cluster was significant (Table 4). The maximum number of fruits per cluster (4.793) was found from K_2B_2 (120 kg/ha of K + 1.2 kg B per ha) which was statistically similar to K_3B_1 where the minimum number of fruits per cluster (3.85) was obtained from K_0B_0 (no K + no B) which was similar to K_0B_1, $K_0B_{3,}$ $K_1B_{0.}$

4.2.4 Number of fruits per plant

Number of fruits per plant varied significantly due to the application of different Levels of potassium. The maximum (37.93) of number of fruits per plant was recorded from K2 (120 kg/ha K) while the minimum (26.19) number of fruits per plant were recorded from K0 (control) treatment (Table 4 and Fig. 10).

Boron had significantly influenced the number of mature fruits per plant (Table 4 and Fig. 11) The maximum number of mature fruits (37.31) per plant was obtained from 1.2 kg B/ha. The minimum number of fruits (27.97) was harvested from the control (0 kg B/ha). The results clearly showed that the number of mature fruits per plant was gradually influnced with the increasing levels of boron. Naresh (2002) reported that B also had positive effects on flowers and number of fruit set per plant, resulting in an increase in the number of fruits per plant and total yield.

Combined effect of different levels of potassium and boron on number of fruits per plant was found to be statistically significant ((Table 4 & Appendix VII). The maximum number of ripe commercial size fruits per plant (42.82) was obtained from the treatment combination of K_2B_2 (120 kg/ha of K + 1.2 kg B per ha). It might be due to the fact that this combination provided sufficient available nutrients in soil than other treatment combinations. The minimum number (24.14) was obtained from the treatment combination of zero potassium with no boron per hectare.

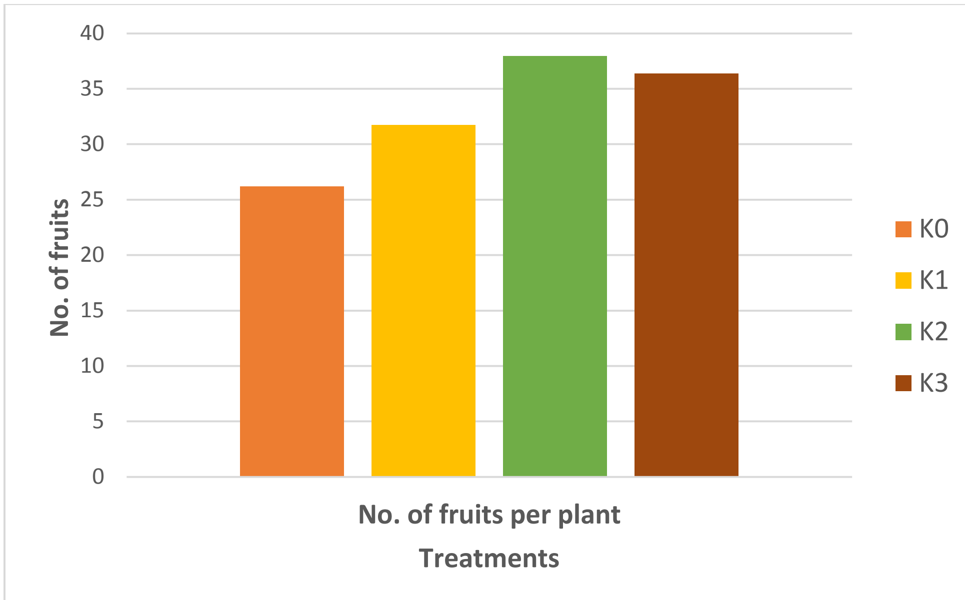


Figure 10. No. of fruits per plant of tomato as influenced by potassium (K)

Here, K_0: 0 kg K ha^{-1} K_1: 80 kg K ha^{-1} K_2: 120 kg K ha^{-1} K_3: 140 kg K ha^{-1}

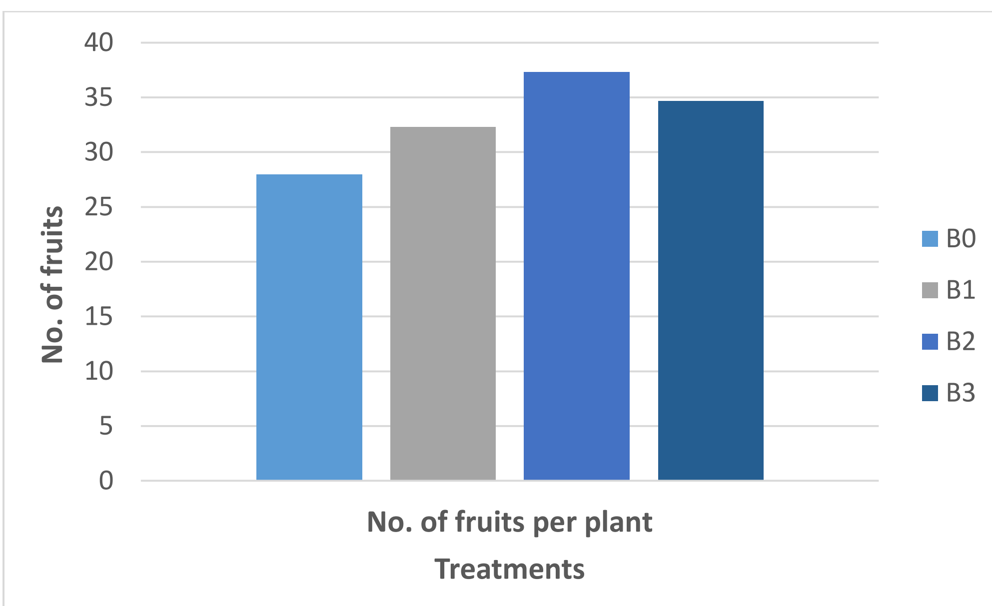


Figure 11. No. of fruits per plant of tomato as influenced by boron (B)

Here, B_0: 0 kg B ha^{-1}, B_1: 0.6 kg B ha^{-1}, B_2: 1.2 kg B ha^{-1}, B_3: 1.8 kg B ha^{-1}

4.3 Yield parameters

4.3.1 Fruit weight per plant (Kg)

Fruit weight per plant (Kg) was significantly varied with the application of different levels of potassium (Table 5 and Fig. 12). The maximum fruit wt per plant (Kg) (0.95) was recorded from K_2 (120 kg/ha K) which was statistically similar with K_3 (140 kg/ha K) while the minimum fruit wt per plant (Kg) (0.67) was recorded from K0 (control) treatment (Table 4). Sofonias *et al.* (2018) reported that fruit diameter, fruit weight per plant, total yield and fruit dry matter content showed significant increase with an increase in potassium level from 0 to 150 kg K_2O/ha.

Boron had significantly influenced the fruit wt per plant (Kg) (Table 5 and Fig. 13). The maximum fruit wt. per plant (Kg) (0.93) was obtained from 1.2 kg B/ha. The minimum fruit wt. per plant (0.69) was harvested from the control (0 kg B/ha). The results clearly showed that the fruit wt. per plant was greatly influenced with the increasing levels of boron than maximum treatment of boron 1.8 kg/ha because optimum level of boron is very critical dose and differ very shortly.

Combined effect of different levels of potassium and boron on fruit wt. per plant (Kg) was found to be statistically significant (Table 5 & Appendix VII). The maximum fruit wt. per plant (Kg) (1.070) was obtained from the treatment combination of K_2B_2 (120 kg/ha of K + 1.2 kg B per ha) and similar to the treatment combination of K_3B_2 (140 kg/ha of K + 1.2 kg Boron per ha). It could be happen due to the matter that this treatment combination ensure optimum available nutrients in soil than other treatment combinations. The minimum fruit wt. per plant (Kg) (0.63) was obtained from the treatment combination of zero potassium with no boron per hectare which was similar to K_0B_1.

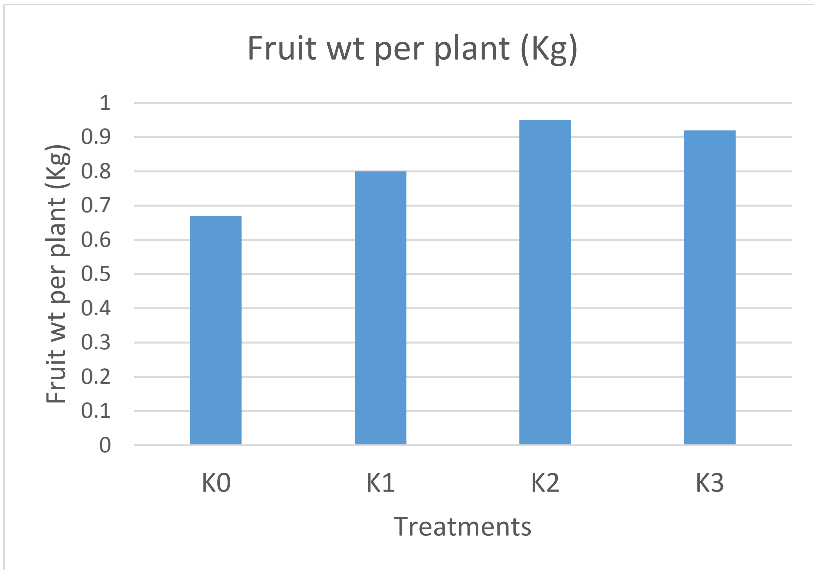


Figure 12. Fruit wt. per plant of tomato as influenced by potassium (K)

Here, K_0: 0 kg K ha^{-1} K_1: 80 kg K ha^{-1} K_2: 120 kg K ha^{-1} K_3: 140 kg K ha^{-1}

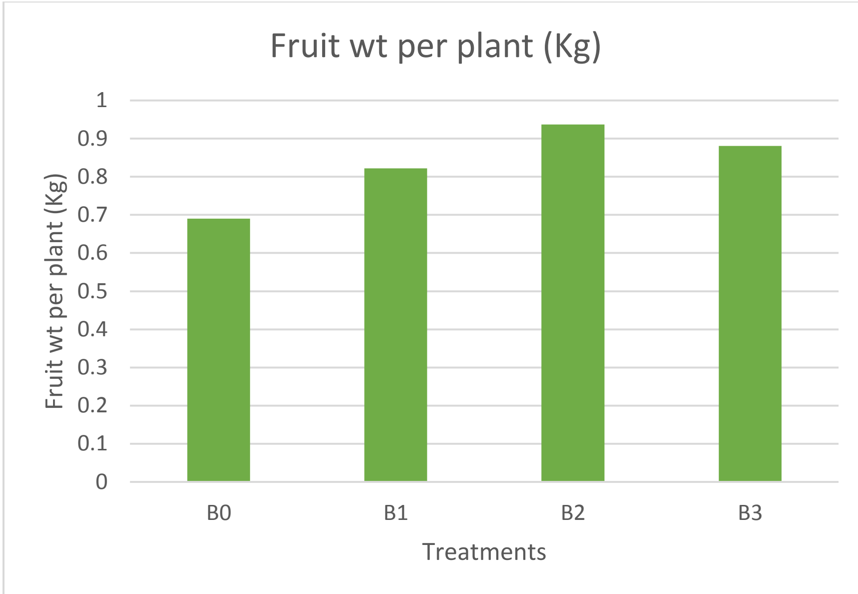


Figure 13. Fruit wt. per plant of tomato as influenced by boron (B)

Here, B_0: 0 kg B ha^{-1}, B_1: 0.6 kg B ha^{-1}, B_2: 1.2 kg B ha^{-1}, B_3: 1.8 kg B ha^{-1}

Table 5. Yield parameters of tomato as influenced by potassium (K) and boron (B)

Treatment	Yield parameters		
	Fruit wt per plant (Kg)	Fruit wt per plot (Kg)	Fruit yield (t ha^{-1})
Effect of potassium (K)			
K_0	0.67 c	3.99 c	44.36 d
K_1	0.80 b	4.78 b	53.14 c
K_2	0.95 a	5.68 a	63.19 a
K_3	0.92 a	5.51 a	61.22 b
$LSD_{0.05}$	0.08	0.24	0.4253
CV(%)	4.10	7.06	8.06
Effect of boron (B)			
B_0	0.69	4.14 d	45.97 d
B_1	0.82	4.92 c	54.67 c
B_2	0.93	5.62 a	62.50 a
B_3	0.88	5.29 b	58.78 b
$LSD_{0.05}$	0.40	0.23	0.7388
CV(%)	4.10	7.06	8.06
Combined effect of K and B			
K_0B_0	0.63 e	3.79 j	42.11 i

K_0B_1	0.64 e	3.82 j	42.44 i
K_0B_2	0.70 de	4.24 gh	47.11 fgh
K_0B_3	0.69 de	4.12 hi	45.78 gh
K_1B_0	0.66 e	3.96 ij	44.00 hi
K_1B_1	0.79 cd	4.77 e	53.00 e
K_1B_2	0.92 bc	5.52 d	61.33 cd
K_1B_3	0.81 cd	4.88 e	54.22 e
K_2B_0	0.74 de	4.48 f	49.78 f
K_2B_1	0.95 ab	5.73 c	63.67 c
K_2B_2	1.07 a	6.42 a	71.33 a
K_2B_3	1.02 ab	6.12 b	68.00 b
K_3B_0	0.72 de	4.32 fg	48.00 fg
K_3B_1	0.89 bc	5.36 d	59.55 d
K_3B_2	1.05 a	6.32 a	70.22 ab
K_3B_3	1.00 ab	6.04 b	67.11 b
$LSD_{0.05}$	0.11	0.19	3.051
CV(%)	4.10	7.06	8.06

K_0 = 0 kg K ha^{-1} (control), K_1= 80 kg K ha^{-1}, K_2 = 120 kg K ha^{-1}, K_3 = 140 kg K ha^{-1}

B_0 = 0 kg B ha^{-1} (control), B_1 = 0.6 kg B ha^{-1}, B_2 = 1.2 kg B ha^{-1}, B_3 = 1.8 kg B ha^{-1}

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

4.3.2 Fruit weight per plot (Kg)

Fruit weight per plot (Kg) was significantly varied with the application of different levels of potassium (Table 5). The maximum fruit wt per plant (Kg) (5.68) was recorded from K_2 (120 kg/ha K) which was statistically similar with K_3 (140 kg/ha K) and mean value was 5.51 while the minimum fruit wt per plot (Kg) (3.99) was recorded from K0 (control) treatment (Table 4). Sofonias *et al.* (2018) reported that fruit diameter, fruit weight per plant, total yield and fruit dry matter content showed significant increase with an increase in potassium level from 0 to 150 kg K_2O/ha.

Boron had significantly influenced the Fruit wt per plot (Kg) (Table 5). The maximum fruit wt. per plot (Kg) (5.62) was obtained from 1.2 kg B/ha. The minimum fruit wt. per plot (4.13) was harvested from the control (0 kg B/ha). The results clearly showed that the fruit wt. per plot was greatly influenced with the increasing levels of boron other than maximum treatment of boron 1.8 kg/ha because optimum level of boron is very critical dose and differ very shortly.

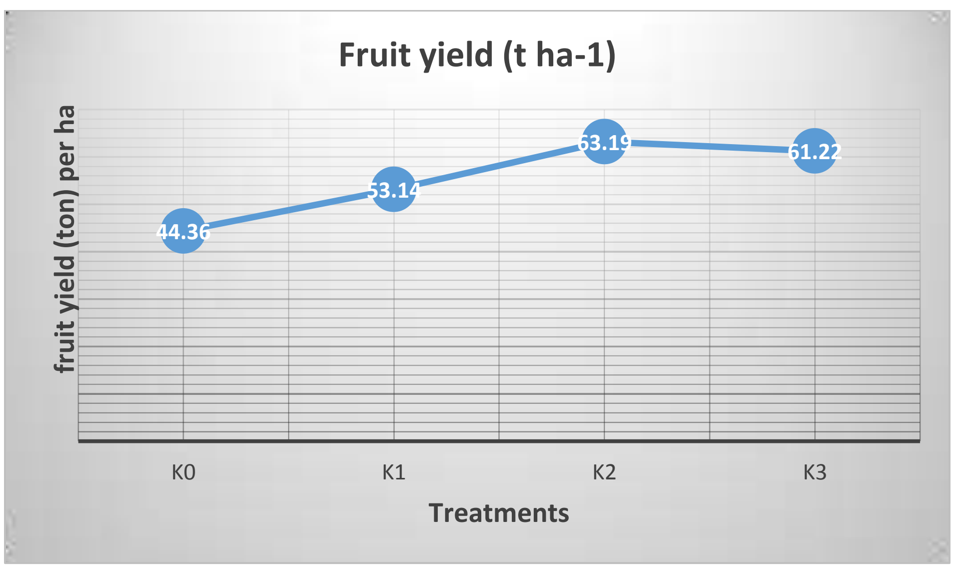
Combined effect of different levels of potassium and boron on fruit wt. per plot (Kg) was found to be statistically significant ((Table 5 & Appendix VII). The maximum fruit wt. per plot (Kg) (6.420) was obtained from the treatment combination of K_2B_2 (120 kg/ha of K + 1.2 kg B per ha) and similar to the treatment combination of K_3B_2 (140 kg/ha of K + 1.2 kg Boron per ha). It might be due to the fact that this combination provided sufficient available nutrients in soil than other treatment combinations. The minimum fruit wt. per plant (Kg) (3.79) was obtained from the treatment combination of zero potassium with no boron per hectare which was similar to K_0B_1.

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

Different level of potassium showed significant variation for fruit yield per hectare of tomato (Table 5 and Appendix VIII, Fig. 14). The highest (63.19 t/ha) yield was recorded from K2 (120 kg K ha-1) which was statistically higher (61.22 t/ha) to K3 (140 kg K ha-1), while the lowest (44.36 t/ha) yield was found from K_0 (control) treatment (Table 4). Pansare *et al*., (2004) reported that the maximum yield tomato was obtained when straight fertilizers were added in the 130 kg K2O/ha. Harneet *et al*., (2004) reported that appropriate amount of potassium increased the yield of tomato.

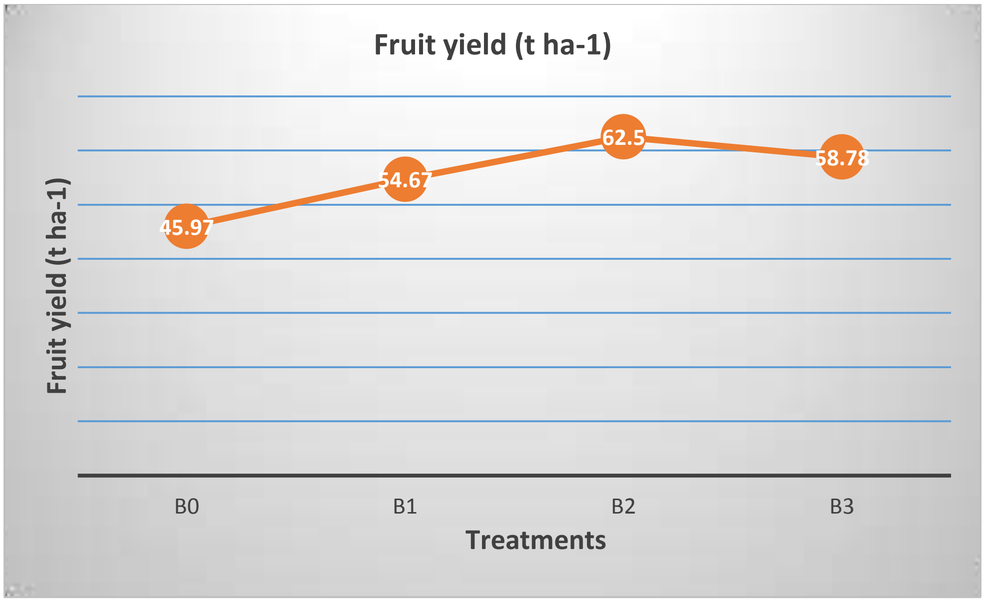
The effect of B on fruit yield was found positive and significant (Table 5 and Appendix VIII, Fig. 15). Fruit yield increased with increasing level of B up to higher level of B (1.2 kg B/ha). Application of 1.2 kg B/ha produced the highest fruit yield (62.50 t/ha). The minimum fruit yield (45.97 t/ha) was recorded in control treatment. Prasad et al., (1997) found highest fruit yield with the application of 2.5 kg borax/ha. Pregno and Arour (1992) observed highest tuber yield of potato with 2 kg B/ha application.

The interaction effects of different doses of potassium and boron on fruit yields per plot as well as per hectare were found to be statistically significant (Table 5 & Appendix VIII). Fruit yield per hectare varied from 42.11 ton to 71.33 ton. The highest yield per hectare (71.33 ton) was achieved from the treatment combination of K_2B_2 (120 kg/ha of K + 1.2 kg B per ha) and the lowest yield per hectare (42.11 ton) was achieved from the treatment combination of zero potassium with no boron per hectare which was similar to K_0B_1 (Table 4).



Here, K_0: 0 kg K ha^{-1} K_1: 80 kg K ha^{-1} K_2: 120 kg K ha^{-1} K_3: 140 kg K ha^{-1}

Figure 14. Fruit yield per hectare tomato as influenced by potassium (K)



Here, B_0: 0 kg B ha^{-1}, B_1: 0.6 kg B ha^{-1}, B_2: 1.2 kg B ha^{-1}, B_3: 1.8 kg B ha^{-1}

Figure 15. Fruit yield per hectare tomato as influenced by boron (B)

4.4 Quality parameters

4.4.1 Total soluble solids % (TSS)

Total soluble solids of tomato are predominantly sugars, which determine flavor and other fruit quality characteristic.

The result presented in (Table 6 and Appendix VIII) indicates that TSS was significantly influenced by potassium levels. The highest value (7.352) was recorded from 120 kg K /ha while the lowest (6.22) was obtained with application of 0 kg K /ha. Similarly Javaria *et al*., (2012) found that TSS was significantly influenced by the application of K. TSS showed increment when K doses were increased up to 375 kg K 2 O/ha the author added. The increase of TSS in the fruits with the increase of K levels confirms that K played an important role in the configuration of quality profile in tomato fruits (Caretto *et al*., 2008). In contrary to the current findings Al Moshileh *et al.*, (2017) reported that k application did not have significant effect on TSS of tomatoes.

The result presented in ((Table 6 and Appendix VIII) indicates that TSS was significantly influenced by boron levels. The highest value (7.30) was recorded from 1.2 kg B /ha which was statistically similar to B_3 while the lowest (6.358) was obtained with application of 0 kg B /ha.

The interaction effects of different doses of potassium and boron on total soluble solids were found to be statistically significant ((Table 6 and Appendix VIII). Total soluble solids varied from 6.040 to 71.33. The highest total soluble solids (7.84) was achieved from the treatment combination of K_2B_2 (120 kg/ha of K + 1.2 kg B per ha) and the lowest total soluble solids (6.04) was achieved from the treatment combination of zero potassium with no boron which was similar to K_0B_1 (Table 5).

Table 6. Quality parameters of tomato as influenced by potassium (K) and boron (B)

Treatment	Quality parameters		
	TSS %	β-Carotene (mg per 100g)	Vitamin-C (mg per 100g)
Effect of potassium (K)			
K_0	6.220 c	0.2400	69.51 d
K_1	6.815 b	0.2900	81.66 c
K_2	7.352 a	0.3325	96.50 a
K_3	7.230 a	0.3183	92.92 b
$LSD_{0.05}$	0.2861	0.2416	1.051
CV(%)	7.35	4.10	5.83
Effect of boron (B)			
B_0	6.358 c	0.2550	73.00 d
B_1	6.855 b	0.2917	81.73 c
B_2	7.300 a	0.3258	97.18 a
B_3	7.105 a	0.3083	88.67 b
$LSD_{0.05}$	0.2362	0.08543	1.518
CV(%)	7.35	4.10	5.83
Combined effect of K and B			
K_0B_0	6.040 i	0.2267 h	64.87 k
K_0B_1	6.120 hi	0.2333 gh	65.28 jk
K_0B_2	6.400 g	0.2533 ef	75.97 h
K_0B_3	6.320 gh	0.2467 efg	71.92 i
K_1B_0	6.280 gh	0.2433 fgh	68.77 ij
K_1B_1	6.870 e	0.2900 cd	81.75 f
K_1B_2	7.180 c	0.3333 b	90.47 cd
K_1B_3	6.930 de	0.2933 cd	85.64 e
K_2B_0	6.630 f	0.2867 d	80.52 fg
K_2B_1	7.320 c	0.3367 b	92.62 c
K_2B_2	7.840 a	0.3600 a	112.6 a
K_2B_3	7.620 ab	0.3467 ab	100.2 b
K_3B_0	6.480 fg	0.2633 e	77.84 gh
K_3B_1	7.110 cd	0.3067 c	87.28 de
K_3B_2	7.780 a	0.3567 a	109.7 a
K_3B_3	7.550 b	0.3467 ab	96.88 b
$LSD_{0.05}$	0.2174	0.01668	3.506
CV(%)	7.35	4.10	5.83

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

Here, K_0: 0 kg K ha^{-1} (control), K_1: 80 kg K ha^{-1}, K_2: 120 kg K ha^{-1}, K_3:140 kg K ha^{-1}

B_0: 0 kg B ha^{-1} (control), B_1: 0.6 kg B ha^{-1}, B_2: 1.2 kg B ha^{-1}, B_3: 1.8 kg B ha^{-1}

4.4.2 β-Carotene (mg per 100g)

The result presented in ((Table 6 and Appendix VIII) indicates that β-Carotene (mg per 100g) was not significantly influenced by potassium levels. The highest value (0.33) was recorded from 120 kg K /ha whereas other treatments are statistically similar.

The result presented in ((Table 6 and Appendix VIII) indicates that β-Carotene (mg per 100g) was significantly influenced by boron levels. The highest value (0.33) was recorded from 1.2 kg B /ha which was statistically similar to B_3 while the lowest (0.25) was obtained with application of 0 kg B /ha.

The interaction effects of different levels of potassium and boron on β-Carotene (mg per 100g) were found to be statistically significant ((Table 6 and Appendix VIII). B-Carotene (mg per 100g) varied from 0.22 to 0.36. The highest β-Carotene (mg per 100g) (0.36) was achieved from the treatment combination of K_2B_2 (120 kg/ha of K + 1.2 kg B per ha) and the lowest β-Carotene (mg per 100g) (0.22) was achieved from the treatment combination of zero potassium with no boron which was similar to K_0B_1 (Table 5).

4.4.3 Vitamin-C (mg per 100g)

The result presented in ((Table 6 and Appendix VIII) indicates that Vitamin-C (mg per 100g) was significantly influenced by potassium levels. The highest value (96.50) was recorded from 120 kg K /ha while the lowest (69.51) was obtained with application of 0 kg K /ha. Similarly Javaria *et al*., (2012) found that Vitamin-C (mg per 100g) was significant ly influenced by the application of K. Vitamin-C (mg per 100g) showed increment when K doses were increased up to 375 kg K 2 O/ha the author added. Vitamin C contents in tomato fruits increased with K application in the form of MOP Ehsan *et al.* (2010).

The result presented in ((Table 6 and Appendix VIII) indicates that Vitamin-C (mg per 100g) was significantly influenced by boron levels. The highest value (97.18) was recorded from 1.2 kg B /ha while the lowest (73.00) was obtained with application of 0 kg B /ha.

The interaction effects of different levels of potassium and boron on Vitamin-C (mg per 100g) were found to be statistically significant (Table 6 and Appendix VIII). Vitamin-C (mg per 100g) varied from 64.87 to 112.6. The highest Vitamin-C (mg per 100g) (112.6) was achieved from the treatment combination of K_2B_2 (120 kg/ha of K + 1.2 kg B per ha) which was similar to K_3B_2 and the lowest Vitamin-C (mg per 100g) (64.87) was achieved from the treatment combination of zero potassium with no boron which was similar to K_0B_1 (Table 5).

4.5 Performance on economic return

4.5.1 Cost of production

Due to effect of different treatment combinations showed major differences in terms of cost of production of Tomato (Table 7 and Appendix IX). The highest cost of production of Tomato (208679 Taka/ha) was obtained from K_3B_3. The lowest cost of production of Tomato (200595 Tk/ha) was obtained from $K_0B_{0.}$

4.5.2 Gross return

In case of gross return, different treatment combination showed considerable gross return of Tomato production (Table 7 and Appendix IX). The highest gross return of Tomato (855960Taka/ha) was obtained from K_2B_2 and the second highest gross return of Tomato production (842640 Taka/ha) was obtained from K_3B_2. The lowest gross return of Tomato production (505320 Taka/ha) was obtained from $K_0B_{0.}$

4.5.3 Net return

Different treatment combinations showed large differences in terms of net return from Tomato production (Table 7 and Appendix IX). The highest net return of Tomato production (649195 Taka/ha) was obtained from K_2B_2 and the second highest net return of Tomato production (635298 Taka/ha) was obtained from K_3B_2. The lowest net return of Tomato production (304725 Taka/ha) was obtained from K_0B_0.

Table 7. Economic analysis of tomato production as influenced by potassium (K) and boron (B)

Treatments	Yield (t ha^{-1})	Total cost of production (Tk. ha^{-1})	Gross return (Tk. ha^{-1})	Net return (Tk. ha^{-1})	BCR
K_0B_0	42.11	200595	505320	304725	2.52
K_0B_1	42.44	201933	509280	307347	2.52
K_0B_2	47.11	203271	565320	362049	2.78
K_0B_3	45.78	204608	549360	344752	2.68
K_1B_0	44.00	202936	528000	325064	2.60
K_1B_1	53.00	204274	636000	431726	3.11
K_1B_2	61.33	205612	735960	530348	3.58
K_1B_3	54.22	206950	650640	443690	3.14
K_2B_0	49.78	204090	597360	393270	2.93
K_2B_1	63.67	204274	764040	559766	3.74
K_2B_2	71.33	206765	855960	649195	4.14
K_2B_3	68.00	208103	816000	607897	3.92
K_3B_0	48.00	204666	576000	371334	2.81
K_3B_1	59.55	206004	714600	508596	3.47
K_3B_2	70.22	207342	842640	635298	4.06
K_3B_3	67.11	208679	805320	596641	3.86

K_0 = 0 kg K ha^{-1} (control), K_1= 80 kg K ha^{-1}, K_2 = 120 kg K ha^{-1}, K_3 = 140 kg K ha^{-1}

B_0 = 0 kg B ha^{-1} (control), B_1 = 0.6 kg B ha^{-1}, B_2 = 1.2 kg B ha^{-1}, B_3 = 1.8 kg B ha^{-1}

Rate of tomato @ 12 Tk/kg

Gross return = Total yield (t/ha) × Tk. 12×1000

Net return = Gross return - Total cost of production

Benefit Cost Ratio (BCR) = Gross return/Total cost of production

4.5.4 Benefit cost ratio

Significant differences were showed by different treatment combinations on benefit cost ratio of tomato production (Table 7 and Appendix IX). Results indicated that the highest benefit cost ratio (4.14) was obtained from K_2B_2 and the second highest benefit cost ratio (4.06) was obtained from K_3B_2. The lowest benefit cost ratio (2.52) was obtained from K_0B_0. From economic point of view, it is apparent from the above results that the combination of K_2B_2 was more profitable treatment combination than rest of the combinations.

CHAPTER 5

SUMMARY AND CONCLUSION

The effect of potassium and boron on the quality and yield of tomato were investigated at the Horticulture farm of the Sher-e-Bangla Agricultural University, Dhaka, during the rabi season (October 2019 to March 2020). The experiment consisted of two factors, (i) four different levels of potassium (K) viz., 0, 80, 120, 140 kg/ha, (ii) four different doses of boron (B) viz., 0, 0.6, 1.2, 1.8 kg/ha. The experiment was comprised of 16 treatment combinations and laid out in Randomized Complete Block Design (RCBD) with three replications. Five plants were randomly selected in each plot to record the data on growth, yield and yield contributing characters as well as quality. The collected data were statistically analyzed and the difference between means was evaluated by LSD.

The results of the experiment revealed that all the characters studied were significantly influenced by different levels of potassium. It was observed that there was an increasing response of all the parameters with the increasing levels of potassium upto certain level (120 kg K/ha) and then it was declined onwards. The maximum plant height (113.9 cm), Number of leaves per plant (42.92), number of flower clusters per plant (8.32), number of flowers per cluster (6.59), number of fruits per cluster (4.54) , number of mature fruits per plant (37.93), weight of fruits per plant (0.95kg), weight of fruits per plot (5.68 kg), yield per hectare (63.19 ton/ha) were recorded from K_2 (120 kg K ha-1) while the minimum result was found from all this parameters from the treatment K_0 (control) due to no use of potassium. Quality parameter like total soluble solids % (TSS), β -Carotene (mg per 100g) and Vitamin-C (mg per 100g) also showed significant variation on different levels of potassium. The highest value of total soluble solids % (TSS) (7.352), β -Carotene mg per 100g (0.33) and Vitamin-C mg per 100g (96.50) was recorded from the treatment K_2 (120 kg K /ha). Almost all yield and quality parameters showed minimum results in case of the treatment K0 (control).

The results of the experiment revealed that all the characters studied were significantly influenced by different levels of boron. It was observed that there was an increasing response of all the parameters with the increasing levels of boron upto certain level (1.2 kg K/ha) and then it was declined onwards. The maximum plant height (112.2 cm), Number of leaves per plant (39.78), number of flower clusters per plant (8.24), number of flowers per cluster (6.59)) number of fruits per cluster (4.50) , number of mature fruits per plant (37.31), weight of fruits per plant (0.93 kg), weight of fruits per plot (5.62 kg), yield per hectare (62.50 ton/ha) were recorded from B_2 (1.2 kg/ha B) while the minimum result was found from all this parameters from the treatment B0 (control) due to no use of boron. .Quality parameter like total soluble solids % (TSS), β -Carotene (mg per 100g) and Vitamin-C (mg per 100g) also showed significant variation on different levels of potassium. The highest value of total soluble solids % (TSS) (7.30), β -Carotene mg per 100g (0.33) and Vitamin-C mg per 100g (97.18) was recorded from the treatment B_2 (1.2 kg B /ha). Almost all yield and quality parameters showed minimum results in case of the treatment B_0 (control).

The maximum plant height (119.2 cm), Number of leaves per plant (42.92), number of flower clusters per plant (8.93), number of flowers per cluster (7.44), number of fruits per cluster (4.79) , number of mature fruits per plant (42.82), weight of fruits per plant (1.07 kg), weight of fruits per plot (6.42 kg), yield per hectare (71.33 ton/ha) were produced from the treatment combination of 120 kg K/ha with 1.2 kg B/ha. Quality parameter like total soluble solids % (TSS), β -Carotene (mg per 100g) and Vitamin-C (mg per 100g) also showed significant variation on different treatment combinations. The highest value of total soluble solids % (TSS) (7.84), β -Carotene mg per 100g (0.36) and Vitamin-C mg per 100g (112.6) was recorded from the treatment combination K_2B_2 (120 kg K /ha 1.2 kg B /ha). Almost all yield and quality parameters showed minimum results in case of the treatment combination K_0B_0 (control).

The overall results found from this study facilitated to draw the following conclusions.

1. The second highest dose of potassium (120 kg K/ha) was found to produce maximum total fruit yield and superior to others on qualitative data also.

2. Boron at 1.2 kg/ha was found most effective and may be used in tomato cultivation as it gave the highest fruit yield than control.

3. The combination of the doses of potassium (120 kg K/ha) with boron (1.2 kg B/ha) may be recommended for tomato cultivation since this combination significantly produced the highest fruit yield.

CHAPTER V

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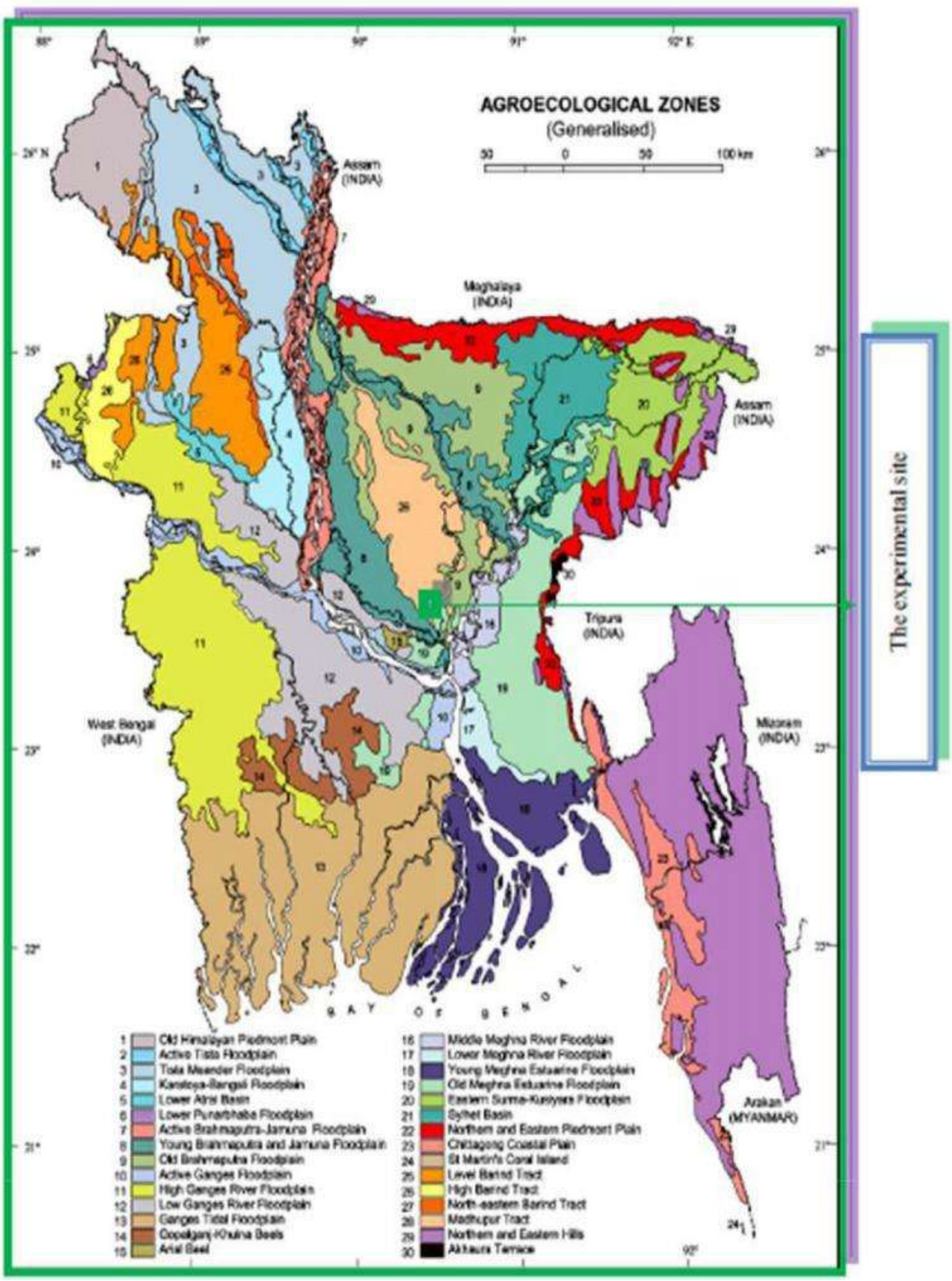
APPENDICES

Appendix I. Experimental location on the map of agro-ecological zones of Bangladesh



Appendix II. Monthly record of air temperature, relative humidity, rainfall and sunshine hour of the experimental site during the period from November 2018 to April 2019

Month	Air temperature (ºC)		Relative humidity (%)	Total Rainfall (mm)	Sunshine (hr)
	Maximum	Minimum			
November, 2018	25.8	16.0	76	00	6.8
December, 2018	22.6	13.4	78	05	6.9
January, 2019	24.9	12.2	64	02	5.8
February, 2019	26.7	16.9	69	30	6.7
March, 2019	27.5	19.4	81	22	6.9
April, 2019	28.8	20.8	88	26	6.9

Source: Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka-1212

Appendix III. Soil characteristics of experimental field as analyzed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate,Dhaka

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Horticulture farm field , SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

B. Physical and chemical properties of the initial soil

Characteristics	Value
% Sand	26
% Silt	43
% clay	31
Textural class	Sandy loam
pH	5.9
Catayan exchange capacity	2.64 meq 100 g/soil
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10

Appendix IV. Analysis of variance on plant height at different days after transplanting (DAT) of Tomato

Source of variation	Degree of Freedom	Mean square		
		Plant height (cm) at		
		20 DAT	60 DAT	90 DAT
Replication	2	26.275	193.365	28.797
Potassium (A)	3	45.938	231.374	356.745
Boron (B)	3	27.405	152.027	239.299
Interaction (A×B)	9	1.483	6.332	7.521
Error	30	0.055	0.351	0.437

*: Significant at 0.05 level of probability

**: Significant at 0.01 level of probability

Appendix V. Analysis of variance on number of leaves at different days after transplanting (DAT) of Tomato

Source of variation	Degree of Freedom	Mean square		
		Number of Leaf at		
		30 DAT	60 DAT	90 DAT
Replication	2	2.736	3.939	3.087
Potassium (A)	3	19.560	75.163	53.048
Boron (B)	3	12.372	47.560	22.200
Interaction (A×B)	9	0.425	1.957	4.458
Error	30	0.065	0.020	2.645

*: Significant at 0.05 level of probability

**: Significant at 0.01 level of probability

Appendix VI. Analysis of variance on number of flower clusters per plant, number of flowers per cluster and number of fruits per cluster of Tomato

Source of variation	Degree of Freedom	Mean square		
		Number of flower clusters per plant	Number of flowers per cluster	Number of fruits per cluster
Replication	2	0.218	2.212	0.185
Potassium (A)	3	6.689	6.833	0.938
Boron (B)	3	4.477	5.554	0.379
Interaction (A×B)	9	0.105	0.279	0.027
Error	30	0.302	1.579	0.001

*: Significant at 0.05 level of probability

**: Significant at 0.01 level of probability

Appendix VII. Analysis of variance on Number of fruits per plant, Fruit wt per plant (Kg) and Fruit wt per plot (Kg) of Tomato

Source of variation	Degree of Freedom	Mean square		
		Number of fruits per plant	Fruit wt per plant (Kg)	Fruit wt per plot (Kg)
Replication	2	0.009	0.009	0.308
Potassium (A)	3	0.197	0.197	7.180
Boron (B)	3	0.135	0.135	4.899
Interaction (A×B)	9	0.010	0.010	0.346
Error	30	0.000	0.000	0.003

*: Significant at 0.05 level of probability

**: Significant at 0.01 level of probability

Appendix VIII. Analysis of variance on Fruit yield (t ha^{-1}), TSS % and Vitamin-C (mg per 100g) of Tomato

Source of variation	Degree of Freedom	Mean square			
		Fruit yield (t ha^{-1})	TSS %	β-Carotene (mg per 100g)	Vitamin-C (mg per 100g)
Replication	2	38.071	0.093	0.003	130.840
Potassium (A)	3	886.459	3.133	0.020	1783.855
Boron (B)	3	604.807	1.993	0.011	1265.893
Interaction (A×B)	9	42.715	0.114	0.001	60.134
Error	30	0.347	0.257	0.000	2.420

*: Significant at 0.05 level of probability

**: Significant at 0.01 level of probability

Appendix IX: Cost of production of tomato per hectare

A. Input cost (Tk. ha^{-1})

Treatments	Cost of land preparation and cultivation with labor	Tomato seed cost	Insecticide cost (Tk./ha)	Irrigation	Cow dung	Fertilizer			Boric acid	Seedling raising cost	Transplanting cost with labor	Subtotal (A)
						Urea	TSP	MoP				
K_0B_0	30000	7000	20000	18000	20000	1600	5000	0	0	4000	40000	145600
K_0B_1	30000	7000	20000	18000	20000	1600	5000	0	1225	4000	40000	146825
K_0B_2	30000	7000	20000	18000	20000	1600	5000	0	2450	4000	40000	148050
K_0B_3	30000	7000	20000	18000	20000	1600	5000	0	3675	4000	40000	149275
K_1B_0	30000	7000	20000	18000	20000	1600	5000	2144	0	4000	40000	147744
K_1B_1	30000	7000	20000	18000	20000	1600	5000	2144	1225	4000	40000	148969
K_1B_2	30000	7000	20000	18000	20000	1600	5000	2144	2450	4000	40000	150194
K_1B_3	30000	7000	20000	18000	20000	1600	5000	2144	3675	4000	40000	151419
K_2B_0	30000	7000	20000	18000	20000	1600	5000	3200	0	4000	40000	148800
K_2B_1	30000	7000	20000	18000	20000	1600	5000	2144	1225	4000	40000	148969
K_2B_2	30000	7000	20000	18000	20000	1600	5000	3200	2450	4000	40000	151250
K_2B_3	30000	7000	20000	18000	20000	1600	5000	3200	3675	4000	40000	152475
K_3B_0	30000	7000	20000	18000	20000	1600	5000	3728	0	4000	40000	149328
K_3B_1	30000	7000	20000	18000	20000	1600	5000	3728	1225	4000	40000	150553
K_3B_2	30000	7000	20000	18000	20000	1600	5000	3728	2450	4000	40000	151778
K_3B_3	30000	7000	20000	18000	20000	1600	5000	3728	3675	4000	40000	153003

B. Overhead cost (Tk. ha^{-1}), Cost of production (Tk. ha^{-1}), Gross return (Tk. ha^{-1}), Net return (Tk. ha^{-1}) and BCR

Treatments	Overhead cost			Subtotal (B)	Subtotal (A)	Total cost of production (A+B)	Yield (t ha^{-1})	Gross return (Tk. ha^{-1})	Net return (Tk. ha^{-1})	BCR
	Cost of leased land for 6 months (8% of value of land 10,00,000/-)	Miscellaneous cost (Tk. 5% of the input cost)	Interest on running capital for 6 months (8% of cost year^{-1})							
K_0B_0	40000	7280	7715	54995	145600	200595	42.11	505320	304725	2.52
K_0B_1	40000	7341.25	7767	55108	146825	201933	42.44	509280	307347	2.52
K_0B_2	40000	7402.5	7818	55221	148050	203271	47.11	565320	362049	2.78
K_0B_3	40000	7463.75	7870	55333	149275	204608	45.78	549360	344752	2.68
K_1B_0	40000	7387.2	7805	55192	147744	202936	44.00	528000	325064	2.60
K_1B_1	40000	7448.45	7857	55305	148969	204274	53.00	636000	431726	3.11
K_1B_2	40000	7509.7	7908	55418	150194	205612	61.33	735960	530348	3.58
K_1B_3	40000	7570.95	7960	55531	151419	206950	54.22	650640	443690	3.14
K_2B_0	40000	7440	7850	55290	148800	204090	49.78	597360	393270	2.93
K_2B_1	40000	7448.45	7857	55305	148969	204274	63.67	764040	559766	3.74
K_2B_2	40000	7562.5	7953	55515	151250	206765	71.33	855960	649195	4.14
K_2B_3	40000	7623.75	8004	55628	152475	208103	68.00	816000	607897	3.92
K_3B_0	40000	7466.4	7872	55338	149328	204666	48.00	576000	371334	2.81
K_3B_1	40000	7527.65	7923	55451	150553	206004	59.55	714600	508596	3.47
K_3B_2	40000	7588.9	7975	55564	151778	207342	70.22	842640	635298	4.06
K_3B_3	40000	7650.15	8026	55676	153003	208679	67.11	805320	596641	3.86