EFFECT OF BORON AND GIBBERELLIC ACID ON GROWTH, YIELD AND QUALITY OF TOMATO

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DHAKA-1207

December, 2015

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REG. NO.: 09-03382

A Thesis
submitted to the Faculty of Agriculture,
Sher-e-Bangla Agricultural University, Dhaka,
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE (MS)
IN
AGRICULTURAL BOTANY
SEMESTER: JULY-DECEMBER, 2015

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CERTIFICATE

*This is to certify that thesis entitled, **"EFFECT OF BORON AND GIBBERELLIC ACID ON GROWTH, YIELD AND QUALITY 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 **AGRICULTURAL BOTANY**, embodies the result of a piece of bonafide research work carried out by **Chandra Shekhar Bhowmik ,Registration No. 09-03382** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dated: *Professor Dr. Md. Ashabul Hoque*
Place: Dhaka, Bangladesh *Supervisor*

ACKNOWLEDGEMENT

All praises are due to the Almighty god, the great, the gracious, merciful and supreme ruler of the universe to complete the research work and thesis successfully for the degree of Master of Science in Agricultural Botany.

*The author would like to express his deepest sense of gratitude to his respected supervisor **Professor Dr. Md. Ashabul Hoque,** Chairman, Department of Agricultural Botany, Sher-e-Bangla Agricultural University, Dhaka, for his scholastic guidance, support, encouragement, valuable suggestions and conducting and successfully completing the research work and in the preparation of the manuscript writing including data analysis.*

*The author would like to expresses his gratefulness to his respected Co-Supervisor **Professor Dr. Kamal Uddin Ahamed**, Department of Agricultural Botany, Sher-e-Bangla Agricultural University, Dhaka, for his scholastic guidance, helpful comments and constant inspiration, inestimable help, valuable suggestions throughout the research work and in preparation of the thesis.*

The author also wants to express heartfelt thanks to all the teachers of the Department of Agricultural Botany, Sher-e-Bangla Agricultural University, Dhaka, for their valuable suggestions, instructions, and cordial help.

The author would like to thank his friends who helped him with technical support to prepare this thesis paper. He also thanks them to help me in my research work.

The author want to thank his parents, brother and other relative's for their moral support, encouragement and love with cordial understanding.

Finally, the author appreciates the assistance rendered by the staff members of the Department of Agricultural Botany, Sher-e-Bangla Agricultural University, Dhaka, who have helped him during the period of study.

The author

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ABSTRACT

A field experiment was conducted at the research farm of Sher-e-Bangla Agricultural University, Dhaka-1207, during the Rabi season from November 2015 to March 2016 to study the effects of boron (B) and gibberellic acid (GA_3) on growth, yield and quality of tomato. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications of each treatment. The unit plot size was 2m x 1.8m. There were 12 treatment combinations in the experiment comprising 3 levels of Boron (0 kg ha^{-1}, 0.8 kg ha^{-1} & 1 kg ha^{-1} designated as B_0, B_1 & B_2 respectively) and 4 levels of gibberellic acid (0 ppm, 50 ppm, 100 ppm & 150 ppm designated as G_0, G_1, G_2 & G_3 respectively). The effect of different doses of boron, gibberellic acid and their combined effect showed significant variations in growth, yield and quality of tomato. Individual application of B_1 @ 0.8 kg ha^{-1} gave the highest plant height, no. of leaves per plant, flower clusters per plant, flowers per cluster, fruit per plant, fruit wt per plant (2.391 Kg), fruit wt per plot (24.91 Kg), fruit yield (69.20 t ha^{-1}), TSS 7.233 %, vitamin-C (98.72 mg per 100g) but B_2 @ 1 kg ha^{-1} gave highest β-carotene (0.3167 mg per 100g). And G_2 @ 100 ppm gave the highest plant height, number of Leaves per plant, flower clusters per plant, fruit per plant (1.995 kg), fruit wt per plot (19.67 kg), fruit yield (54.63 t ha^{-1}), TSS 7.389 %, β-carotene (0.3178 mg per 100g), vitamin-C (91.45 mg per 100g). In case of combined effect, B_1G_2 (B_1 @ 0.8 kg ha^{-1} + G_2 @ 100 ppm) gave the highest plant height, no. of leaves per plant, flower clusters per plant, flowers per cluster, fruit per cluster, fruit per plant, fruit wt per plant (2.57 Kg), fruit wt per plot (28.25 Kg), fruit yield (78.46 t ha^{-1}), TSS 7.6%, β-Carotene (0.35 mg per 100g), vitamin-C (111.5 mg per 100g). Finally, it was concluded that B_1G_2 (B_1 @ 0.8 kg ha^{-1} + G_2 @ 100 ppm) was the best for growth, yield and quality of tomato.

CONTENTS

CONTENTS (Cont'd)

CONTENTS (Cont'd)

LIST OF TABLES

LIST OF TABLES ((Cont'd))

LIST OF FIGURES

LIST OF APPENDICS

LIST OF PLATES

LIST OF ACCRONYMS AND ABBREVIATION

ABBREVIATION	ELABORATION
SAU	Sher-e-Bangla Agricultural University
B	Boron
GA_3	Gibberellic Acid
RCBD	Randomized Complete Block Design
et al.	and others
FAO	Food and Agricultural Organiztion
m	Meter
kg ha^{-1}	Kilograms per hectare
ppm	Parts per million
t ha^{-1}	Ton per hectare
kg	Kilogram
No.	Number
TSS	Total Soluble Solids
β	Beta
IU	International Unit
g	Gram
mg	Milligram
BBS	Bangladesh Bureau of Statistics
USA	United States of America
i.e	id est
cv.	Cultivar
%	Percent
mg L^{-1}	Milligram per litre
mg kg^{-1}	Milligram per kilogram

LIST OF ACCRONYMS AND ABBREVIATION (Cont'd)

ABBREVIATION	ELABORATION
q ha^{-1}	Quintal per hectare
Rs	Real shit
ml	Millilitre
gm^{-3}	Gram per mitre cube
sq. m	Square meter
FYM	Farm Yard Manure
dSm^{-1}	Decisiemens per metre
i.e.	id est (L), that is
^{0} C	Degree Centigrade
BARI	Bangladesh Agricultural Research Institute
@	At the rate
nm	Nanometre
DMRT	Duncan's Multiple Range Test
DAT	Days After Transplanting
m^2	Square Metre
Fig.	Figure
j.	Journal
Sci.	Science
Hort.	Horticulture
p.	Page
pp.	Particular pages
Agri.	Agriculture
Exp.	Experimental

LIST OF ACCRONYMS AND ABBREVIATION (Cont'd)

ABBREVIATION	ELABORATION
Bot.	Botany
Res.	Research
ed.	Edition
Assoc.	Association
Amer.	American
Soc.	Society
Univ.	University
Agron.	Agronomy
BAU	Bangladesh Agricultural University
Dept.	Department
M. Sc.	Master of Science
UK.	United Kingdom
Nucl.	Nuclear
Vol.	Volume
Advan.	Advance
Cont'd	Continued
Prog.	Progressive
mol m^{-3}	Mole per metre cube
wt.	Weight

CHAPTER I

INTRODUCTION

One of the most palatable vegetables which usually occupy the maximum number of our daily dishes and thus takes its possession in market is tomato (*Lycopersicon esculentum* Mill.). Among the members of the Solanaceous crop it possesses versatile use. Due to the excellent adaptability to wider range of soil and climatic conditions, it can be grown in any part of the world (Ahmed, 1976). The climatic condition of Bangladesh favours tomato to grow in winter season and it can be cultivated in all parts of the country (Haque *et al.,* 1999). Now a day's several varieties of tomato have been developed for cultivation in summer season. It originated in tropical America (Salunkhe *et al.,* 1987), mainly in the region of the Andes Mountain in Peru and Bolivia (McCollum, 1992). It ranks third in the worlds vegetable production next to potato and sweet potato (FAO, 2003) but as a processing crop ranks first among the vegetables (Choudhury, 1979 ; Shanmugavelu, 1989).

Tomato has a significant role in human nutrition because of its rich source of lycopene, minerals and vitamins such as ascorbic acid (vitamin-C) and β-carotene (vitamin-A) which are antioxidants that promote good health (Wilcox *et al*., 2003). Lycopene is a very powerful antioxidant which can help prevent the development of many forms of cancer. Vitamin-C is important in forming collagen, a protein that gives structures to bones, cartilage, muscle and blood vessels. It also helps to maintain capillaries, bones and teeth and aids in the absorption of iron. Vitamin-A is important for bone growth, cell division and differentiation, helping in the regulation of immune system and maintaining surface linings of eyes, respiratory, urinary and intestinal tracts. It is highly nutritious as it contains 94.1% water, 23 calories energy, 1.90 g protein, 1 g calcium, 7 mg magnesium, 1000 IU vitamin A, 31 mg vitamin C, 0.09 mg thiamin, 0.03 mg riboflavin, 0.8 mg niacin per 100 g edible portion (Rashid, 1983). Moreover it possesses medicinal value for human health and much popular as raw salad. It is also used as vegetable or as processed food items such as sauce, soup, juice, ketchup, pickles, paste, puree, powder, jam, and jelly. Excellent nutritional and processing qualities have made tomato demand full in both domestic and foreign markets.

In Bangladesh, the recent statistics shows that tomato was grown in 63000 acres of land and the total production was approximately 255000 metric tons during the year 2011-2012 and the average yield of tomato was 4035 kg acre^{-1} (BBS, 2012*)* While it was 69.41 t ha^{-1} in USA, 21.27 t ha^{-1} in India, 31.13 t ha^{-1} in China and 65.45 t ha^{-1} in Japan (FAO. 2004). The yield of tomato in our country is not satisfactory in comparison to its requirement. The low yield of tomato in Bangladesh; however, is not an indication of low yielding ability of this crop, but of the fact that low yielding variety, low standard crop management practices and lack of better technologies.

Adequate supply of micronutrients also plays an important role in tomato production. Among the plant micro nutrients, boron (B) plays an important role directly and indirectly in improving the growth, yield and quality of tomato in addition to checking various diseases and physiological disorders (Magalhaes *et al.,* 1980). Crops differ in their sensitivity to boron deficiency. Tomato's in general having a high boron requirement (Mengel and Kirkby, 1987). Fruit and seed set failure is a major reason for lower yield of rabi crops and this problem can be attributed to boron deficiency, as reported in tomato (Rahman *et al.,* 1993). Boron deficiency may cause sterility i.e. less fruits per plant attributing lower yield (Islam and Anwar, 1994). Deficiency of boron causes restriction of water absorption and carbohydrate metabolism which ultimate affects fruit and seed formation and thus reduces yield. In fertilizer schedule, an inclusion of boron often decides the success and failure of the crops (Dwivedi *et al.,* 1990). It is reported that the ranges between deficiency and toxicity of boron are quite narrow and that an application of boron can be extremely toxic to plants at concentrations only slightly above the optimum rate (Gupta *et al*., 1985). This emphasizes the need for a judicial use of boron fertilizer.

Again, Plant Growth Regulators such as Gibberellic acid (GA_3) can also play an important role for better yield of tomato. The application of GA_3 had significantly increased the number of fruits per plant than the untreated controls. GA_3 (55 ppm) sprayed on flower cluster resulted to increase in fruit weight (Tomar and Ramgiry, 1997; Adlakha and Verma, 1995). To increase the yield and to avoid flower and fruit dropping, application of GA_3 at right concentration and right time is important. Gibberellic acid has great effects on plant physiological systems including fruit setting, leaf expansion, germination, breaking dormancy, increasing fruit size, improving fruit quality and in many other aspects of plant growth and thereby increased crop production.

Numerous researches on the effect of boron in association with application of GA_3 on the growth, yield and quality of tomato in developed countries but information on systematic research in this context in Bangladesh is limited. Therefore, the present study was undertaken with the following objectives:

- To find out the effect of boron on the growth, yield and quality of tomato
- To determine the effect of GA_3 on the growth, yield and quality of tomato
- To find out an appropriate combination of boron and GA_3 for ensuring proper growth, yield and good quality of tomato.

Chapter II

REVIEW OF LITERATURE

Tomato *(Lycopersicum esculentum* Mill.) is one of the most important vegetable crops in Bangladesh and received much attention to the researcher throughout the world. Boron (B) and Plant growth regulators like Gibberellic acid (GA_3) both of them are most important elements for maximizing the yield of tomato. Experimental evidences showed that there has a great influence of boron (B) fertilizers on this crop. The fertilizer requirements, however, varies with the soil and cultural conditions. Application of this GA_3 has different modifying influences on growth, yield and quality; and yield contributing characters of tomato as well as other crops. Research works have been done in various parts of the world more or less adequate but is not conclusive in Bangladesh. Some of the important and informative works conducted home and abroad in this aspect, have been reviewed in this chapter.

2.1 Effect of Boron (B) on growth, yield and quality of tomato

Tomato crop requires sufficient amount of fertilizers for growth, yield and quality. For improving plant growth and development, use of organic and inorganic manure or fertilizers is essential. It is well established fact that chemical fertilizers improve plant growth directly. Like other nutrients, boron has a pronounced effect on the production and quality of tomato. Boron is needed by the crop plants for cell division, nucleic acid synthesis, and uptake of calcium and transport of carbohydrates. Boron also plays an important role in flowering and fruit formation.

Yadav *et al.* (2006) evaluated that the effects of boron (0.0, 0.10, 0.15, 0.20, 0.25, 0.30 or 0.35 %) that applied to foliage after transplanting for the yield of tomato cv. DVRT-1 in Allahabad, Uttar Pradesh, India, during 2003-2004. The maximum number of fruits per plant (44.0), number of fruits per plot (704.0), yield per plant (0.79 kg), yield per plot (12.78 kg) and yield per ha (319.50 quintal) were obtained with 0.20 % boron, whereas the excellent fruit weight (27.27 g) was recorded for 0.10 % boron.

Smit and Combrink (2004) observed that insufficient fruit set of tomatoes indicate 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. 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 boron levels. At the low boron level, leaves were brittle and appeared pale-green and very high flower abscission percentages were found. Fruit set, fruit development, colour, total soluble solids, firmness and shelf life seemed to be close to optimum was investigated at 0.16 mg L^{-1} boron level. The highest boron level had no detrimental effect on any of the yield and quality related parameters.

Ben and Shani (2003) stated that Boron is inevitable for growth at low concentrations and limits growth as well as yield when in excess. The influences of B and water supply on tomatoes (*Lycopersicon esculentum* Mill.) were investigated in lysimeters where 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.

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 among with 45 x 45 and 65 x 45 spacing's 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 spacing's, closer spacing showed less fruit cracking and among the different nutrient treatments, the spraying of B with Ca was effective in controlling fruit cracking.

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

A greenhouse experiment involving 4 rates of B (0, 5, 10 and 20 mg) and 3 rates of Zn (0, 10 and 20 mg) was conducted by Gunes *et al.* (2000) in tomato plants (cv. Lale). B toxicity symptoms occurred at B rates of 10 and 20 mg. These symptoms were lower in plants grown with applied Zn. Fresh and dry weights of the plants clearly decreased with increasing applied B concentration. 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.

A greenhouse experiment was carried out by Singaram and Prabha (1999) on tomato hybrid Naveen (115 days duration) and non-hybrid cv. Co.3 (105 days duration) to evaluate the interaction of naturally occurring Ca with applied B. The Ca concentration in different parts of the tomato plant varied significantly among treatments. Foliar spray (0.3 %) accounted for higher content of B in the shoot. Application of boronated superphosphate and 30 kg borax ha^{-1} resulted in higher B content in shoots similar to that of foliar application. Soil application of borax at 30 kg ha^{-1} accounted for higher accumulation of B. The equivalent Ca : B ratio in the shoot was significantly and negatively correlated with the fruit yield.

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^{-1}), calcium carbonate along with phosphorus (60 kg ha^{-1}) and potassium (40 kg ha^{-1}) were applied before transplanting, whereas nitrogen (100 kg ha^{-1}) was applied in split doses at 25 and 50 days after transplanting. They observed that the application of 2 kg B ha^{-1} + 2 kg Ca ha^{-1} recorded the highest yield.

Prasad *et al.* (1997) carried out a field experiment in rabi (winter) 1991-1994 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^{-1}) at final field preparation or a foliar boron application (0.0, 1.0, 1.5, 2.0 or 2.5 kg borax ha^{-1}) 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^{-1} (48.74, 152.61 and 227.67 q ha^{-1} in 1991-92, 1992-93 and 1993-94, respectively). Foliar application of borax at 2.5 kg ha^{-1} also gave the highest average yield (143.06 q ha^{-1}) and the highest net additional income (Rs 7324).

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

Palkovics and Gyori (1984) determined 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^{-1} 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 $ZnSO_4$ ha^{-1} or foliar application of 0.1 % boron solution. They observed that both Zn and B application increased tuber yield by 100-150 kg ha^{-1}.

Naresh (2002) carried out an investigation in Nagaland, India during 1998-2000 to identify the effects of foliar application of boron (50, 100, 150, 200, 250 and 300 ppm) on the growth, yield and quality of tomato cv. Pusa Ruby. Boron improved the yield and quality of the crop. The highest yield (327.18 and 334.58 q ha^{-1}) was obtained when the plant was streamed with 250 ppm aqueous solution of boron. B also had positive effects on plant height, number of branches, flowers and number of fruit set per plant, resulting in an increase in the number of fruits per plant and total yield. At lower rates, B improved the chemical composition of tomato fruits and at higher rates increased the total soluble solids, reducing sugar and ascorbic acid contents of the fruits. Acidity of fruits showed a marked increase with increasing levels of B up to 250 ppm. However, the significant effects of B were recorded in the second year only.

Cardozo *et al.* (2001) concluded the effects of Ca and B fertilizers on the productivity of tomato cv. Debora Max were investigated in Espirito Santo do Pinhal, Sao Paulo, Brazil from April to July 2000. Aminobor at 300 ml per 100 litres gave the highest value for fruit weight, while Ca at 60 g per 100 litres and B at 150 g per 100 litres recorded the highest number of fruits.

Lozek and Fecenko (1992-93) studied in a small plot trial on loamy brown soil where potato was grown with the foliar applications of 2 kg sodium humate, 0.5 kg Mn, 0.2 kg B or both. Without foliar fertilizer application, tuber yield was average 20.15 t ha^{-1}. Yield increased by 4.2 % with sodium humate alone, 11.7-15.7 % with Mn and/or B and 17.8-23.6 % with sodium humate + Mn and/or B. Tuber nitrate content was 45.5 mg kg^{-1} in the control and increased to 50.5 mg kg^{-1} with Mn alone and 47.2 mg with B alone; it decreased with the other treatments and was lowest (30.1 mg kg^{-1}) with sodium humate + B.

Baevre (1990) reported that growing the glasshouse cultivar Jet in peat with different levels of B (1.4, 2.2 or 4.6 g m^{-3}), reduced mean fruit weight and increased the proportion of fruits weighing between 5 and 30 g. Increased B supply improved fruit shape and reduced hollowness (puffiness), especially in fruits with a salable weight. The effect of B on seed development was most marked for small fruits. B rate had no significant effect on the relationship between seed weight/fruit and fruit weight.

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

Delibas and Akgun (1996) examined 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.

Piexoto *et al.* (1996) conducted an experiment in Brazil and found that dry matter, yield and average tuber weight increased linearly with increasing rate of N, P, and K. B had no significant effect on yield of potato tubers.

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

Gunes *et al.* (1999) carried out a greenhouse experiment involving 4 levels of boron (0, 5, 10 and 20 mg) and 3 levels of zinc (0, 10 and 20 mg) were conducted on tomato cv. Lale. Boron toxicity symptoms occurred at 10-20 mg B. 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.

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

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

2.2 Effect of GA_3 on the growth, yield and quality of tomato

Gibberellic acid (GA_3) is a naturally occurring plant hormone that affects cell enlargement and division which leads to internodes elongation in stems. They have a dwarf reversing response e.g. it allows certain dwarf cultivars to grow to normal height when treated with GA_3. It also affect many developmental processes, particularly those controlled by temperature and light such as seed and plant dormancy, germination, seed stalk and fruit development are controlled by GA_3.

Shittu and Adeleke (1999) investigated the effects of foliar application of GA_3 (0, 10, 250 or 500 ppm) on growth and development of tomatoes cv, 158-3 grown on pots. Plant height and number of leaves were significantly enhanced by GA_3 treatment. Plants treated With GA_3 with 250 ppm were the tallest plant with the highest number of leaves.

Tomar and Ramgiry (1997) studied that tomato plant treated with GA_3 showed significantly greater number of branches plant^{-1} than untreated controls.

Sanyal *et al.*(1995) observed that the effects of plant growth regulators (IAA or NAA at 15, 25 or 50 ppm or GA_3 at 50, 75 or 100 ppm) and methods of plant growth regulator application on the quality of tomato fruits. Plant growth regulators had profound effects on fruit length, weight and sugar : acid ratio. The effects of foliar application of plant growth regulators were more profound than presoaking alone.

Alam (2007) observe that application of Miyobi had tremendous effect on growth and development of lentil. The rate of increase of dry matter/unit time/unit land area is the CGR. Maola (2005) reported that seed yield was strongly correlated with crop growth rate.

Hathout *et al.* (1993) found that application of 10 ppm IAA as foliar sprays or to the growing media of tomato plants had a stimulatory effect on plant growth, development and fruit which was accompanied by increases in endogenous auxin, gibberellins and cytokinin contents. However, IAA at 80 ppm had an inhibitory effect on plant growth and development, which was accompanied by increase in the level and activity of indigenous inhibitors and by low levels of auxins, cytokines and gibberellins.

EI- Habbasha *et al.* (1999) carried out a field experiment with tomato cv. Castel rock over two growing seasons (1993-94). The effects of GA_3 and 4-CPA on fruit yield and quality were investigated. Many of the treatments significantly increased fruit set percentage and total fruit yield, but also the percentages of puffy and parthenocarpic fruits compared to the controls.

Gulnaz *et al.* (1999) reported that seeds of wheat treated with 10 ppm of GA_3 resulted in 36-43 % increase in dry weight at $13.11 dSm^{-1}$. The growth regulators (GA_3 at 10^{-5} M) increased total dry matter. Application of 10^{-5} M GA_3 on mustard at 40 or 60 days after sowing significantly increased total dry matter (Khan *et al.,* 1998).

Total dry matter of a crop is the output of net photosynthesis Patel and Saxena (1994) reported that presoaking of seed of gram in varying concentrations of GA_3 showed the best results on dry weights. Application of GA_3 at 50 and 100 ppm in french bean increased leaf number over control (Gabal *et al.* 1999). The increased leaf number could intercept most of the incident radiation and result in higher dry matter production in faba bean (Takano *et. al* (1995).

Lilov and Donchev (1984) observed that by the application of GA_3 at 20, 40 or 100 mg L^{-1} the yields were reduced compared with the non-treated control.

Leonard *et al.* (1983) reported that inflorescence development in tomato plants grown under low light regimes was promoted by GA_3 application directly on the inflorescence.

Saleh and Abdul (1980) performed an experiment with GA_3 *(*25 or 50 ppm) applied 3 times in June or early July. They observed that GA_3 stimulated plant growth of tomato. The substance reduced the total number of flowers per plant but increased the total yield compared with the control. GA_3 also improved fruit quality.

Chern *et al.* (1983) presented that one month old transplanted tomato plants were sprayed with 1, 10 or 100 ppm GA_3 and observed that GA_3 at 100 ppm increased leaf area, plant height and stem fresh and dry weight but 10 ppm inhibited growth.

Wu *et al.* (1983) sprayed one-month old transplanted tomato plants with GA_3 at 1, 10 or 100 ppm and reported that GA_3 100 ppm increased plant height and leaf area.

Briant (1974) sprayed GA_3 on the growth of leaves of young tomato plants and observed that total leaf weight and area were increased by GA_3.

Bora and Selman (1969) working with tomato demonstrated that four foliar sprays of GA_3 (0, 5, 50 or 500 ppm) applied at 7, 17, 27 and 37 DAT increased the leaf area, weight and height of tomato plants. The best treatment was 5 ppm GA_3 at 27 days after transplanting.

Jansen (1970) reported that tomato plants treated with GA_3 neither increased the yield nor accelerated fruit ripening. He also mentioned that increasing concentration of GA_3 reduced both the number and size of fruits.

Mehta and Mathi (1975) reported that GA_3 application at 25 ppm improved the yield of tomato. GA_3 produced earlier fruit setting and maturity.

Hossain (1974) investigated the effect of GA_3 along with 4-CPA on the production of tomato. He found that GA_3 applied with 50, 100 and 200 ppm produced an increased fruit set. However, GA_3 treatment induced small size fruit production. A gradual increase in the yield/plant was obtained with higher concentration of GA_3.

Sawhney and Greyson (1972) reported that application of GA_3 non flowering plants of tomato induced multilocular, multicarpellary ovaries which were larger at anthesis than control upon pollination produced fruits which were significantly larger with higher fresh weight.

Adlakha and Verma (1964) observed that when the first four clusters of tomato plants were sprayed three times at unspecified intervals with GA_3 at 50 and 100 ppm, the fruit setting increased by 5 % with higher concentration.

Kaushik *et al.* (1974) in an experiment applied GA_3 at 1, 10 or 100 mg L^{-1} on tomato plants at two leaf stage and then at weekly interval until 5 leaf stage. They found that GA_3 increased the number and weight of fruits per plant at the highest concentration.

Choudhury and Faruque (1972) indicated that the percentage of seedless fruit increased with the increase in GA_3 concentration from 50 ppm to 100 ppm. However the fruit weight was found to decrease by GA_3.

Gustafson (1960) spraying of GA_3 on tomato flower and flower buds of the first three clusters (35 and 70 ppm) and established that GA_3 improved fruit set but reduced fruit weight of tomato.

Rapport (1960) proved that GA_3 had no significant effect on fruit weight and size either at cool (11^0C) or warm (23°C) night temperatures; but it strikingly waned fruit size at an optimum temperature (17^0C).

Chapter III

MATERIALS AND METHODS

The details of the materials and methods of this research work were described in this chapter. It consists of a short description of experimental site, climate and weather, experimental design, layout, materials used for experiment, raising of seedling, treatments, land preparation, manuring and fertilizing, transplantation of seedlings, intercultural operations, harvesting, collection of data and statistical analysis which are given below:

3.1 Experimental site

The experiment was conducted at the research farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, and Dhaka 1207. The location of the site was $23^{0}74^{/}$ N latitude and $90^{0}35^{/}$ E longitude with an elevation of 8.2 meter from sea level.

3.2 Experimental period

The experiment was carried out during the Rabi season from November 2015 to March 2016. Seedlings were sown on 05 November, 2015 and were harvested up to 10 March, 2016.

3.3 Soil type

The experimental site was situated in the subtropical zone. The soil of the experimental site lies in agro-ecological regions of "Madhupur Tract" (AEZ No. 28). Its top soil is clay loam in texture and olive grey with common fine to medium distinct dark yellowish brown mottles. The pH 4.47 to 5.63 and organic carbon contents is 0.8

3.4 Weather

The monthly mean of daily maximum, minimum and average temperature, relative humidity, monthly total rainfall and sunshine hours received at the experimental site during the period of the study have been collected from Bangladesh Meteorological Department, Agargaon, Dhaka 1207 (Appendix II).

3.5 Materials used for experiment

The tomato, variety BARI Tomato-14 was used for the experiment. Seeds were collected from Bangladesh Agricultural Research Institute, Joydevpur, Gazipur.

3.6 Raising of seedling

Tomato seedlings were raised in two seed beds of 2m x 1m size. The soil was well prepared and converted into loose friable condition in obtaining good tilth. All weeds, stubbles and dead roots were removed. Twenty grams of seeds were sown in each seedbed. The seeds were sown in the seedbed on 15 October, 2015. Seeds were then covered with finished light soil and shading was provided by bamboo mat (chatai) to protect young seedlings from scorching sunshine and rainfall. Light watering, weeding and mulching were done as and when necessary to provide seedlings with a good condition for growth.

3.7 Treatments

The two factor experiment consisted of three levels of boron (Factor A) and four levels of Gibberellic acid (Factor B). The factors were as follows:

Factor A: levels of Boron	Factor B: levels of GA_3
B_0 = 0 kg ha^{-1}	G_0 = 0 ppm
B_1 = 0.8 kg ha^{-1}	G_1 = 50 ppm
B_2 = 1 kg ha^{-1}	G_2 = 100 ppm
	G_3 = 150 ppm

There were all together 12 treatments combination used in each block and were as follows: B_0G_0 , B_0G_1 , B_0G_2 , B_0G_3 , B_1G_0 , B_1G_1 , B_1G_2 , B_1G_3, B_2G_0 , B_2G_1 , B_2G_2 , B_2G_3

3.8 Experimental design and layout

Field layout was done after final land preparation. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The whole plot was divided into three blocks each containing twelve (12) plots of 2m x 1.8m size, giving 36 unit plots. The space was kept 0.5 m between the blocks and 0.5m between the plots were kept. The distance between row to row and plant to plant was 60 cm and 50 cm, respectively. The layout of the experiment is shown in Figure-1.

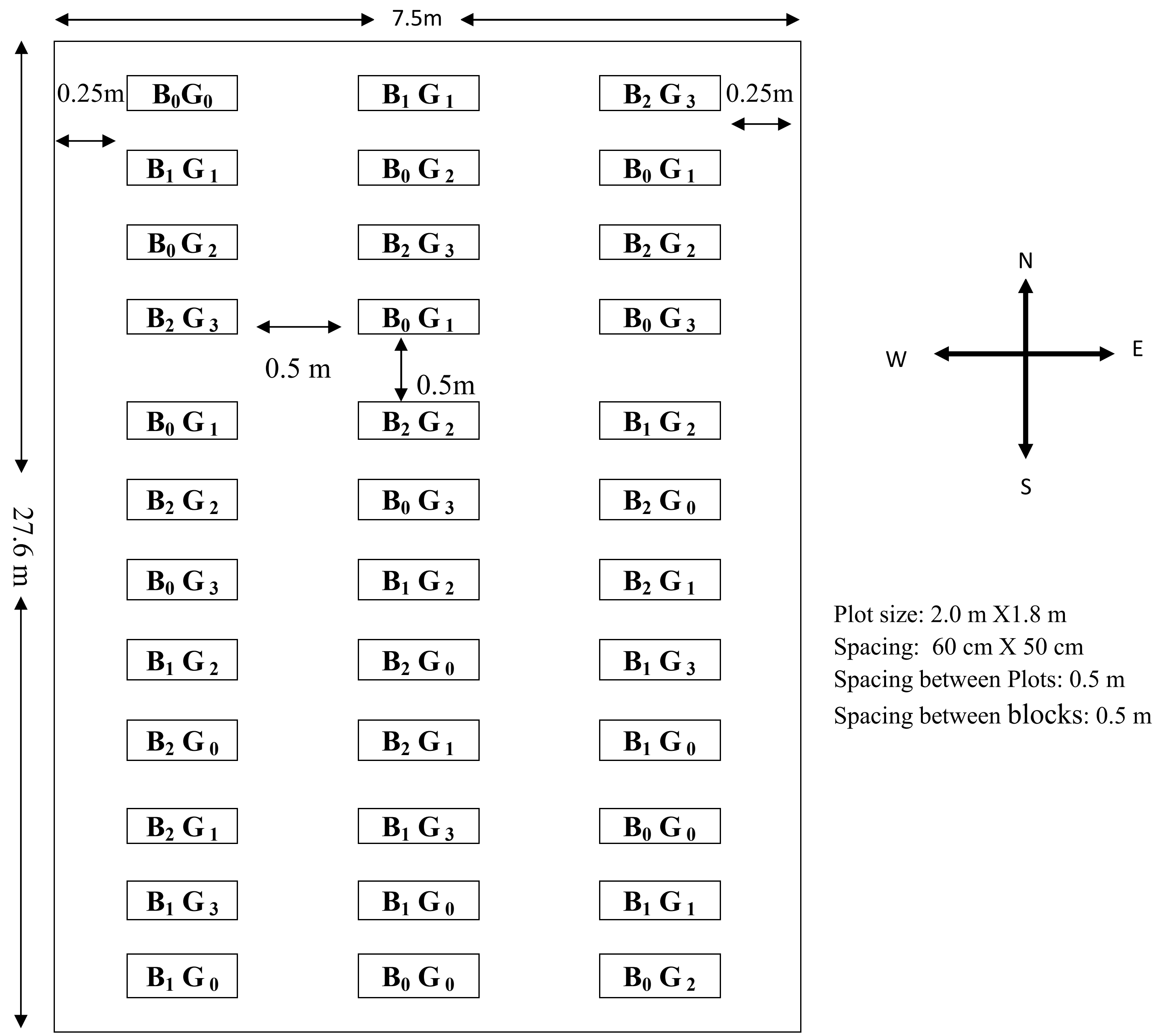


Fig. 1: Layout of the experimental plot

3.9 Land preparation

The experimental field was thoroughly ploughed and cross ploughed and cleaned prior to seed sowing and application of fertilizers and manure were done in the field. The experimental field was prepared by thorough ploughing followed by laddering to have a good tilth. Finally the land was properly leveled before transplanting. Then plots were prepared as per the design.

3.10 Application of manure and fertilizers

The sources of N, P_2O_5, K_2O as urea, TSP and MP were applied, respectively. The entire amounts of TSP and MP were applied during the final land preparation. Urea was applied in three equal installments at 25, 35 and 45 days after seedling transplanting (DAT). Well-rotten cowdung 10 t ha^{-1} also applied during final land preparation.

Table1. Fertilizer and manure applied for the experimental field preparation. Manure and fertilizers were used as recommended by BARI (2005).

Manure / Fertilizers	**Rate/ha**	**Application (%)**			
		Basal	25 DAT	35 DAT	45 DAT
Cow dung	20 ton	100	-	-	-
Urea	100kg	-	33.33	33.33	33.33
TSP	200 kg	100	-	-	-
MP	220 kg	100	-	-	-

3.11 Preparation and application of GA_3

The stock solution of 1000 ppm of GA_3 with small amount of ethanol to dilute and then mixed in 1 litre of water turn as per requirement of 50 ppm, 100 ppm and 150 ppm solution of GA_3. 50, 100 and 150 ml of stock solution were mixed with 1 litre of water.

3.12 Transplanting of seedlings

Healthy and uniform 20 days old seedlings were uprooted separately from the seed bed and were transplanted in the experimental plots in the afternoon of 05 November, 2015 maintaining a spacing of 60 cm x 50 cm between the rows and plants respectively. This allowed an accommodation of 12 plants in each plot. The seedbed was watered before uprooting the seedlings from the seedbed so as to minimize damage of the roots. The seedlings were watered after transplanting. Seedlings were also planted around the border area of the experimental plots for gap filling.

3.13 Gap filling

Gap filling was done as and when needed.

3.14 Intercultural operation

After transplanting of seedlings, various intercultural operations such as irrigation, weeding, staking and top dressing etc. were accomplished for better growth and development of the tomato seedlings.

3.14.1 Irrigation and drainage

Over-head irrigation was provided with a watering cane to the plots once immediately after transplanting seedlings in every alternate day in the evening up to seedling establishment. Further irrigation was provided when needed. Excess water was effectively drained out at the time of heavy rain.

3.14.2 Staking

When the plants were well established, staking was given to each plant by bamboo sticks to keep them erect.

3.14.3 Weeding

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

3.14.4 Control of pest and disease

Malathion 57 EC was applied @ 2 ml L^{-1} against the insect pests like cut worm, leaf hopper, fruit borer and others. The insecticide application was made fortnightly for a week after transplanting to a week before first harvesting. Furadan 10 G was also applied during final land preparation as soil insecticide. During foggy weather precautionary measured against disease infection of tomato was taken by spraying Dithane M-45 fortnightly @ 2 g L^{-1}, at the early vegetative stage. Ridomil gold was also applied @ 2 g L^{-1} against blight disease of tomato.

3.15 Harvesting

Fruits were harvested at 5 days intervals during maturity to ripening stage. The maturity of the crop was determined on the basis of red colouring of fruits. Harvesting was started from 20 February, 2016 and completed by 10 March, 2016.

3.16 Collection of data

Five plants were selected randomly from each unit plot for data collection in such a way that the border effect could be avoided at the highest precision. Data on the following parameters were recorded from the sample plants during the course of experiment.

3.16.1 Plant height

Plant height was measured from the sample plants in centimeter from the ground level to the tip of the longest stem and means value was calculated. Plant height was recorded 20, 40 and 60 days after planting to observe the growth rate.

3.16.2 Number of leaves

Number of leaves was measured from the sample plants and recorded from 20, 40 and 60 days of planting to observe the growth rate of the plants.

3.16.3 Number of flower clusters per plant

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

3.16.4 Number of flowers per cluster

The number of flowers per cluster was calculated as follows:

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

3.16.5 Number of fruits per cluster

The number of flowers per cluster was calculated as follows:

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

3.16.6 Number of fruits per plant

The number of fruits was recorded from the sample plants, and the average number of fruit clusters produced per plant was recorded.

3.16.7 Fruit weight per plant (kg)

Fresh fruit weight (kg) of plant was taken by an electric balance after harvest and was recorded.

3.16.8 Fruit weight per plot (Kg)

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

3.16.9 Fruit yield per hectare

It was measured by the following formula:

$$\text{Fruit Yield per hectare (ton)} = \frac{\text{Fruit yield per plot (kg)} \times 10000\text{m}^2}{\text{Area of plot in square meter (m}^2\text{)} \times 1\,000\text{kg}}$$

3.16.10 Measurement of Total Soluble Sugar (TSS %)

One drop ripens tomato juice was used to take the TSS % reading in a digital brix meter (ATOGA, Japan). Reading from brix meter recorded in percentage.

3.16.11 Measurement of β- carotene

At first 15-20g flesh of ripen tomato was taken and crushed by mortar and pastel. Then 5g paste was taken in a plastic container having airtight lid. There after 50ml mixture (Acetone : n-Hexane = 2:3) was poured in the container by a measuring cylinder and the container was placed in a vertical shaker for 10 minutes. Then the solution was centrifuged at 5000-6000 rpm. After centrifuge, the supernatant (clear transparent) was taken in a glass vial. Then spectrophotometer reading was recorded at four different nanometer length viz. 663 nm, 645 nm, 505 nm and 453nm. Finally, β- carotene was calculated by the following formula:

β- carotene (mg)= 0.216 (reading of 664 nm) + 0.452 (reading of 453 nm)-1.22 (reading of 645 nm)-0.304(reading of 505 nm)

3.16.12 Measurement of Vitamin C

Vitamin C content of green and dry fruits was determined by 2, 6- dichlorophenol indophenols visual titration method. The following reagents were used for the estimation of vitamin C contains.

3.16.12.1 Reagents

i. **3 % Metaphosphoric acid (HPO_3):** Is was prepared by dissolving 30 g of HPO_3 and 80 ml glacial acetic acid in distilled water and volumes made up to one liter.

ii. **Standard ascorbic acid solution:** 10 % of L- ascorbic acid solvent was made by dissolving ascorbic acid in 3 metaphosphoric acid solution.

iii. **Dry solution:** It was prepared by dissolving 260 mg of sodium salt of 2, 6-dicholophenol indophenols in one liter of distilled water.

3.16.12.2 Procedure

Standardization of dye solution:

Dilute 5 ml of standard ascorbic acid solution with 5 ml of Meta phosphoric acid. A micro burette was loaded with dye solution and the mixed solution was titrated with dye solution using phenolphthalein as indicator to a the pink colored end point which insisted for at least 15 sec. Dye factor was enumerated using the following formula:

$$\text{Dye factor} = \frac{0.5}{\text{Titre}}$$

3.16.12.3 Preparation of sample

Five grams of fresh ripen fruit was taken in a 100 ml beaker with 50 ml 3 % metaphosphoric acid and then it was transferred to blender and homogenized with same concentration of metaphosphoric acid. First blending then it was filtered and centrifuged at 2000 rpm for 5 minutes. The homogenized liquid was transferred to a 100 ml volumetric flask and was made up to the mark with 3 % metaphosphoric acid.

Titration:

Five ml of the aliquot was taken in conical flask and titrated with 2, 6-dicholophenol indophenols dye, phenolphthalein was used as indicator to a ping colored end point, which persisted at least 15 seconds. The ascorbic acid content (Vitamin C) of the sample was calculated by using the following formula:

$$\text{Ascorbic acid (mg/100g)} = \frac{T \times d \times V_1}{V_2 \times W} \times 100$$

Where,
T = Titre value (ml)
D = Dye factor
V_1 = Volume to be made (ml)
V_2 = Volume of extract taken for titration (ml)
W = Weight of sample taken for estimation (gm)

3.17 Analysis of data

Data statistically analyzed by randomized complete block design through MSTAT-C software and Duncan's multiple range tests was used to analyze the growth, yield and quality characters of tomato to find out the statistical significance. The significance of the difference was evaluated by Duncan's Multiple Range Test (DMRT) according to Gomez and Gomez, (1984) for interpretation of the results at 5% level of probability.

Chapter IV

RESULTS AND DISCUSSIONS

This chapter comprises the presentation and discussion of the results obtained from the effect of Boron and Gibberellic acid (GA_3) on the growth, yield and quality of tomato. The effects due to different doses of Boron (B) and Gibberellic acid (GA_3) and their interaction on the growth, yield and yield contributing characters have been presented in tables 2-13 and figures 2-4. Relationship between parameters also presented figure 5-13. Results of the different parameters studied in this experiment have been presented and discussed under the following headings.

4.1 Effect of B and GA_3 on growth and yield of tomato

4.1.1 Plant height

Plant height of tomato varied significantly due to the application of different levels of boron at 20, 40, and 60 DAT (Table 2). At 20 DAT, the highest plant height was found in B_1 (13.02 cm) which were statistically different from all other treatments, while the lowest plant height was found in B_2 (10.28 cm). At 40 DAT, the highest plant height was found in B_1 (61.97 cm) which were statistically different from all other treatments, while the lowest plant height was found in B_2 (54.45 cm). At 60 DAT, the highest plant height was found in B_1 (96.40 cm) which were statistically different from all other treatments, while the lowest plant height was found in B_o (90.80 cm). At 20 DAT, B_2 showed the lowest plant height due to boron toxicity at younger stage of tomato which is supported by the findings of Singh and Tiwari (2013). Hatwar *et al.* (2003) also supported that application of boron has been increased plant height of tomato.

Plant height of tomato varied significantly due to the application of different levels of gibberellic acid (GA_3) at 20, 40, and 60 DAT (Table 3). At 20 DAT, the highest plant height was found in G_2 (12.94 cm) which was statistically different from all other treatments, while the lowest plant height was found in G_3 (10.91 cm) which was statistically similar with G_0 (11.19 cm). At 40 DAT, the highest plant height was found in G_2 (61.97 cm) which was statistically different from all other treatments, while the lowest plant height was found in G_3 (56.20 cm). At 60 DAT, the highest plant height was found in G_2 (98.83 cm) which was statistically different from all other treatments, while the lowest plant height was found in G_0 (92.99 cm). The present finding also agreed to the result of Rai *et al.* (2006) and Nibhavanti *et al.* (2006). They observed that GA_3 increased plant height at 25 and 50 ppm. Wu *et al.* (1983) reported that 100 ppm GA_3 increased maximum plant height.

Combine effect of boron and gibberellic acid (GA_3) showed statistically significant variation on plant height at 20, 40, and 60 DAT (Table 4). The highest plant height at 20 DAT was found in case of B_1G_2 (15.33 cm) which was statistically different from all other treatments and was followed by B_1G_1 (14.00 cm), B_0G_3 (13.43 cm), while lowest plant height at 20 DAT was found in case of B_2G_3 (8.767 cm). The highest plant height at 40 DAT was found in case of B_1G_2 (69.27 cm) which was statistically different from all other treatments and was followed by B_1G_1 (62.23 cm), B_0G_3 (61.10 cm), B_1G_0 (60.17 cm), while the lowest plant height at 40 DAT was found in case of B_2G_3 (51.30 cm) which was followed by B_2G_0 (54.37 cm), B_2G_1 (55.17 cm), B_1G_3 (56.20 cm). The highest plant height at 60 DAT was found in case of B_1G_2 (105.3 cm) which was statistically different from all other treatments, while the lowest plant height at 60 DAT was found in case of B_2G_3 (87.6 cm) and was followed by B_0G_0 (88.4 cm), B_0G_1 (90.13 cm),

B_0G_2 (90.8 cm). El-Mahdy (2007) expressed that the highest plant height was observed in the combined application of H_3BO_3 (350 ppm) + GA_3 (350 ppm).

Table 2. Effect of boron (B) on growth attributes of tomato

Treatment	Plant height (cm)			No. of leaves per plant		
	20 DAT	40 DAT	60 DAT	20 DAT	40 DAT	60 DAT
B_0	12.12 b	59.61 b	90.80 c	4.667 b	12.17 b	30.08 b
B_1	13.02 a	61.97 a	97.74 a	7.083 a	15.17 a	34.58 a
B_2	10.28 c	54.45 c	96.40 b	4.750 b	10.92 c	30.92 b
$Lsd_{0.05}$	0.3429	.4284	0.5301	1.074	1.215	2.030
CV (%)	1.72	.43	.33	11.52	5.63	3.76

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

$B_0 = 0$ kg ha^{-1}, $B_1 = 0.8$ kg ha^{-1}, $B_2 = 1$ kg ha^{-1}

DAT= Days after transplanting

Table 3. Effect of gibberellic acid (GA_3) on growth attributes of tomato

Treatment	Plant height (cm)			No. of leaves per plant		
	20 DAT	40 DAT	60 DAT	20 DAT	40 DAT	60 DAT
G_0	11.19 c	57.68 c	92.99 c	4.889 b	12.78 ab	31.00 b
G_1	12.18 b	58.86 b	94.26 b	5.444 ab	12.89 ab	31.78 b
G_2	12.94 a	61.97 a	98.83 a	6.111 a	13.56 a	33.00 a
G_3	10.91 c	56.20 d	93.84 b	5.556 ab	11.78 b	31.67 b
$Lsd_{0.05}$	0.3429	0.4284	0.5301	1.074	1.215	1.030
CV (%)	1.72	.43	.33	11.52	5.63	3.76

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

G_0 = 0 ppm, G_1 = 50 ppm, G_2 = 100 ppm, G_3 = 150 ppm

DAT= Days after transplanting

Table 4. Combined effect of boron (B) and gibberellic acid (GA_3) on growth attributes of tomato

Treatment	Plant height (cm)			No. of leaves per plant		
	20 DAT	40 DAT	60 DAT	20 DAT	40 DAT	60 DAT
B_0G_0	11.10 f	58.50 g	88.40 j	3.333 g	10.33 f	28.00 h
B_0G1	11.63 e	59.17 f	90.13 i	4.333 fg	11.33 f	29.00 gh
B_0G_2	12.30 d	59.67 e	90.80 h	5.333 def	13.00 de	31.00 efg
B_0G_3	13.43 c	61.10 c	93.87 e	5.667 cde	14.00 cd	32.33 bcde
B_1G_0	12.20 d	60.17 d	92.30 g	6.333 bcd	14.67 c	33.67 bc
B_1G_1	14.00 b	62.23 b	93.27 f	7.000 b	16.00 b	34.33 b
B_1G_2	15.33 a	69.27 a	105.3 a	8.333 a	17.33 a	37.00 a
B_1G_3	10.53 g	56.20 i	100.1 b	6.667 bc	12.67 e	33.33 bcd
B_2G_0	10.27 g	54.37 k	98.27 d	5.000 ef	13.33 de	31.33 def
B_2G_1	10.90 f	55.17 j	99.37 c	5.000 ef	11.33 f	32.00 cde
B_2G_2	11.20 f	56.97 h	100.4 b	4.667 ef	10.33 f	31.00 efg
B_2G_3	8.767 h	51.30 l	87.60 k	4.333 fg	8.667 g	29.33 fgh
$Lsd_{0.05}$	0.3429	0.4284	0.5301	1.074	1.215	2.030
CV (%)	1.72	.43	.33	11.52	5.63	3.76

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

$B_0 = 0$ kg ha^{-1}, $B_1 = 0.8$ kg ha^{-1}, $B_2 = 1$ kg ha^{-1}

G_0 = 0 ppm, G_1 = 50 ppm, G_2 = 100 ppm, G_3 = 150 ppm

DAT= Days after transplanting

4.1.2 Number of leaves per plant

The effect of different levels of boron in respect of number of leaves per plant was significant at 20, 40, and 60 DAT (Table 2). At 20 DAT the maximum number of leaves per plant was found in B_1 (7.083) which were statistically different from all other treatments, while the minimum number of leaves per plant was found in B_0 (4.667) which was statistically similar with B_2 (4.750). At 40 DAT, the maximum number of leaves per plant was found in B_1 (15.17) which were statistically different from all other treatments, while the minimum number of leaves per plant was found in B_2 (10.92). At 60 DAT, the maximum number of leaves per plant was found in B_1 (34.58) which were statistically different from all other treatments, while the minimum number of leaves per plant was found in B_o (30.08), which is statistically similar with B_2 (30.92). Harris and Mathuma (2015) found that maximum number of leaves per plant by the application of boron at 60 DAT.

Number of leaves per plant varied significantly due to the application of different level of GA_3 at 20, 40, and 60 DAT (Table 3). At 20 DAT, the maximum number of leaves per plant was found in G_2 (6.111) which was statistically similar with G_3 (5.556) and G_1 (5.444), while the minimum number of leaves per plant was found in G_0 (4.889) which was statistically similar with G_1 (5.444) and G_3 (5.556). At 40 DAT, the maximum number of leaves per plant was found in G_2 (13.56) which was statistically similar with G_1 (12.89) and G_0 (12.78), while the minimum number of leaves per plant was found in G_3 (11.78) which was statistically similar with G_0 (12.78) and G_1 (12.89). At 60 DAT, the maximum number of leaves per plant was found in G_2 (33.00) which were statistically different from all other treatments, while the minimum number of leaves per plant was found in G_0 (31.00) which was statistically similar with G_3 (31.67) and G_1 (31.78). The result also supported to the finding of Rai *et al.* (2006) and Nibhavanti *et al*. (2006) observed that GA_3 increased the number of leaves per plant at 25 and 50 ppm which is support the present study.

Combined effect of boron and GA_3 showed statistically significant variation for number of leaves per plant at 20, 40, and 60 DAT (Table 4). At 20 DAT, the maximum number of leaves per plant was found in B_1G_2 (8.333) which was statistically different from all other treatments, and was followed by B_1G_1 (7.00), B_1G_3 (6.667), B_1G_0 (6.333). On the other hand, the minimum number of leaves per plant was found in B_0G_0 (3.333), which is statistically similar with B_0G_1 (4.333) and B_2G_3 (4.333). At 40 DAT, the maximum number of leaves per plant was found in B_1G_2 (17.33) which was statistically different from all other treatments, and was followed by B_1G_1 (16.00), B_1G_0 (14.67), B_0G_3 (14.00). On the other hand, the minimum number of leaves per plant was found in B_2G_3 (8.667) which were statistically different from all other treatments. At 60 DAT, the maximum number of leaves per plant was found in B_1G_2 (37.00) which was statistically different from all other treatments, and was followed by B_1G_1 (34.33), B_1G_0 (33.67), B_2G_1 (32.00), B_2G_0 (31.33). On the other hand, the minimum number of leaves per plant was found in B_0G_0 (28.00) which was statistically similar with B_0G_1 (29.00), B_2G_3 (29.33). Shakir *et al*. (2014) obtained higher number of leaves in tomato at the concentration of combined application of GA_3 (1250 ppm) + B (1250 ppm), which was Eight times higher than the concentration used in this experiment B (150 ppm) + GA_3 (150 ppm). Singh and Tiwari, (2013) found that number of leaves increased due to the foliar application of GA_3 (12.5 ppm) and B (12.5 ppm) which is supported to the present study.

4.1.3 Number of flower clusters per plant

There was significant effect of different doses of boron on the number of flower clusters per plant (Table 5). The maximum number of flower clusters per plant was found in B_1 (12.33) which was statistically different from all other treatments, while the minimum number of flower clusters per plant was found in B_0 (8.25) which was statistically similar with B_2 (9.00). Ullah *et al.* (*2015)* founds that, the highest number of flowers cluster per plant (27.55) was noted in plants with 0.15 % boron, followed by (24.80) and (21.81) in plants of 0.1 % and 0.05 % B, respectively.

Statistically significant variation was found in number of flower clusters per plant in different doses of GA_3 (Table 6). The maximum number of flower clusters per plant was found in G_2 (10.44) which was statistically similar with G_1 (10.00), G_0 (9.667) while the minimum number of flower clusters per plant was found in G_3 (9.333). Flower primodia was promoted by GA_3 with increase number of flower cluster per plant which is found by Onofeghara (1983).

Interaction effect of boron and GA_3 on the number of flower clusters per plant was significant (Table 7). The maximum number of flower clusters per plant was found in B_1G_2 (13.67) which was statistically similar with B_1G_3 (12.33), B_1G_1 (12.00) and was followed by B_1G_0 (11.33), B_2G_0 (11.00), B_2G_1 (10.67), B_0G_3 (10.33). The minimum number of flower clusters per plant was found in B_2G_3 (5.333) which was statistically similar with B_0G_0 (6.667), B_0G_1 (7.333) and was followed by B_0G_2 (8.667), B_2G_2 (9.00), B_0G_3 (10.33), B_2G_1 (10.67) B_2G_0 (11.00). Number of flower clusters per plant increased by application of boron was reported by Basavarajeswari *et al*., 2008 and of GA_3 by Kiran *et al.,* 2010.

Table 5. Effect of boron (B) on yield contributing characters of tomato

Treatment	Flower clusters per plant	Flowers per cluster	Fruit per cluster	Fruit per plant
B_0	8.250 b	6.333 b	4.917 a	37.25 b
B_1	12.33 a	8.750 a	5.667 a	59.08 a
B_2	9.000 b	7.250 b	5.000 a	40.33 b
$Lsd_{0.05}$	2.139	1.176	1.038	5.876
CV (%)	12.81	9.33	11.81	7.62

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

B_0 = 0 kg ha^{-1}, B_1 = 0.8 kg ha^{-1}, B_2 = 1 kg ha^{-1}

4.1.4 Number of flowers per cluster

Effect of different doses of boron on number of flowers per cluster was significant (Table 5). The maximum number of flowers per cluster was found in B_1 (8.75) which was statistically different from all other treatments, while the minimum number of flowers per clusters was found in B_0 (6.333) which were statistically similar with B_2 (7.250). Haque *et* al. (1999) revealed that maximum number of flower cluster 5.59 and 5.36 in plants sprayed with B @ 0.1 % and 0.15 %, whereas the least number of flowers cluster (4.63).

There were no significant variations in number of flowers per cluster in different doses of GA_3 (Table 6). The maximum number of flowers per cluster was found in G_2 (8.222) which were statistically similar with G_3 (7.333). The minimum number of flowers per cluster was found in G_0 and G_1 (7.111) which were statistically similar. Application of GA_3 had increased the number of flower buds and open flowers that reported by Paroussi *et al.* (2002).

Effect of different doses of boron and GA_3 on the number of flowers per cluster was significantly influenced (Table 7). The maximum number of flowers per cluster was found in B_1G_2 (10.67) which was statistically different from all other treatments, and was followed by B_1G_3 (9.333), B_2G_0 (8.667). The minimum number of flowers per cluster was found in B_2G_3 (5.00) which was statistically similar with B_0G_1 (5.333), B_0G_0 (5.667). The result is in agreement with the report of Sujatha *et al.*(2002) and Karaguzel *et al.* (1999) who stated that the number of flowers per cluster increased with combined application of growth regulators and boron combination.

Table 6. Effect of gibberellic acid (GA_3) on yield contributing characters of tomato

Treatment	Flower cluster per plant	Flower per cluster	Fruit per cluster	Fruit per plant
G_0	9.667 a	7.111 a	4.889 a	41.22 b
G_1	10.00 a	7.111 a	5.222 a	48.00 a
G_2	10.44 a	8.222 a	5.778 a	51.67 a
G_3	9.333 b	7.333 a	4.889 a	41.33 b
$Lsd_{0.05}$	1.009	1.176	1.038	5.876
CV (%)	12.81	9.33	11.81	7.62

G_0 = 0 ppm, G_1 = 50 ppm, G_2 = 100 ppm, G_3 = 150 ppm

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

Table 7. Combined effect of boron (B) and gibberellic acid (GA_3) on yield contributing characters of tomato

Treatment	Flower clusters per plant	Flowers per cluster	Fruit per cluster	Fruit per plant
B_0G_0	6.667 fg	5.667 fg	4.000 cd	25.33 h
B_0G1	7.333 efg	5.333 g	4.667 bcd	31.33 g
B_0G_2	8.667 def	6.667 ef	5.333 b	42.00 f
B_0G_3	10.33 bcd	7.667 cde	5.667 ab	50.33 d
B_1G_0	11.33 bc	7.000 de	5.000 bc	43.33 ef
B_1G_1	12.00 ab	8.000 cd	5.667 ab	63.67 b
B_1G_2	13.67 a	10.67 a	6.667 a	70.67 a
B_1G_3	12.33 ab	9.333 b	5.333 b	58.67 bc
B_2G_0	11.00 bcd	8.667 bc	5.667 ab	55.00 cd
B_2G_1	10.67 bcd	8.000 cd	5.333 b	49.00 de
B_2G_2	9.000 cde	7.333 de	5.333 b	42.33 f
B_2G_3	5.333 g	5.000 g	3.667 d	15.00 i
$Lsd_{0.05}$	2.139	1.176	1.038	5.876
CV (%)	12.81	9.33	11.81	7.62

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

B_0 = 0 kg ha^{-1}, B_1 = 0.8 kg ha^{-1}, B_2 = 1 kg ha^{-1}

G_0 = 0 ppm, G_1 = 50 ppm, G_2 = 100 ppm, G_3 = 150 ppm

4.1.5 Number of fruits per cluster

Statistically no significant variations were found in number of fruits per cluster in different doses of boron (Table 5) and GA_3 (Table 6). Smit *et al.* (2004) revealed the same result in case of boron application in appropriate doses. Balraj and Mahesh (2005) reported the same findings that support the result.

Significant interaction effect of different doses of boron and GA_3 were found on the number of fruits per cluster (Table 7). The maximum number of fruits per cluster was found in B_1G_2 (6.667) which was statistically similar with B_1G_1 (5.667), B_2G_0 (5.667). On the other hand, the minimum number of fruits per cluster was found in B_2G_3 (3.667) which was statistically similar with B_0G_0 (4.00), B_1G_0 (5.00). Tomar and Ramgiry (1997) found that plants treated with combined application of B and GA_3 showed significantly greater number of fruits per cluster than untreated controls.

4.1.6 Number of fruits per plant

Statistically significant variation was found in number of fruits per plant in different doses of boron (Table 5). The highest number of fruits per plant was recorded in B_1 (59.08) which were statistically different from all other treatments while the lowest number of fruits per plant was found in B_0 (37.25) which were statistically similar with B_2 (40.33). Shnain *et al.* (2014) showed that application of B at 150 and 100 ppm increased number of fruits per plant by 216% and 94.7%, respectively.

The result showed that there was significant effect in different doses of GA_3 on the number of fruits per plant (Table 6). The highest number of fruits per plant was recorded in G_2 (51.67) which were statistically similar with G_1 (48.00) while the lowest number of fruits per plant was found in G_0 (41.22) which were statistically similar with G_3 (41.33). Maximum number fruit in 50 ppm (38.26) and minimum was found in 0 ppm (17.25) was found by Adlakha and Verma (1964), Uddain *et al.* (2009) and Mehta and Mathi (1975) which is support the present study.

Combined effect of different doses of boron and GA_3 on the number of fruits per plant was found to be statistically significant (Table 7). The highest number of fruits per plant was recorded in B_1G_2 (70.67) which was statistically different from all other treatments, and was followed by B_1G_1 (63.67), B_1G_3 (58.67), B_2G_0 (55.00) and B_0G_3 (50.33). The lowest number of fruits per plant was recorded in B_2G_3 (15.00) which was statistically different from all other treatments, and was followed by B_0G_0 (25.33), B_0G_1 (31.33), B_0G_2 (42.00), B_2G_2 (42.33), B_1G_0 (43.33). Combined application of GA_3 and boron increased the number of fruits per plant in tomato was reported by Yadav *et al.* (2001).

Table 8. Effect of boron (B) on yield and yield contributing characters of tomato

Treatment	Fruit wt per plant (Kg)	Fruit wt per plot (Kg)	Fruit yield (t ha^{-1})
B_0	1.834 b	17.66 b	49.06 b
B_1	2.391 a	24.91 a	69.20 a
B_2	1.381 c	12.44 c	34.55 c
$Lsd_{0.05}$	0.2395	2.139	5.943
CV (%)	7.64	6.89	6.89

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

B_0 = 0 kg ha^{-1}, B_1 = 0.8 kg ha^{-1}, B_2 = 1 kg ha^{-1}

Table 9. Effect of gibberellic acid (GA_3) on yield and yield contributing characters of tomato

Treatment	Fruit wt per plant (Kg)	Fruit wt per plot (Kg)	Fruit yield (t ha^{-1})
G_0	1.798 b	17.86 ab	49.60 ab
G_1	1.898 ab	18.75 ab	52.09 ab
G_2	1.995 a	19.67 a	54.63 a
G_3	1.709 b	17.07 b	47.43 b
$Lsd_{0.05}$	0.1095	2.139	5.943
CV (%)	7.64	6.89	6.89

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

G_0 = 0 ppm, G_1 = 50 ppm, G_2 = 100 ppm, G_3 = 150 ppm

4.1.7 Weight of fruits per plant (kg)

It was noticed that different doses of boron exhibited significant effect on weight of fruits per plant (Table 8). The highest weight of fruits per plant obtained from B_1 (2.391 kg) which was statistically different from all other treatments, while the lowest weight of fruits per plant obtained from B_2 (1.381 kg) which was statistically different from all other treatments, and was followed by B_0 (1.834 kg). Bhatt *et al.* (2004) showed application of H_3BO_3 at 150 and 100 ppm increased weight of fruits by 88 % and 49 %, respectively.

It was noticed that different doses of GA_3 exhibited significant effects on weight of fruits per plant (Table 9). The maximum weight of fruits per plant obtained from G_2 (1.995 kg) which was statistically similar with G_1 (1.898 kg), while the minimum weight of fruits per plant obtained from G_3 (1.709 kg). Similar result was found by Kaushik *et al.* (1974) and Uddain *et al.* (2009).

Statistically significant variation was recorded in combined effect of different doses of boron and GA_3 on weight of fruits per plant (Table 10). The highest weight of fruits per plant was recorded in B_1G_2 (2.570 kg) which was statistically similar with B_1G_1 (2.377 kg), B_1G_0 (2.370 kg). The lowest weight of fruits per plant was recorded in B_2G_3 (0.8367 kg) which was statistically different from all other treatments, and was followed by B_2G_2 (1.160 kg), B_0G_0 (1.443 kg). Sindhu *et al.* (1999) reported that foliar application of B and GA_3 increase fruit weight which is support the present study.

4.1.8 Weight of fruits per plot (kg)

Results showed that, different doses of boron exhibited significant variation on weight of fruits per plot (Table 8). Maximum weight of fruits per plot was recorded in B_1 (24.91 kg) which was statistically different from all other treatments, while minimum weight of fruits per plot was recorded in B_2 (12.44 kg) and was followed by B_0 (17.66 kg).

Statistically significant variation was recorded in effect of different doses of GA_3 on weight of fruits per plot (Table 9). The highest weight of fruits per plot was recorded in G_2 (19.67 kg) which was statistically similar with G_1 (18.75 kg), G_0 (17.86 kg). The lowest weight of fruits per plot was recorded in G_3 (17.07 kg) which was statistically different from all other treatments. Tomar and Ramgiry (1997) found that plants treated with GA_3 125 ppm showed significantly greater yield per plot than untreated controls.

There was significant combined effect of different doses of boron and GA_3 on weight of fruits per plot (Table 10). The highest weight of fruits per plot was recorded in B_1G_2 (28.25 kg) which was statistically similar with B_1G_1 (26.15 kg), and was followed by B_1G_0 (22.77 kg), B_1G_3 (22.48 kg), B_0G_3 (22.30 kg), B_0G_2 (19.18 kg). The lowest weight of fruits per plot was recorded in B_2G_3 (6.437 kg) which was followed by B_2G_2 (11.58 kg), B_0G_0 (13.47 kg), B_2G_1 (14.41kg).

Table 10. Combined effect of boron (B) and gibberellic acid (GA_3) on yield and yield contributing characters of tomato

Treatment	Fruit wt per plant (Kg)	Fruit wt per plot (Kg)	Fruit yield (t ha^{-1})
B_0G_0	1.443 e	13.47 ef	37.42 ef
B_0G1	1.747 cd	15.70 de	43.61 de
B_0G_2	1.917 c	19.18 c	53.27 c
B_0G_3	2.230 b	22.30 b	61.95 b
B_1G_0	2.370 ab	22.77 b	63.24 b
B_1G_1	2.377 ab	26.15 a	72.64 a
B_1G_2	2.570 a	28.25 a	78.46 a
B_1G_3	2.247 b	22.48 b	62.45 b
B_2G_0	1.927 c	17.33 cd	48.13 cd
B_2G_1	1.600 de	14.41 e	40.02 e
B_2G_2	1.160 f	11.58 f	32.18 f
B_2G_3	0.8367 g	6.437 g	17.88 g
$Lsd_{0.05}$	0.2395	2.139	5.943
CV (%)	7.64	6.89	6.89

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

$B_0 = 0$ kg ha^{-1}, $B_1 = 0.8$ kg ha^{-1}, $B_2 = 1$ kg ha^{-1}

$G_0 = 0$ ppm, $G_1 = 50$ ppm, $G_2 = 100$ ppm, $G_3 = 150$ ppm

4.1.9 Fruit yield per hectare

The variation in fruit yield per hectare was found to be significant due to the application of different doses of boron (Table 8). The maximum fruit yield per hectare was found in B_1 (69.20 t ha^{-1}) which was statistically different from all other treatments and the lowest fruit yield per hectare was recorded in B_2 (34.55 t ha^{-1}) (Fig. 1). Chaudhary (1979) reported application of 0.15 % B resulted in increase yield to 23.33 t ha^{-1} followed by 22.12 t ha^{-1} in the plants received 0.1 % B, while minimum (18.54 t ha^{-1}) was recorded in control plants.

The different GA_3 doses showed significant variation in fruit yield per hectare (Table 9). The maximum fruit yield per hectare was found in G_2 (54.63 t ha^{-1}) while the minimum number of fruit yield per hectare was found in G_3 (47.43 t ha^{-1}) (Fig. 2). Hossain (1974) found a gradual increase in the yield per plant with higher concentration (120 ppm) of GA_3. Khan *et al*. (1998) reported that irrespective of its concentration, spray of gibberellic acid proved beneficial for the most parameters.

The interaction effects of various doses of boron and GA_3 fruit yield per hectare were found to be statistically significant (Table 10). The maximum fruit yield per hectare was recorded in B_1G_2 (78.46 t ha^{-1}) which was statistically similar with B_1G_1 (72.64 t/ha), and was followed by B_1G_0 (63.24 t ha^{-1}), B_1G_3 (62.45 t ha^{-1}), B_0G_3 (61.95 t ha^{-1}), B_0G_2 (53.27 t ha^{-1}). However, the lowest weight of fruits per plot was recorded in B_2G_3 (17.88 t ha^{-1}) which was followed by B_2G_2 (32.18 t ha^{-1}), B_0G_0 (37.42 t ha^{-1}), B_2G_1 (40.02 t ha^{-1}) (Fig. 3).

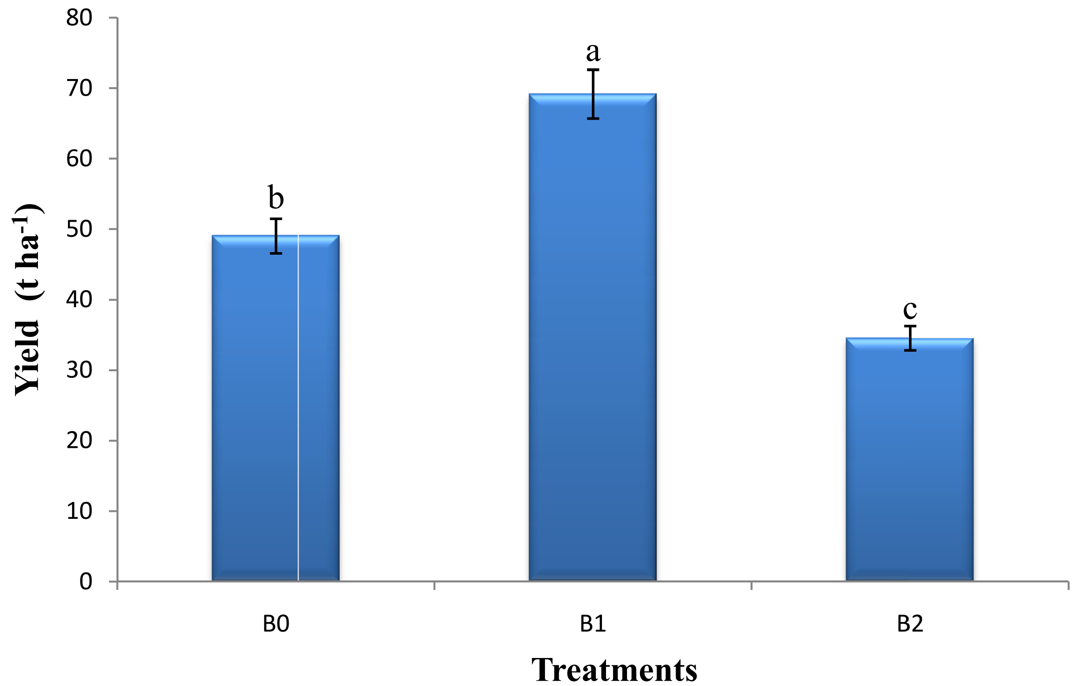


Fig. 2: Effect of boron (B) on the yield of tomato

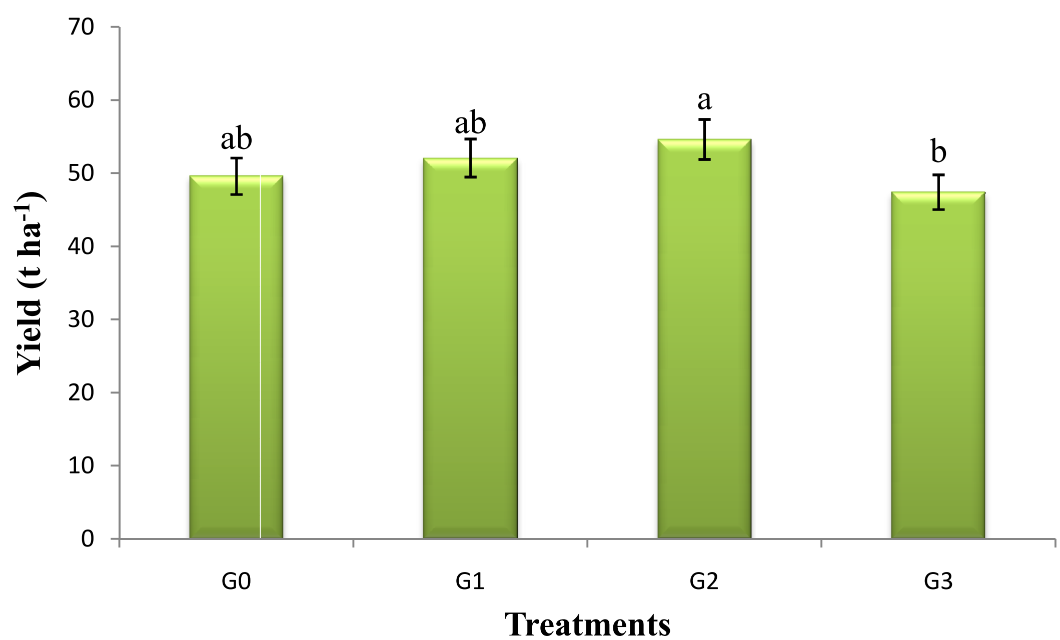


Fig. 3: Effect of Gibberellic acid (GA_3) on the yield of tomato

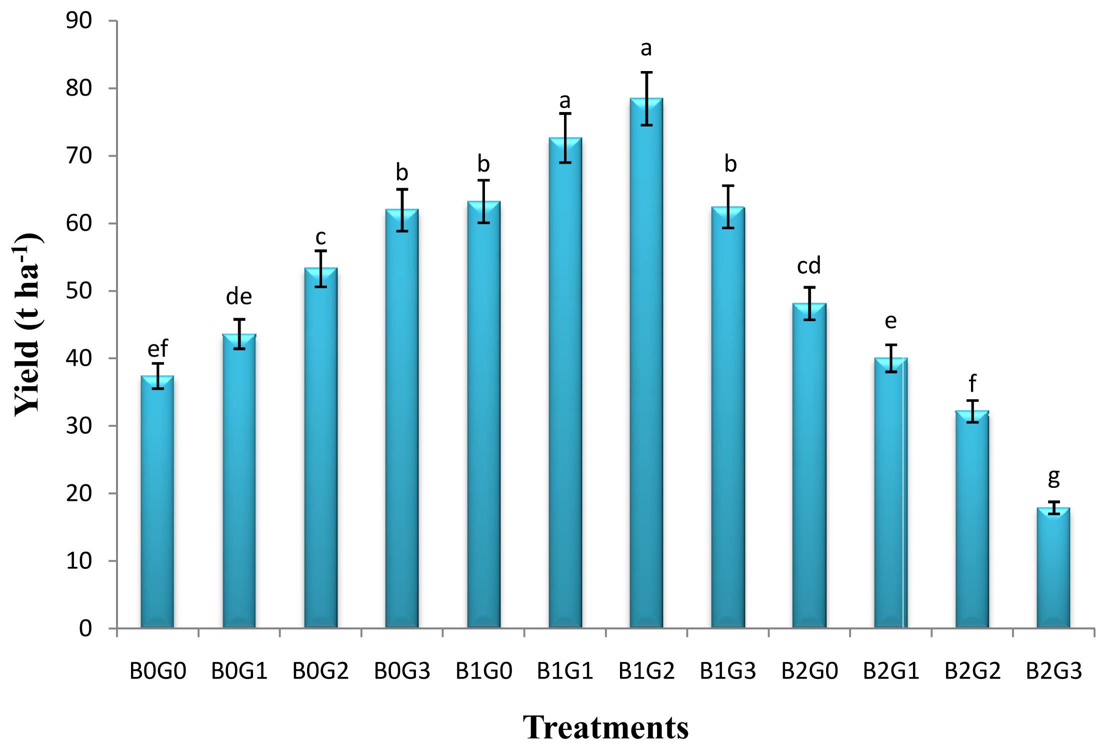


Fig. 4: Combination effect of boron (B) and gibberellic acid (GA_3) on the yield of tomato.

4.2 Effect of B and GA_3 on quality characters of tomato

4.2.1 Total Soluble Solids (TSS %)

There was significant variation among the different doses of boron in respect of total soluble solids (Table 11). The highest total soluble solids were recorded in B_1 (7.233 %) which was statistically different from all other treatments and that was followed by B_0 (7.042 %). Otherwise, the lowest total soluble solids were recorded in B_2 (6.950 %). Yan et *al*. (2003) used boron was used @ 0, 0.3, 1, and 10 micro mol L^{-1} and the results revealed that boron free and 0.3 micro mol L^{-1} treatments showed higher soluble sugar content in stem.

The different GA_3 doses showed significant variation in case of total soluble solids (Table 12). The maximum total soluble solids were recorded in G_2 (7.389 %) which was statistically different from all other treatments .On the other hand, the minimum total soluble solids was recorded in G_3 (6.878 %) which was statistically similar with G_0 (6.967 %) and G_1 (7.067 %). Graham and Ballesteros (2006) found that in tomato maximum TSS % (4.95) was in 50 ppm GA_3 and minimum TSS % (3.80) in control (3.80).

Significant variation was recorded in combined effect of different doses of boron and GA_3 on total soluble solids (Table 13). The maximum total soluble solids were recorded in B_1G_2 (7.60 %) which was statistically similar with B_0G_2 (7.40 %). The minimum total soluble solids were recorded in B_2G_3 (6.533 %) which was statistically similar with B_0G_0 (6.467 %) and was followed by B_2G_1 (6.833%), B_0G_3 (7.033 %), B1G3 (7.067 %). Shnain *et al.* (2014) revealed that the maximum of total soluble solids was recorded statistically significant in boron and zinc application @ (1.25 g L^{-1} B+ 1.25 g L^{-1} Zn) that is T_5, which was recorded (5.80) ^{0}brix, followed by T_6 @ (1.25 g L^{-1} B + 2.0 g L^{-1} Zn) (5.73) ^{0}brix .The minimum of total soluble solids ^{0}brix. (5.00) was noticed with control.

Table 11: Effect of boron (B) on quality contributing of tomato

Treatment	TSS %	β-Carotene (mg per 100g)	Vitamin-C (mg per100g)
B_0	7.042 ab	0.2500 c	74.04 c
B_1	7.233 a	0.3150 b	98.72 a
B_2	6.950 b	0.3167 a	84.94 b
$Lsd_{0.05}$	0.2395	0.0005355	5.524
CV (%)	1.98	2.64	3.80

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

B_0 = 0 kg ha^{-1}, B_1 = 0.8 kg ha^{-1}, B_2 = 1 kg ha^{-1}

Table 12: Effect of gibberellic acid (GA_3) on quality characters of tomato

Treatment	TSS %	β-Carotene (mg per 100g)	Vitamin-C (mg per 100g)
G_0	6.967 b	0.2689 c	80.77 c
G_1	7.067 b	0.2944 b	87.18 ab
G_2	7.389 a	0.3178 a	91.45 a
G_3	6.878 b	0.2944 b	84.19 bc
$Lsd_{0.05}$	0.2395	0.0005355	5.524
CV (%)	1.98	2.64	3.80

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

G_0 = 0 ppm, G_1 = 50 ppm, G_2 = 100 ppm, G_3 = 150 ppm

4.2.2 β-carotene content (mg per 100g)

Results showed that, different doses of boron exhibited significant variation on β-carotene content (Table 11). The maximum β-Carotene was obtained from B_2 (0.3167 mg per 100g) which was statistically different from all other treatments and that was followed by B_1 (0.3150 mg per 100g). The minimum β-carotene was obtained from B_0 (0.2500 mg per 100g) which was statistically different from all other treatments. Boron rate at 10 ppm increased the contents of: carotenoids 27-31 %, protein 26-27 % and starch 7-8 % evidence showed by Griffiths and Lunec, (2001).

It is observed that, different doses of GA_3 exhibited significant variation on β-Carotene content (Table 12). The highest β-carotene was recorded in G_2 (0.3178 mg per 100g) which was statistically different from all other treatments. Otherwise, the lowest β-carotene was recorded in G_0 (0.2689 mg per 100g). Ishiwu *et al.* (2014) supported this finding.

Variation was occurred significantly in combined effect of different doses of boron and GA_3 on β-carotene content (Table 13). The maximum β-carotene was found in B_1G_2 (0.3500 mg per 100g) which was statistically different from all other treatments which was followed by B_2G_2 (0.3467 mg per 100g), B_1G_3 (0.3267 mg per 100g) B_2G_1 (0.3233 mg per 100g). The minimum β-carotene was recorded in B_0G_0 (0.2333 mg per 100g) which was statistically different from all other treatments which was followed by B_0G_1 (0.2500 mg per 100g), B_0G_2 (0.2567 mg per 100g) B_0G_3 (0.2600 mg per 100g).

Table 13: Combined effect of boron (B) and gibberellic acid (GA_3) on quality characters of tomato

Treatment	TSS %	β-Carotene (mg per 100g)	Vitamin-C (mg per 100g)
B_0G_0	6.467 e	0.2333 l	66.66 g
B_0G_1	7.267 bc	0.2500 k	71.80 fg
B_0G_2	7.400 ab	0.2567 j	75.64 f
B_0G_3	7.033 cd	0.2600 i	82.05 e
B_1G_0	7.167 bc	0.2733 h	89.74 cd
B_1G_1	7.100 c	0.3100 e	96.15 b
B_1G_2	7.600 a	0.3500 a	111.5 a
B_1G_3	7.067 cd	0.3267 c	97.43 b
B_2G_0	7.267 bc	0.3000 f	85.90 de
B_2G_1	6.833 d	0.3233 d	93.59 bc
B_2G_2	7.167 bc	0.3467 b	87.18 de
B_2G_3	6.533 e	0.2967 g	73.08 f
$Lsd_{0.05}$	0.2395	0.0005355	5.524
CV (%)	1.98	2.64	3.80

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

B_0 = 0 kg ha^{-1}, B_1 = 0.8 kg ha^{-1}, B_2 = 1 kg ha^{-1}

G_0 = 0 ppm, G_1 = 50 ppm, G_2 = 100 ppm, G_3 = 150 ppm

4.2.3 Vitamin-C content (mg per 100g)

Statistically significant variation was recorded on Vitamin-C in ripened fruits due to effect of different doses of boron (Table 11). The highest Vitamin-C was obtained from B_1 (98.72 mg per 100g) which was statistically different from all other treatments. The lowest Vitamin-C was obtained from B_0 (74.04 mg per 100g). Jyolsna *et al.* (2008) partially support this result.

It was noticed that different doses of GA_3 exhibited significant variation on Vitamin-C in ripened fruits (Table 12). The maximum Vitamin-C was found in G_2 (91.45 mg per 100g) which was statistically similar with G_1 (87.18 mg per 100g). The minimum Vitamin-C was found in G_0 (80.77 mg per 100g).

Variation was occurred significantly in combined effect of different doses of boron and GA_3 on Vitamin-C in ripened fruits (Table 13). The highest Vitamin-C was recorded in B_1G_2 (111.5 mg per 100g) which was statistically different from all other treatments which was followed by B_1G_3 (97.43 mg per 100g), B_1G_1 (96.15 mg per 100g), B_2G_1 (93.59 mg per 100g). The lowest Vitamin-C was recorded in B_0G_0 (66.66 mg per 100g) which was statistically different from all other treatments which was followed by B_0G_1 (71.80 mg per 100g), B_2G_3 (73.08 mg per 100g), B_0G_2 (75.64 mg per 100g). Mallick and Muthukrishnan (1980) and Dube *et al.* (2003) conformed that maximum increase in vitamin C content of tomato fruits (25.27 mg per 100 g and (23.85 mg per 100 g) was recorded to the application of zinc and boron respectively.

4.3 Relationship between TSS % and β-Carotene (mg per 100 g) of fruits

Significant relationship was found between TSS % and β-Carotene (mg per 100 g) when correlation was made between these two parameters in case of boron (Fig. 5). The highly significant ($p<0.01$), strong (R^2 = 0.082) and positive (slope= 0.047) correlation was found between TSS % and β-Carotene (mg per 100 g), i.e. β-Carotene (mg per 100 g) of tomato increases with the increases of TSS % of fruit.

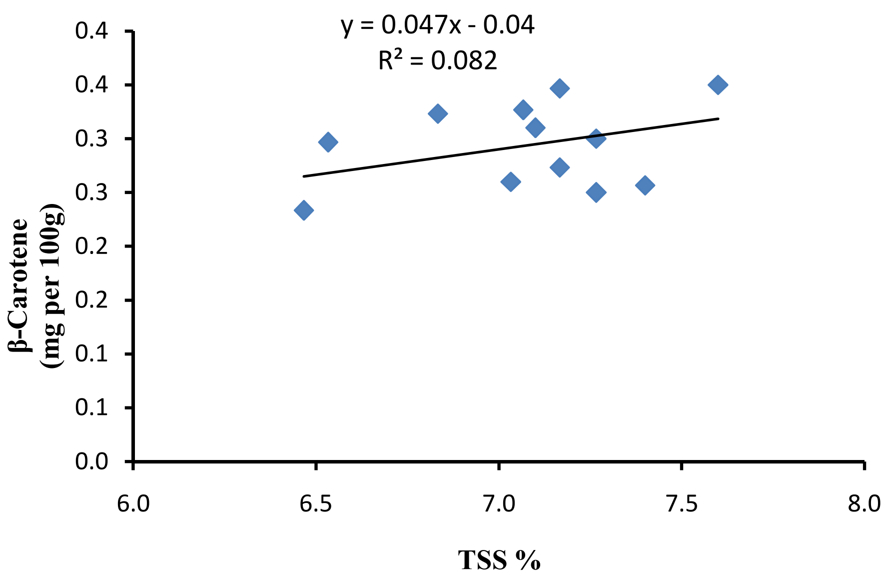


Fig. 5: Relationship between TSS and β-Carotene of tomato in case of boron

Due to gibberellic acid, significant relationship was found between TSS % and β-Carotene (mg per 100 g) when correlation was made between these two parameters (Fig. 6). The highly significant ($p<0.01$), strong (R^2 = 0.022) and positive (slope= 0.066) correlation was found between TSS % and β-Carotene (mg per 100 g), i.e. β-Carotene (mg per 100 g) of tomato increases with the increase of TSS % of fruit.

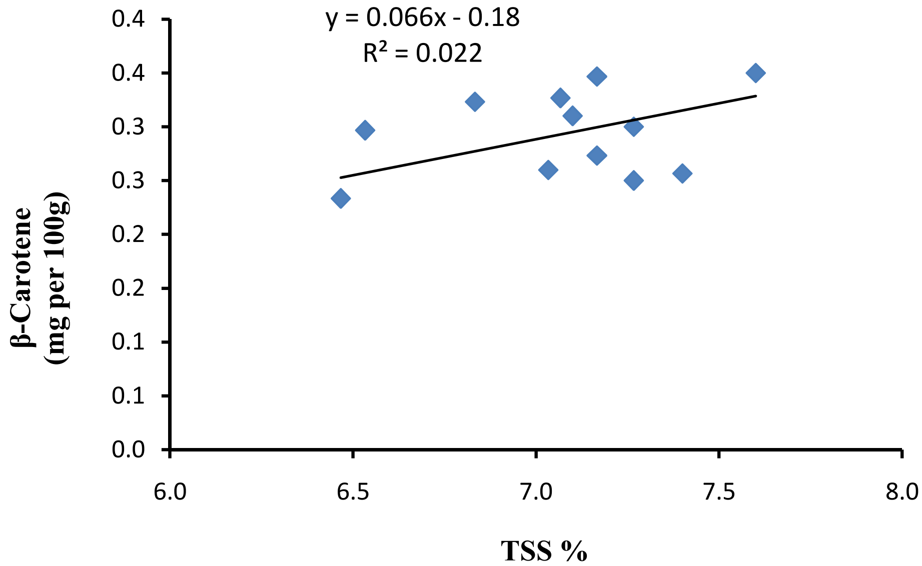


Fig. 6: Relationship between TSS and β-Carotene of tomato in case of boron

In the combined effect of boron and gibberellic acid, significant relationship was found between TSS % and β-Carotene (mg per 100 g) when correlation was made between these two parameters (Fig. 7). The highly significant ($p<0.01$), strong (R^2 = 0.091) and positive (slope = 0.035) correlation was found between TSS % and β-Carotene (mg per 100 g), i.e. β-Carotene (mg per 100 g) of tomato increases with the increases TSS % of fruit.

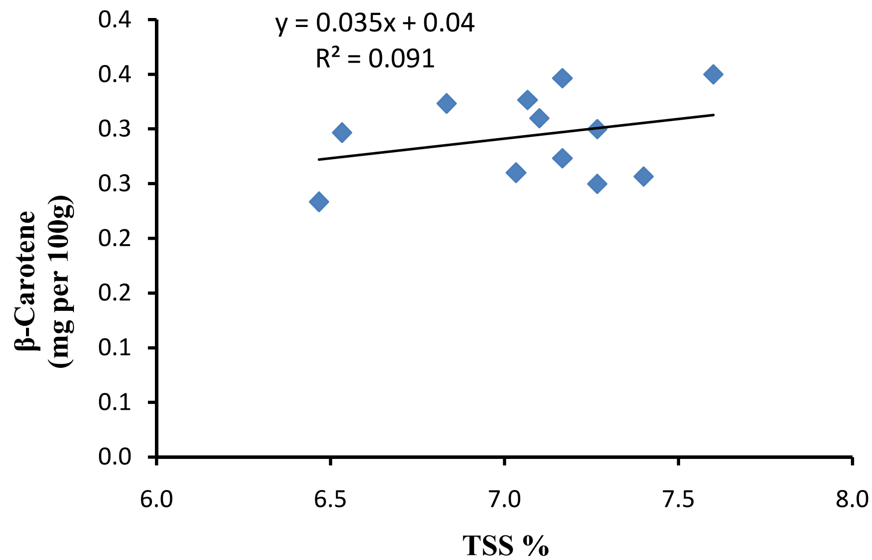


Fig. 7: Relationship between TSS and β-Carotene of tomato in case of boron and gibberellic acid

4.4 Relationship between TSS % and Vitamin-C (mg per 100 g) of fruits

Due to boron, significant relationship was found between TSS % and vitamin C (mg per 100 g) when correlation was made between these two parameters (Fig. 8). The highly significant ($p<0.01$), very strong (R^2 = - 0.75) and positive (slope = 60.78) correlation was found between TSS % and vitamin C (mg per 100 g), i.e. vitamin C (mg per 100 g) of tomato increases with the increases TSS % of fruit.

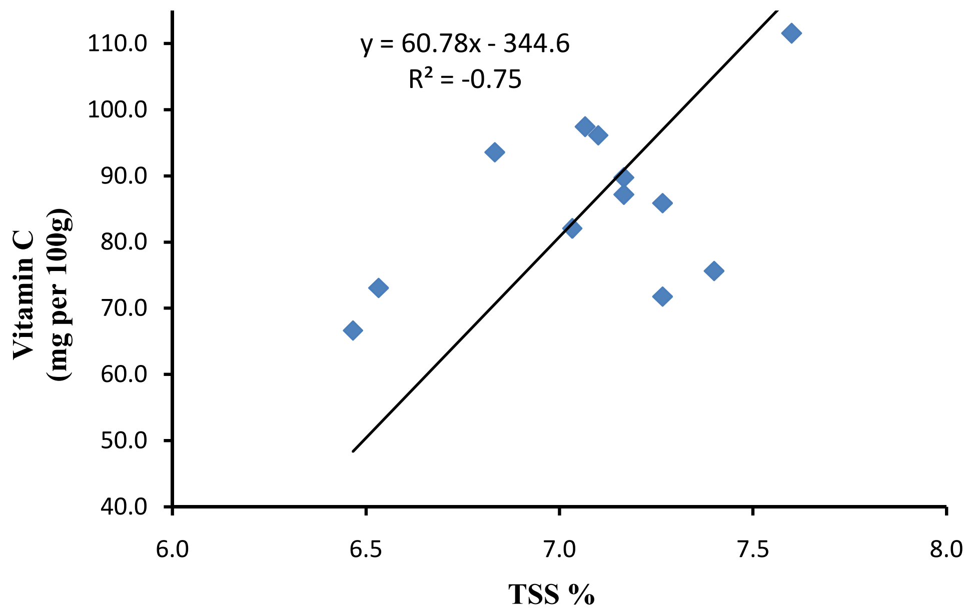


Fig. 8: Relationship between TSS and Vitamin C of tomato in case of boron

Significant relationship was found between TSS % and vitamin C (mg per 100 g) when correlation was made between these two parameters in case of gibberellic acid (Fig. 9). The highly significant ($p<0.01$), very strong (R^2 = 0.279) and positive (slope = 17.60) correlation was found between TSS % and vitamin C (mg per 100 g), i.e. vitamin C (mg per 100 g) of tomato increases with the increases TSS % of fruit.

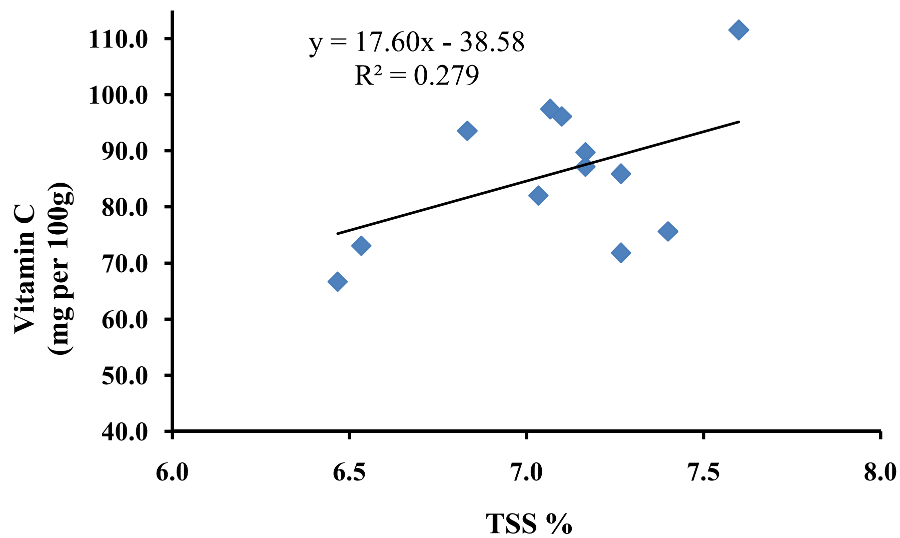


Fig. 9: Relationship between TSS and Vitamin C of tomato in case of gibberellic acid

In the combined effect of boron and gibberellic acid, significant relationship was found between TSS % and vitamin C (mg per 100 g) when correlation was made between these two parameters in case of gibberellic acid (Fig. 10). The highly significant ($p<0.01$), very strong (R^2 = 0.286) and positive (slope = 20.90) correlation was found between TSS % and vitamin C (mg per 100 g), i.e. vitamin C (mg per 100 g) of tomato increases with the increases TSS % of fruit.

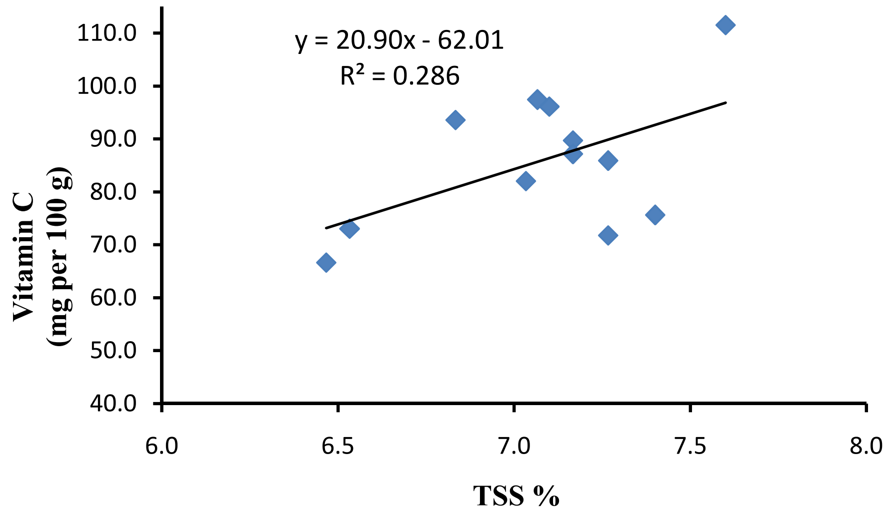


Fig. 10: Relationship between TSS and Vitamin C of tomato in case of boron and gibberellic acid

Chapter V

SUMMARY AND CONCLUSION

A field experiment was conducted at the Research farm of Sher-e-Bangla Agricultural University, Dhaka, during the Rabi season from November 2015 to March 2016 to study the effects of boron and gibberellic acid (GA_3) on growth, yield and quality of tomato. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications of each treatment. The unit plot size was 2 m x 1.8 m. There were 12 treatment combinations in the experiment comprising 3 levels of Boron (0 kg ha^{-1}, 0.8 kg ha^{-1} and 1 kg ha^{-1} designated as B_0, B_1 and B_2 respectively) and 4 levels of gibberellic acid (0 ppm, 50 ppm, 100 ppm and 150 ppm designated as G_0, G_1, G_2 and G_3 respectively).The individual and combined effects of boron (B) and gibberellic acid (GA_3) on growth, yield and quality content in plants of tomato were studied.

Data on growth, yield and quality contributing parameters were recorded, and the collected data were statistically analyzed to evaluate the treatment effects. The summary of the results has been presented in this chapter.

At 60 days after transplantation boron had a significant effect on plant height. Plants grown with higher doses of boron showed a gradual increase in plant height. The tallest plant (97.74 cm) was produced by B_1 @ 0.8 kg ha^{-1}, whiles the shortest (90.80 cm) plant was observed in control treatment. In case of GA_3, the tallest plant (98.83 cm) was produced by GA_3 @ 100 ppm and the shortest plant (92.99 cm) was shown by control treatment. The treatment combinations demonstrated significant variation in plant height at 20, 40, and 60 DAT. At 60 DAT the tallest plant (105.3 cm) was found in B_1G_2 (B_1 @ 0.8 kg ha^{-1} + G_2 @ 100 ppm) treatment while the shortest (87.60 cm) was shown in B_2G_3 (B_2 @ 1 kg ha^{-1} + G_3 @ 150 ppm) treatment.

At 60 DAT different levels of boron showed significant effect on number of leaves per plant. The maximum value (34.58) of this character was found at B_1 @ 0.8 kg ha^{-1} and the minimum value (30.08) was obtained from control treatment. On the other hand, at 60 DAT statistically significant variation was found in number of leaves per plant with the application of different level of GA_3. The maximum number of leaves per plant (33.00) was produced by GA_3 @ 100 ppm and the minimum number of leaves per plant (31.00) was shown by control treatment. The treatment combinations demonstrated significant variation in plant height at 20, 40, and 60 DAT. The maximum number of leaves (37.00) was given by the combined treatment of B_1G_2 (B_1 @ 0.8 kg ha^{-1} + G_2 @ 100 ppm) and minimum number of leaves (28.00) was given in control treatment.

The effect of boron on number of flower cluster per plant was influenced significantly. The highest number of flower cluster per plant (12.33) was recorded from the treatment of B_1 @ 0.8 kg ha^{-1} and the lowest number of flower cluster per plant (8.250) was shown in control treatment. But statistically significant variation was found in number of flower clusters per plant in different doses of GA_3. The maximum number of flower cluster per plant (10.44) was produced by GA_3 @ 100 ppm and the minimum number of flower cluster per plant (9.333) was shown by GA_3 @ 150 ppm. Combined treatment of B_1G_2 (B_1 @ 0.8 kg ha^{-1} + G_2 @ 100 ppm) produced the maximum number of flower cluster per plant (13.67) the lowest number of flower cluster per plant (5.333) was obtained from B_2G_3 (B_2 @ 1 kg ha^{-1} + G_3 @ 150 ppm) treatment.

Number of flowers per cluster progressively increased with increasing level of boron. The highest number of flowers per cluster (8.75) was produced by B_1 @ 0.8 kg ha^{-1} and the lowest number of flowers per cluster (6.333) was observed in control treatment. Again, statistically no significant variation was found in number of flowers per cluster per plant in different doses of GA_3. Interaction effect of B and GA_3 on the number of flower per cluster was significant. The highest number of flower per cluster (10.67) was found in B_1G_2 (B_1 @ 0.8 kg/ha + G_2 @ 100 ppm) treatment and the lowest number of flower per cluster (5.0) was produced by B_2G_3 (B_2 @ 1 kg/ha + G_3 @ 150 ppm) treatment.

Statistically no significant variation was found in number of fruits per cluster per plant in different doses of both boron and gibberellic acid. The treatment combinations of boron and gibberellic acid on number of fruits per cluster were significant. The highest fruit per cluster (6.667) was obtained in B_1G_2 (B_1 @ 0.8 kg ha^{-1} + G_2 @ 100 ppm) treatment and the lowest number of fruits per cluster (3.667) was produced by B_2G_3 (B_2 @ 1 kg ha^{-1} + G_3 @ 150 ppm) treatment.

There were significant differences among the different levels of boron in respect of number of fruits per plant. The highest number of fruits per plant (59.08) was obtained with the application of B_1 @ 0.8 kg ha^{-1} and the lowest number of fruit per plant (37.25) was produced by control treatment. Number of fruits per plant gradually increased with increasing level of gibberellic acid up to higher level. The highest number of fruit per plant (51.67) was obtained with the application of GA_3 @ 100 ppm and the lowest number of fruit per plant (41.22) was found in control treatment. The treatment combinations of boron and gibberellic acid on number of fruits per plant were significant. The highest fruit per plant (70.67) was found in B_1G_2 (B_1 @ 0.8 kg ha^{-1} + G_2 @ 100 ppm) application and the lowest number of fruit per plant (15.00) was produced by B_2G_3 (B_2 @ 1 kg ha^{-1} + G_3 @ 150 ppm) treatment.

Fruit weight per plant increased with increasing level of boron up to 0.8 kg ha^{-1}. The highest fruit weight per plant (2.391 kg) was obtained in B_1 treatment and the lowest fruit weight per plant (1.381 kg) was obtained in B_2 @1 kg ha^{-1} treatment. But fruit weight per plant was significantly affected by different levels of gibberellic acid. The maximum fruit weight per plant (1.995 kg) was produced by GA_3 @ 100 ppm and the minimum fruit weight per plant (1.709 kg) was shown by GA_3 @ 150 ppm. The treatment combinations of boron and gibberellic acid on number of fruit weight per plant were significant. The highest fruit weight per plant (2.57) was obtained in B_1G_2 (B_1 @ 0.8 kg ha^{-1} + G_2 @ 100 ppm) treatment and the lowest number of fruit weight per plant (0.8367) was produced by B_2G_3 (B_2 @ 1 kg ha^{-1} + G_3 @ 150 ppm) treatment.

Plant receiving boron at the rate of 0.8 kg ha^{-1} produced significantly higher weight of fruit per plot (24.91 kg) and the lowest weight of fruit per plot (12.44 kg) was recorded in B_2 @ 1 kg ha^{-1} treatment. On the other hand, the highest weight of fruit per plot (19.67) was obtained with the application of GA_3 @ 100 ppm and the lowest weight of fruit per plot (17.07) was obtained with the application of GA_3 @ 150 ppm. The combined effect of boron and gibberellic acid on weight of fruit per plot of tomato was significant. The combined B_1G_2 (B_1 @ 0.8 kg ha^{-1} + G_2 @ 100 ppm) treatment gave the highest weight of fruit per plot (28.25 kg) and the lowest weight of fruit per plot (6.437) was produced by B_2G_3 (B_1 @ 1 kg ha^{-1} + G_2 @ 150 ppm) treatment.

Individual application of boron at the rate of 0.8 kg/ha produced the highest fruit yield (69.20 t ha^{-1}) and the lowest fruit yield (34.55 t ha^{-1}) was obtained in B_2 @ 0.8 kg ha^{-1} treatment. Fruit yield increased with increasing level of gibberellic acid up to higher level. Application of GA_3 @ 100 ppm produced the highest fruit yield (54.63 t ha^{-1}) and the minimum fruit yield (47.43 t ha^{-1}) was recorded in GA_3 @ 150 ppm. In combination, the highest fruit yield (78.46 t ha^{-1}) was produced by B_1G_2 (B_1 @ 0.8 kg ha^{-1} + G_2 @ 100 ppm) and the lowest fruit yield (17.88 t ha^{-1}) was obtained from B_2G_3 (B_2 @ 1 kg ha^{-1} + G_3 @ 150 ppm) treatment.

Total soluble solids increased with increasing level of boron up to 0.8 kg/ha. The highest total soluble solids (7.233 %) was obtained in B_1 treatment and the lowest total soluble solids (6.950 %) was obtained in B_2 @ 1 kg/ha treatment. On the other hand, application of GA_3 @ 100 ppm produced the highest total soluble solids (7.389 %) and the minimum total soluble solids (6.878 %) were recorded in GA_3 @ 150 ppm. The combined B_1G_2 (B_1 @ 0.8 kg ha^{-1} + G_2 @ 100 ppm) treatment gave the highest weight of fruit per plot (7.600 %) and the lowest weight of fruit per plot (6.467) was produced by control treatment.

The maximum β-Carotene (0.3167 mg per 100g) with increasing level of boron up to 0.8 kg ha^{-1} and the minimum β-Carotene (0.25 mg per 100g) were obtained from control treatment. On the other hand, application of GA_3 @ 100 ppm produced the highest total soluble solids (0.3178 mg per 100g) and the minimum total soluble solids (0.2689 mg per 100g) were recorded in control treatment. The combined B_1G_2 (B_1 @ 0.8 kg ha^{-1} + G_2 @ 100 ppm) treatment gave the highest β-Carotene (0.3500 mg per 100g) and the lowest β-Carotene (0.2333 mg per 100g) was produced by control treatment.

The highest vitamin-C (98.72 mg per100g) was obtained from B_1 @ .8 kg ha^{-1} and lowest vitamin-C (74.04 mg per 100g) was obtained from control treatment. Otherwise, the highest vitamin-C (91.45 mg per 100g) was obtained with the application of GA_3 @ 100 ppm and the lowest vitamin-C (80.77 mg per 100g) was obtained with the application of control treatment. The combined B_1G_2 (B_1 @ 0.8 kg ha^{-1} + G_2 @ 100 ppm) treatment gave the highest vitamin-C (111.5 mg per 100g) and the lowest vitamin-C (66.66 mg per 100g) was produced control treatment.

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

- Individual effect of boron (B_1 @ 0.8 kg ha^{-1}) and gibberellic acid (G_2 @ 100 ppm) played positive and significant role on the growth, yield and yield contributing characters of tomato
- Quality contributing characters of tomato were also significantly influenced by the individual application of boron (B_1 @ 0.8 kg ha^{-1}) and gibberellic acid (G_2 @ 100 ppm)
- The combined effect of boron and gibberellic acid (B_1 @ 0.8 kg ha^{-1} + G_2 @ 100 ppm) enhanced growth, yield, yield contributing characters and quality of tomato.

Further research works at different agro-ecological zones of the country are needed to be carried out for the confirmation of the present findings.

Chapter VI

REFERENCES

Adlakha, P.A. and Verma, S.K. (1964). Effect of gibbellic acid on the quality of tomato fruit. The Punjab Hort. J. 4(3-4): 148-151.

Adlakha, P.A. and Verma, S.K. (1995). Effect of gibbellic acid on fruiting and yield of tomatoes. Sci. and cult. p. 31.

Ahmed, K.U. (1976). "Phul Phal O Shak Sabjee". 3rd Edn. Alhaj Kamis Uddin Ahmed, Banglow No. 2, Farmgate, Dhaka-1500, Bangladesh. p. 544.

Alam, M.J. 2007. Effect of Miyodo on growth and yield in lentil. M. S Thesis, Dept. Crop Bot., Bangladesh Agric. Univ., Mymensingh.

Amrachandra and Verma, B. K. (2003). Effect of boron and calcium on plant growth and seed yield of tomato. JNKVV Res. J. India. 37(2): 13-14.

Awasthi, A.P. and Grewal, J. S. (1977). Response of potatoes to micronutrient application. India Farm. 39(6): 13-15.

Baevre, O.A. (1990). Effects of boron on fruit and seed development in the tomato. Norwegian Journal of Agricultural Sciences. 4(3): 233-237.

Balraj, S. and Mahesh, K. (2005). Effect of plant spacing and stem pruning on growth and yield of cherry tomato in greenhouse. Haryana J. Hort. Sci. 34(1/2): 179-180.

Basavarajeswari, C.P., Hosamni, R.M., Ajjappalavara, P.S., Naik, B.H., Smitha, R.P. and Ukkund. (2008). Effect of foliar application of micronutrients on growth,yield components of tomato (*Lycopersicon esculentum* Mill). Karnataka J. Agri. Sci. 21(3): 428- 430.

BBS. (2012) Statistical Year Book of Agricultural Statistics of Bangladesh Statistics Division, Ministry of Planning, Govt. of the People's Republic of Bangladesh, Dhaka, 2006. p. 125.

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

Bora, P.C. and Selman, J.W. (1969). Growth and nitrogen accumulation in young tomato plants treated with gibberellic acid. J. Exp. Bot. 288-301.

Briant, R E. (1974). An analysis of the effect of gibberellic acid on tomato leaf growth .J. Exp. Bot. 25: 764-771.

Cardozo, V.P., Pizetta, N.V. and Teixeira, N. T. (2001). Manuring to foliate with calcium and boron in the culture of the tomato (*Lycopersicon esculentum* Mill) cv. Debora Max. Ecossistema. 26(1): 39-41.

Chern, J. K., Wu, C. W., Lin, J K. and Tarng, S. F. (1983). Effect of plant growth regulators on the growth and development of tomato. J. Agnc. Assoc. China. 124: 31-42.

Choudhury, B. (1979). Vegetables. 6th Revised Edn. National Book Trust, New Delhi, India. p. 46.

Choudhury, S.H. and Faruque, A.H M. (1972). Effect of GA_3 on seedlessness of tomato. Bangladesh Hort. 1(1): 13-16.

Davis, J. M., Sanders, D. C., Nelson, P. V., Lengnick L. and Sperry, W. J. (2003). Boron improves growth, yield, quality, and nutrient content of tomato. J. Amer. Soc. Hort. Sci. 128(3): 441-44.

Delibas, L. and Akgun, I. (1996). Effects of irrigation water with high boron content on some yield characteristics of tomato. J. Tekirdag Agril. Fac. 5(1/2): 135-142.

Dube, B.K., Pratima, S., Chatterjee, C. and Sinha, P. (2003). Effect of zinc on the yield and quality of tomato. Indain Journal of Horticulture. 60(1): 59-63.

Dwivedi, G.K., Madhu, D. and Pal, S.S. (1990). Modes of application of micronutrients in soil in soyabean wheat crop sequence. J. Indian Soc. Soil Sci. 38(5): 458-463.

Efkar, A., Jan, N., Khattak, S.G., Khattak, M.J. and Ahmad, E. (1995). Potato yield as affected by boron fertilizer mixing with and without farm yard manure. Sarhad J. Agril. 11(6): 725-728.

EI-Habbasha, K.M., Gomaa, H.M., EI-Gizawy, A.M. and Mohamed, S.S. (1999). Response of tomato plants to foliar spray with some growth regulators under later summer conditions. Egyptian J. Hort. 26: 3546.

El-Mahdy, R.E.(2007). Effect of heavy nitrogen application on pepper plant (Capsicum annuum). M. Sci. Thesis. Faculty of Agriculture. Mansoura Univ., Egypt.

FAO, (2003). FAO Production Yearbook. Basic Data Branch, Statistics Division, FAO, Rome, Italy. 57: 140-142.

FAO. (2004). Production Year Book. Food and Agricultural of the United Nations. Rome, Italy. 42: 190-193.

Gabal G.M., Oben G. and Garcell R. (1999). Effect of GA on morph physiological characters and yield of kidney beans (*Phaseiolus valgaris*). J. Agron. Crop. Sci. 160(2): 91-101.

Gomez, K. A. and Gomez, A. A. 1984. Statistical Procedures for Agricultural Resserch (2^{nd} Edn.) John Willey and Sons, Singapore. pp. 28-92.

Graham, H.D. and Ballesteros, M. (2006). Effect of plant growth regulators on plant nutrients, J. Food Sci. DOI: 10.1111/j.1365-2621.1980.tb04086.x

Grewal, J. S. and Trehan, S. P. (1981). Potato needs micronutrients. Indian Farm. 31(8): 3-5.

Griffiths, H.R. and Lunec, J. (2001). Ascorbic acid in the 21st Century-more than a simple antioxidant. Enivron. Toxicol. Pharmacol. 10: 173-182.

Gulnaz, A., Iqbal. J. and Awn, F. (1999). Seed treatment with growth regulators and crop productivity. II. Response of critical growth stages of wheat (*Triticum aestivum* L.) under salinity stress. Cereal Res. Communications, 27(4): 419-426.

Gunes, A., Alpaslan, M., Cikili,Y. and Ozcan, H.(1999). Effect of zinc on the alleviation of boron toxicity in tomato. Department of Soil Science and Plant Nutrition, Faculty of Agriculture, University of Ankara, Turkey. Journal of Plant Nutrition. 22(7): 1061-1068.

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

Gupta, T.R., Saini, J.S. and Gangasaran. (1985). Rai response to fertilizer. Indian J. Agron. 33(3): 342-343.

Gustafson. F.G. 1960. Influence of gibberellic acid on setting and development of fruits in tomato Plant Physiol. 35:521-23.

Haque, M.S., Islam, M.T. and Rahman, M. (1999). Studies on the presentation of semi-concentrated tomato juice. Bangladesh J. Agril. Sci. 26(1): 37-43.

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

Hathout, T.A., Sheteawi, S.A. and Khallal, S.M. (1993). Effect of mode of application of some hormonal contents Egyptian J. Physiol, Sci. Botany Department. Women's College. Ain Shams University, Cairo, Egypt, 17 (1): 45-62.

Hatwar, G.P., Gondane, S. M., Urkade, S.M. & Gahukar, O.V. (2003). Effect of micronutrients on growth and yield of chilli. Soils and Crops, 13(1): 123-125.

Hossain, M.A.E. (1974). Studies on the effect of parachlorophenoxy acetic acid and gibberellic acid on the production of tomato. An M. Sc. Thesis, Dept. of Hort.; BAU, Mymensingh, 25.

Ishiwu, C.N., Iwouno, J.O., Obiegbuna, J.E. and Ezike, T.C. (2014). Effect of thermal processing on lycopene, beta-carotene and Vitamin C content of tomato. Journal of Food and Nutrition Sciences. 2(3): 87-92

Islam. M.S. and Anwar. M.N. (1994). Production technologies of vegetable crops. Recommendation and Future plan. In proceedings of workshop on transfer of technology of CDP crops under Research Extension linkage programme, BARI, Gazipur. pp. 20-27.

Jansen, H. (1970). The effect of gibberellic acid and CCC on the yield of tomatoes. Garteribauwissen-Chaft. 35: 303-306.

Jyolsna, V.K. and Mathew, U. (2008) Boron nutrition of tomato (Lycopersicon esculentumL.) grown in the laterite soils of southern Kerala. Journal of Tropical Agriculture. 46 (1-2): 73–75.

Karaguzel, O., Alian, S., Doran, I. and Sogut, Z. 1999. Improvement of gladiolus by growth regulator and nutrient management. J. Japanese Soc. Hort. Sci. 68: 168-175.

Kaushik, M.P., Shanna, J.K. and Singh, I. (1974). Effect of alpha naphthalene acetic acid, gibberellic acid, kinetin and morphactin on yield of tomato PI. Sci. 6: 51-53.

Khan, N.A., Ansari, H.R. and Sanaullah. (1998). Effect of Gibberellic acid spray during ontogeny of Mustard on growth, nutrient uptake and yield characteristics J. Agron. Crop Sci. 181(1): 61-63.

Kiran, J., Vyakaranchal, B.S., Raikar, S.D., Ravikumar, G.H. and Deshpande, V.K. (2010). Seed yield and quality of brinjal as influenced by crop nutrition. Indian J. Agric. Res. 44(1): 1-7.

Kirynkhin, V.P. and Bezzubtseba, T.T. (1980). Application of trace elements to potato. Kartofel, Ovoshch no. 4: 16. [Cited from Potato Abstr., 7(1): 45, 1982].

Leonard, M., Kinet. K.M., Bodson, M. and Bernier, G. (1983). Enhanced Inflorescence development in tomato by growth substance treatments in relation to 14 C assimilate distribution. Physiologia plant arun. 5 (1): 85-89.

Lilov, D. and Donchev, T. (1984). Effect of a Bulgarian gibberellin preparation on tomato fruiting Gradinarska, Lozarska Nauka. 21(1): 49-55.

Lozek, O. and Fecenko, J. (1992-93). Effects of foliar application of Mn, B and Nahumate on the potato production. Department of Agrochemistry and plant Nutrition, University of Agriculture, Trieda Andreja Hlinku 2, 94976 Nitra, Slovakia. [Cited from Field Crop Abstracts. 1997. Vol. 50. No. 9 pp. 910-913].

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

Mallick, M.R.F. and Muthukrishnan, C.R. (1980). Effect of micronutrients on the quality of tomato (*Lycopersicon esculentum* Mill). Vegetable Science. 7(1): 6-13.

Maola, M.M. 2005. Effect of gamma radiation on some important morpho physiological and yield attributes in M_2 generation of lentil. M. S. Thesis. Dept. Crop Bot., Bangladesh Agric. Univ., Mymensingh.

McCollum, J.P. (1992). Vegetable Crops. International Book Distributing Co., Lucknow, India, p. 513.

Mehta, A.K. and Mathi P.J. (1975). Effect of growth regulators on summer tomato (*Lycopersicon esculentum* Mill.). Haryana Hort. Sci. 4(3/4): 167-176.

Mengel, K. and Kirkby, E.A. (1987). Principles of Plant Nutrition. International Potash Institute, Switzerland.

Naresh. B. (2002). Response of foliar application of boron on vegetative growth, fruit yield and quality of tomato var. Pusa Ruby. Indian J. Hill Farm. 15(1): 109-112.

Nibhavanti, B., Bhalekar, M.N., Gupta, N.S. and Anja1i, D. (2006). Effect of growth regulators on growth and yield of tomato in summer. Maharastra J. Agric. 31(1): 64-65.

Omer, F. A.; Hafez and Foda, S. (1982). Efficiency of potassium levels and boron concentration on the production of potatoes. Res. Bull. Agril. Ain Shams Univer. Egypt. 15p.

Onofeghara, F.A. (1983). The effects of growth substances on flowering and fruiting of *Lycopersicon esculentum* and *Vigna unguiculata*. Phytol. Argentina, 40 (1): 107-116.

Oyinlola, E.Y. (2004). Response of irrigated tomatoes (*Lycopersicon lycopersicum*) to boron fertilizer: 2. Growth and nutrient concentration. Nigerian J. Soil Res. 5: 62-68.

Palkovics, M. and Gyori, D. (1984). Trials of boron fertilization on rusty brown forest soil in potatoes. Novenytermeles. 33 (3): 265-273.

Paroussi, G., Voyiatzis, D.G., Paroussis, E. and Drogoudi, P.D. (2002). Growth, flowering and yield responses to GA of strawberry grown under different environmental conditions. Scientia Horticulturae. 96(1/4): 103-113.

Patel, I. and Saxena, O.P. (1994). Screening of PGRs for seed treatment in green gram and blackgram. Indian J. Plant Physiol. 37(3): 206-208.

Peixoto, J.R., Garcia, C.A.P. and Martins, J.F. (1996). Effects of potatoes cv. Achat as a function of rates of NPK and B. Dept. of Agron. Horticultura Brasileira, Brazil. 14(2): 232-235.

Prasad, K.K., Chowdhary, B.M. and Amrendra, K. (1997). Response of tomato to boron application in Chotanagpur region. Journal of Research, Birsa Agricultural University. 9(2): 145-147.

Rahman, A.,Ali, M. I. and Jahiruddin, M. (1993). Response of two tomato varieties to added sulphur and boron in Old Brahmaputra Flood Plain Soil. Bangladesh J. Nucl. Agric. 9: 25-28.

Rai, N., Yadav, D.S., Patel, K.K., Yadav, R.K., Asati, B.S. and Chaubey, T. (2006)Effect of plant growth regulators on growth, yield and quality of tomato*, Solanum lycopersicon* Mill. grown under mid hill of Meghalaya. Vegetable Science. 33(2):180-182.

Rapport, L. (1960). Effect of temperature and gibberellin on the growth of tomato frurts. Naturewissenchaften. 17: 285.

Rashid, M.M. (1983). Sabjeer Chash, 1st Edn., Begum Shahla Rashid Publishers, Joydebpur , Gajipur. p.86.

Sahota, T.S., Lal, S. S. and Grewal, J. S. (1982). Response of potato to micronutrients at Shillong. J. Res. Assam Agril. Univ. 3(2):118-122.

Saleh, M.M.S. and Abdul, K.S. (1980). Effect of gibberellic acid and cycocel on growth, flowering and fruiting of tomato (*Lycopersicen esculentum* Mill.) Plants Mesopotarma J. Agric. 15(1): 137-166.

Salunkhe, D.K., Desai, B.B. and Bhat, N.R. (1987). Vegetables Flower Seed Production. 1st Edn. Agricola Publishing Academy, New Delhi, India. pp. 118-119.

Sanyal, D., Kar, P.L. and Longkumar, M. (1995). Effect of growth regulators on the physicochemical composition of tomato (*Lycopersicon esculetum* Mill.) Advances in Hort. And Forestry. 4: 67-71.

Sawhney, V.K. and Greyson, R.I. (1972). Fruit size increase in tomato following application on gebberellic acid. J. Amer. Soc. Hort. Sci. 97(5): 589-590.

Shanmugavelu, K.G. (1989). Production Technology of Vegetable Crops. Oxford and IBH Publishing Co. New Delhi, India. p. 229.

Shittu, G.A. and Adeleke, I.A. (1999). Effect of gibberellic acid on the growth and development of tomato (*Lycopersicon esculetum* Mill.) cultivar 158-163 Global J. Pure Apply Sci. 5(1): 27-30.

Shnain, R.S., Prasad,V.M. and Saravanan, S. (2014). Effect of zinc and boron on growth, yield and quality of tomato (*Lycopersicon esculentum.*Mill) cv. Heem Sohna, under protected cultivation. European Academic Research Vol. II, Issue 3, pp. 4572-4597.

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

Sindhu, P.C., Ahlawat, V.P. and Nain, A.S. (1999). Effect on yield and fruit quality of grapes (*Vitis vinifera* L.) cv. Perlette. Haryana J. Hort. Sci. 28(2): 19-21.

Singaram, P. and Prabha, K. (1999). Studies on calcium boron interaction in tomato grown in a calcareous soil. Madras Agricultural Journal. 86(10-12): 681-682.

Singh, H.M. & Tiwari, J.K. (2013). Impact of micronutrient spray on growth, yield and quality of tomato (*Lycopersicon esculentum* Mill). Hort. Flora Research Spectrum. 2(1): 87–89.

Smit, J.N. and Combrink, N.J.J. (2004). Pollination and yield of winter-grown greenhouse tomatoes as affected by boron nutrition, cluster vibration and relative humidity. South African Journal of Plant Soil, 22: 110-115.

Sujatha, A., Nair, I., Singh,V. and Sharma, T.V.R.S. 2002. Effect of plant growth regulators on yield and quality of gerbera under Bay Island conditions. Indian J. Hort. 59 (1): 100-105.

Takano, K.P., Bialek, K. and Cohen, J.D. (1995). The effect of growth regulators on two spring legumes, protein peas and french beans Mekedelingen Jan de facutied landbouwwetensch apen Rijksunver siffeit Gent, 52: 1259-1266.

Tomar, I.S. and Ramgiry, S.R. (1997). Effect of growth regulator on yield and yield attributes in tomato (*Lyropersicon esculentum* Mill). Adv Pl Sci. 10 (2): 29-31.

Uddain, J., Hossain, K.M. A., Mostafa, M.G. and Rahman, M.J. (2009). Effect of different plant growth regulators on growth and yield of tomato. International Journal of Sustainable Agriculture. 1(3): 58 -63.

Ullah, R., Ayub, G., Ilyas, M., Ahmad, M., Umar, M., Mukhtar, S. and Farooq, S. Growth and Yield of Tomato (*Lycopersicon esculentum* L.) as Influenced by Different Levels of Zinc and Boron as Foliar Application . American-Eurasian J. Agric. & Environ. Sci. 15(12): 2495-2498.

Vasil, K.G., Dobre, J. N., Milan, J. M., Liljana, K. R., Jevtic, S. and Lazic, B. (1997). The effect of NPK, Mg and B on the yield, morphological characteristics and quality characteristics of industrial tomatoes. Acta Hort., 462: 183-186.

Wu, C.W., Lin, I.Y., Tarug, S.F. and Chem, I.R. (1983). Effect of growth regulators on the growth and development of tomato, *Lyropersicon* e*sculentum* Mill, China J. Agric. Assoc. 124:31-42.

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

Yan, H., Li, W., Guo, Y. and Liu, D. (2003). Effect of boron on carbohydrate assimilation and translocation in wheat. Acta Pedologica Sinica. 40(3): 40 445.

APPENDICES

Appendix I: Experimental site at Sher-e-Bangla Agricultural University, Dhaka-1207

The map of Bangladesh showing experimental site

Appendix II: Monthly records of meteorological observation at the period of experiment (November, 2015 to March, 2016)

Name of months	Temperature (^0C)		Relative humidity (%)	Rainfall (mm)
	Maximum	Minimum		
November, 2015	30	15	66	24
December, 2015	28	13	63	5
January, 2016	26	12	54	8
February, 2016	30	13	49	32
March, 2016	34	14	45	61

Source: Weather Yard, Bangladesh Metrological Department, Dhaka.

Appendix III: Morphological characteristics of soil of the experimental plot

Morphological features	Characteristics
Location	Research farm, SAU, Dhaka
AEZ	Modhupur Tract (28)
General Soil Type	Shallow Red Brown Terrace Soil
Land Type	Medium high land
Soil Series	Tejgaon fairly leveled
Topography	Fairly level
Flood Level	Above flood level
Drainage	Well drained

Appendix-IV: Analysis of variance of different character of tomato

Sources of variation	Degrees of freedom	Mean sum of square					
		Plant height			No. of leaves per plant		
		20 DAT	40 DAT	60 DAT	20 DAT	40 DAT	60 DAT
Replication	2	0.188	0.026	0.084	0.583	1.333	0.194
Boron (B)	2	23.284*	177.341*	162.694*	22.583*	57.250*	68.778*
Gibberellic acid (G)	3	7.848*	53.963*	61.881*	2.259*	4.843*	6.250*
B×G	6	5.938*	28.160*	85.932*	1.843*	13.287*	8.667*
Error	22	0.041	0.064	0.098	0.402	0.515	1.437

DAT= Days after transplanting

* Significant at 5% level

Sources of variation	Degrees of freedom	Mean sum of square			
		Flower clusters per plant	Flowers per cluster	Fruit per cluster	Fruit per plant
Replication	2	1.444	0.361	0.194	0.194
Boron (B)	2	56.694*	17.861*	2.028^{NS}	1675.528*
Gibberellic acid (G)	3	2.028*	2.519^{NS}	1.583^{NS}	239.778*
B×G	6	14.472*	8.046*	2.028*	735.194*
Error	22	1.596	0.482	0.376	12.043

* Significant at 5% level

NS= Not Significant

Appendix-IV: (Cont'd)

Sources of variation	Degrees of freedom	Mean sum of square		
		Fruit wt per plant (Kg)	Fruit wt per plot (Kg)	Fruit yield (t ha^{-1})
Replication	2	0.005	0.102	0.781
Boron (B)	2	3.071*	470.846*	3632.941*
Gibberellic acid (G)	3	0.040*	11.317*	87.279*
B×G	6	0.514*	60.794*	469.030*
Error	22	0.020	1.596	12.319

* Significant at 5% level

Sources of variation	Degrees of freedom	Mean sum of square		
		TSS %	β-Carotene (mg per 100g)	Vitamin-C (mg per 100g)
Replication	2	0.173	0.000	1.235
Boron (B)	2	0.251*	0.017*	1835.364*
Gibberellic acid (G)	3	0.448*	0.004*	185.177*
B×G	6	0.290*	0.001*	207.818*
Error	22	0.020	0.000	10.644

* Significant at 5% level

Plate 1 (a-f): Different steps tomato plantation in experimental plot

a. Seedbed preparation

b. Seedling uprooting

c. A healthy branched plant

d. A flowering plant

e. Treatment application

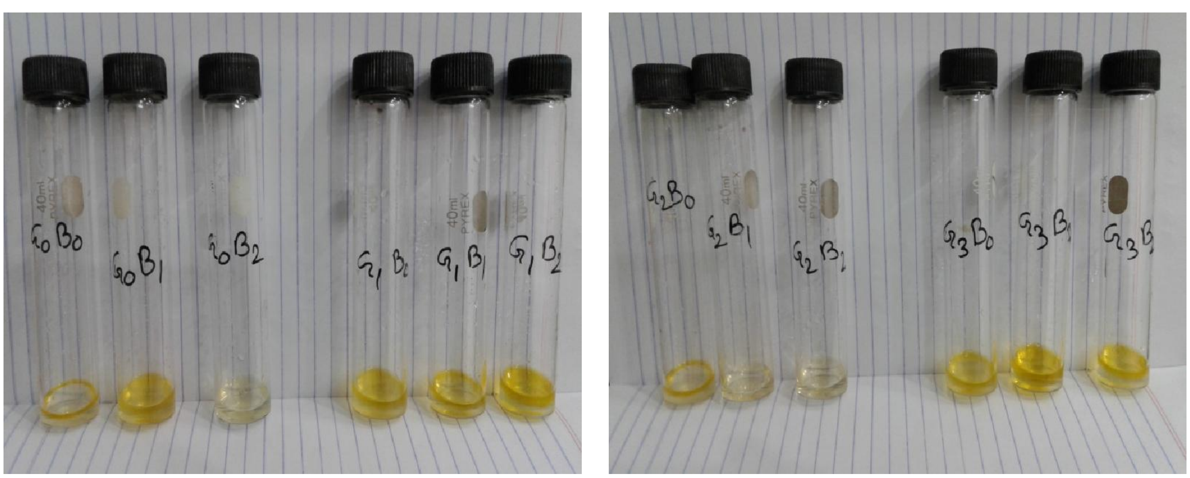
f. Harvesting of tomato

Plate 2: Harvested tomato sample from different experimental Plot (treatment plot)

Plate 2: (Cont'd)

Plate 3 (a-b): Procedure of measuring of β- carotene in ripen tomato

a. Ripen tomato juice with Acetone: n-Hexane mixed solution taken in the glass vial



b. Collected solution (sample) in the marked glass vial

Plate 4 (a-b): Procedure of measuring Vitamin C in ripens tomato

a. Preparing sample by fresh ripen fruit juice with metaphosphoric acid solution

b. Titration by prepared sample with 2, 6- dicholophenol indophenols dye