GROWTH AND YIELD OF TOMATO AS INFLUENCED BY GA_3 AND BORON

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CERTIFICATE

This is to certify that the thesis entitled, ***"GROWTH AND YIELD OF TOMATO AS INFLUENCED BY GA_3 AND BORON"*** *submitted to the Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of* **MASTER OF SCIENCE in HORTICULTURE,** *embodies the result of a piece of bona fide research work carried out by* ***MD. ARIFUL HAQUE****, Registration. No.* ***15-06999*** *under my supervision and my guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dated: June, 2017

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Dedicated To

My Beloved Parents & Respected Research Supervisor

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ABSTRACT

An experiment was conducted at Horticulture Farm of Sher-e-Bangla Agricultural University during the period of October 2016 to March 2017 to evaluate the growth and yield of tomato as influenced by GA_3 and boron. The experiment was laid out in the Randomized Complete Block Design with three replications. Treatment as four levels of GA_3, viz. G_0: Control, G_1: 80 ppm, G_2: 100 ppm, G_3: 120 ppm; and two levels of boron, viz. B_0: Control, B_1: 5 kg boron ha^{-1}. Result indicated that the highest values of vegetative growth i.e. plant height and number of branches per plant and reproductive growth and development i.e. number of cluster $plant^{-1}$, number of fruit $plant^{-1}$, fruit length, fruit girth, individual fruit weight, fruit weight $plant^{-1}$ attributed the highest yield for the treatment G_2 (68.41 t ha^{-1}) and B_1 treatments (67.64 t ha^{-1}). For combined application, G_2B_1 gave the best result for all vegetative and reproductive growth and development. From this experiment it can be concluded that 100 ppm GA_3 with 5 kg Boron ha^{-1} treatment combination is suitable dose for higher yield of tomato.

LIST OF CONTENTS

LIST OF CONTENTS (Cont'd.)

LIST OF CONTENTS (Cont'd.)

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ACRONYMS

ABBREVIATIONS	ELABORATIONS
AEZ	: Agro-Ecological Zone
BARI	: Bangladesh Agricultural Research Institute
BBS	: Bangladesh Bureau of Statistics
CV%	: Percentage of coefficient of variance
DAE	: Department of Agricultural Extension
DAT	: Days after transplanting
^0C	: Degree Celsius
et al	: And others
FAO	: Food and Agriculture Organization of the United Nations
g	: gram(s)
ha^{-1}	: Per hectare
kg	: Kilogram
Max	: Maximum
mg	: Milligram
Min	: Minimum
MP	: Muriate of Potash
N	: Nitrogen
No.	: Number
NS	: Not significant
%	: Percent
SAU	: Sher-e-Bangla Agricultural University
SRDI	: Soil Resources Development Institute
TSP	: Triple Super Phosphate

CHAPTER I

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) belongs to family Solanaceae having chromosome number (2n=24). It is a self-pollinated crop and Peru-Ecuador region is considered to be the centre of origin. Tomato was introduced by the Portuguese. Tomato is cultivated in tropics and subtropics of the world.

Tomato is one of the most popular and important vegetable crop grown in Bangladesh both in rabi and kharif season. It is cultivated in almost all home gardens and also in the field due to its adaptability to wide range of soil and climate (Ahmed, 2001). It ranks next to potato and sweet potato in the world vegetable production and tops the list of canned vegetable (Choudhury, 1979). It has been originated in tropical America (Salunkhe *et al.*, 1987) which includes Peru, Ecuador, Bolivia areas of Andes (Kashem, 2005). Tomato is popular as salad in the new state and is used to make soup, juice, ketchup, pickle, sauce, conserved puree, paste, powder and other products (Ahmed, 2001). Tomato 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). Tomato has high nutritive value especially vitamin A and vitamin C.

In Bangladesh, the statistics shows that tomato was grown in 19643 hectares of land and the total production was approximately 143,058 metric tons during the year 2007-2008 (BBS, 2013), which is very low in comparison to other countries namely, India (15.67 t/ha), Japan (52.82 t/ha) and USA (63.66 t/ha) (FAO, 1995). The yield of tomato in our country is not satisfactory in comparison to its requirement (Aditya *et al.*, 1999). 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, poor crop management practices and lack of improved technologies.

Tomato is one of the most highly praised vegetables consumed widely and it is a major source of vitamins and minerals. It is one of the most popular salad vegetables and is taken with great relish. Tomato is a rich source of lycopene and vitamins. Lycopene may help counteract the harmful effects of substances called "free radicals", which are thought to contribute to age-related processes and a number of types of cancer, including, but not limited to, those of prostate, lung, stomach, pancreas, breast, cervix, colorectal, mouth and esophagus (1-6). Tomato has a significant role inhuman nutrition because of its rich source of lycopene, minerals and vitamins such as ascorbic acid and ß-carotene which are anti-oxidants and promote good health. Plant growth regulators (PGRs) are extensively used in horticultural crops to enhance plant growth and improve yield by increasing fruit number, fruit set and size. Plant growth regulators like promoters, inhibitors or retardants play a key role in controlling internal mechanisms of plant growth by interacting with key metabolic processes such as, nucleic acid metabolism and protein synthesis.

Use of plant growth regulators (PGR's) might be a useful alternative to increase crop production. Recently, there has been global realization of the important role of PGR's in increasing crop yield. GAs constitute a group of plant hormones that control developmental processes such as germination, shoot elongation, tuber formation, flowering, and fruit set and growth in diverse species. Gibberellic acid is one of the most important growth stimulating substances used in agriculture since long ago. The most widely available plant growth regulator is GA3 or gibberellic acid, which induces stem and internode elongation, seed germination, enzyme production during germination and fruit setting and growth (Davies, 1995). Gibberellic acid is an important growth regulator that may have many uses to modify the growth, yield and yield contributing characters of plant (Rafeekher *et al*., 2002).

Plummer and Tomoes (1953) worked on the effect of indole acetic acid and gibberellic acid on normal and dwarf tomatoes. They observed that both varieties did not show significant indole acetic acid while the dwarf plants treated with gibberellic acid exceeded in height than untreated normal plants. Gibberellic acid at the rates of 100-200 mg/plant caused total stem elongation, but the lower rates had no effect. In case of young plants however, stem elongation was increased by all concentration between 2 to 450 mg/plants. He has found that the leaves were enlarged and had entire margins (Rappaport, 1957). Gibberellic acid when applied to flowers controlled fruit drop in tomato (Foefanova, 1962).

The application of Gibberellic acid (GA3) had significantly increased the number of fruits per plant than the untreated controls (Tomar and Ramgiry, 1997). Adlakha and Verma (1964) reported that the application of GA3 on flower cluster resulted in an increase in fruit weight. To increase the yield as well as to avoid flower and fruit dropping, application of GA3 at optimum concentration and at right time is important.

It is, therefore, highly desirable to explore possible ways and means to enhance the productivity of this important crop employing cost effective and easy to use techniques. In this regard, the effect of spray of gibberellic acid (GA3) at very low concentrations could be exploited beneficially as its natural occurrence in plants in minute quantities is known to control their development.

Objectives

a) To find out the effect of gibberellic acid on growth and yield of tomato.
b) To find out the effect of boron on growth and yield and tomato.
c) To investigate the suitable combination of GA_3 and boron for higher growth and yield of tomato.

CHAPTER II

REVIEW OF LITERATURE

Tomato is one of the most important vegetable crops grown under field and greenhouse condition, which received much attention of the researchers throughout the world. Various investigations have been carried out for its successful cultivation. The relevant literature on tomato and some other related crops available in this connection have been reviewed here to the present study.

Literature on GA_3

Pramanik *et al.* (2017) reported that, plant growth regulators (also called plant hormones) are numerous chemical substances that profoundly influence the growth and differentiation of plant cells, tissues and organs. Plant growth regulators function as chemical messengers for intercellular communication. In tomato, different growth regulators play a pivotal role in germination, root development, branching, flower initiation, fruiting, lycopene development, synchronization and early maturation, parthenocarpic fruit development, ripening, TSS, acidity, seed production etcetera.

Gamel *et al.* (2017) stated that, tomato is an important vegetable crop all over the world. Extreme temperatures affect the growth, yield and quality of plant production. This study was conducted with an aim to investigate the impact of presoaking of seeds for 10 h in 10^{-3}, 10^{-5} and 10^{-7} M β-sitosterol and 100 ppm gibberellic acid in addition to temperature on three tomato cultivars (*Lycopersicon esculentum* Mill); Fayrouz, Aziza and N23-48 on growth, leaf anatomy and ultrastructure to show whether temperature can be offset by the application of β-sitosterol or gibberellin. After 28 days from sowing, plants were transferred to growth chambers at three temperature levels (10 and 45±3°C) as low and high, respectively, comparing to tomato grown at 25°C (control), after 42 days from sowing, sampling takes place. The low temperature alone decreased growth parameters, leaf thickness, upper and lower epidermis while palisade and spongy layer increased. Although spongy layer increased markedly by high temperature a decreased in growth parameter, palisade layer, leaf thickness and upper and lower epidermis was detected. Sitosterol and gibberellin treatments in addition to, temperature caused a general significant increase in the determined measurements especially the number and area of leave and the thickness of cell wall epidermis. These results may provide support for the field application of sitosterol and gibberellin to alleviate the harmful effects of temperature on tomato plants. It is evident from the above results that, the resistance of the three cultivars of tomato plant to temperature stress (high and low) was more or less improved by priming the seeds in 100 ppm gibberellic acid or β-sitosterol specially in response to 10-5 M. Thus, these plant growth regulators could be used, as safe compounds to improve the resistance of the used tomato cultivars to temperature stress.

Akand *et al*. (2016) conducted an experiment at the farm of Sher-e-Bangla Agricultural University, Dhaka during the period from October 2013 to March 2014 to study the effect of potassium and GA_3 on the growth and yield of tomato. They found that 60 ppm GA_3 produced the highest yield (58.66 t/ha) and control treatment gave the lowest yield (46.55 t/ha).

Mignolli *et al*. (2016) reported that, in many plant species, ethylene and gibberellins interact to regulate plant growth and development. In some cases, these hormones can act in a synergistic way whereas in others they can be antagonistic. To date, the control of hypocotyl elongation by ethylene and gibberellins has been poorly explored in tomato. In this paper, we report that, application of exogenous ethylene to tomato seedlings or high endogenous ethylene production, as in the epinastic mutant, strongly prevent the effect of gibberellic acid (GA_3) application. Moreover, constitutive activation of gibberellin signal in a DELLA defcient mutant is not able to counteract the inhibitory effect of ethylene on hypocotyl elongation, suggesting that ethylene acts independently from DELLA-mediated gibberellin response. Interestingly, when ethylene perception is blocked, the GA_3 promotive effect on hypocotyl length is less effective, indicating that the presence of a basal level of ethylene could synergistically enhance hypocotyl growth. Taken together, these observations may suggest that, in tomato, supraoptimal concentrations of ethylene are able to antagonize gibberellin effect but normal levels seem to promote gibberellin-induced hypocotyl elongation.

Rahman *et al.* (2015) reported that, an experiment was carried out in pots at Bangladesh Institute of Nuclear Agriculture, Bangladesh to evaluate influence of different concentrations of GA_3 on biochemical parameters at different growth stages in order to maximize yield of summer tomato var. Binatomato-2. The concentrations of GA_3 were 0, 25, 50, 75 and 100 ppm. They were applied at three stages, namely root soaking of seedlings before transplanting, vegetative and flowering stages. The experiment was laid out in a randomized complete block design with four replications. Results indicated that the highest chlorophyll and soluble protein contents were recorded when GA_3 was applied through root soaking followed by vegetative stage and the lowest was found at the flowering stage. In contrast, the highest nitrate reductase activity was observed when GA_3 was applied at the vegetative stage and the lowest activity was recorded at the flowering stage. The applications of 50-75 ppm GA_3 had significantly encouraged the bio-chemical parameters studied at 50 DAT. The amount of GA_3 applied at different stages had significant influence on the yield and yield attributes of summer tomato. The highest plant height was recorded when 50 ppm of GA_3 was applied at the vegetative stage. While, the longest time to first fruit setting was required when the roots of the seedlings were soaked in 100 ppm GA_3 solution. The application of 50 ppm GA_3 by root soaking had significantly increased the number of flowers, fruits and fruit yield per plant but similar results were achieved when only 25 ppm GA_3 was applied at the flowering stage. The fruit yield of tomato per plant increased linearly with the increased number of flowers and fruits per plant.

Patidar (2015) conducted the experiment at the Nursery area, College of Agriculture, Gwalior (M.P.), to study the effect of NAA and GA_3 on growth yield and quality of tomato (*Lycopersicon esculentum* Mill.) variety–Chirayu. In general, it was concluded that G3 (GA_3 @ 20 ppm) was found significantly superior followed by G2 (GA_3 @ 15 ppm) and G1 (GA_3 @ 10 ppm) over control. As regards NAA, N3 (NAA @ 25 ppm) was found significantly superior followed by N2 (NAA @ 20 ppm) and N1 (NAA @ 15 ppm) over control. The interaction effect of GA_3 and NAA showed significant effect on various characters. It was concluded that of G3N3 (20 ppm GA_3 + 25 ppm NAA) which was at par to G3N3 (15 ppm GA_3 + 20 ppm NAA) in maximum observations while the minimum value was recorded under control.

Akand *et al*. (2015) reported that, an experiment was conducted in the Horticultural Farm of Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh, during the period from October 2012 to March 2013 to find out the effect of GA_3 on the growth and yield of tomato. The experiment consisted of four concentrations of GA_3 such as control G0= control (no GA_3), G1= 75 ppm GA_3, G2 = 100 ppm GA3 and G3= 125 ppm. The experiment was laid out in RCBD with three replications. All parameter varied significantly at different concentration of GA_3. The highest yield (92.99 t/ha) was obtained from G3 treatment whereas the G0 gave lowest yield (60.46 t/ha).

Pratibha *et al*. (2015) stated that, a field experiment was carried out with the objective to determine the effect of gibberellic acid (GA_3) on quality characteristics of tomato during rabi season. The experiment consisted of three tomato varieties viz., NDTH-6, NDTH-7 and NDTH-8 and four treatments with four levels of GA_3 (0, 20, 40 and 60 ppm). Carotenoid content decreased with the increasing level of GA_3 as was found maximum in variety NDTH-8 (12.24 mg/100 g) in control treatment. While ascorbic acid, total sugar and reducing sugar increased with increased levels of gibberellic acid and were maximum in treatment GA_3 @ 60 ppm.

Kumar *et al*. (2014) conducted this study with the objective to determine the effects of Gibberellic acid (GA_3) on growth, fruit yield and quality of tomato. The experiment consisted of one tomato variety- Golden, and six treatments with five levels of gibberellic acid (GA_3- 10 ppm, 20 ppm, 30 ppm, 40 ppm and 50 ppm), arranged in randomized block design with three replications. The highest plant height, Number of leaves, Number of fruits, Fresh fruit weight has been observed and ascorbic acid, total soluble solid (TSS) was estimated for GA_3 50 ppm.

Mehraj *et al*. (2014) stated that, an experiment was conducted at Horticultural farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh to assess the response of foliar application of GA_3 with different concentrations to cherry tomato plants. The assessment expressed that the foliar application of 200-ppm gibberellic acid solution provided maximum number of leaves (16.7), tallest plant (70.0 cm), early flower bud initiation (13.0 days), early flowering (16.0 days) and early fruiting (20.3 days); utmost fruit diameter (25.9 mm) and number of fruits (105.0 fruits) per plant; maximum single fruit weight (11.1 g) and total fruit weight (1.2 kg) per plant, whereas the control was lowest.

Van Tonder *et al*. (2013) stated that, the yield of greenhouse tomatoes produced in spring and midwinter was reduced by unfavourable environmental conditions involving low temperatures and low light intensities. This study was evaluated the role of various plant growth regulators including: synthetic cytokinin (CPPU) at 1mLl-', auxins 1-naphthylacetic acid at 1mLl-' and 4-chlorophenoxyacetic acid (4-CPA) at 30mg.L-', gibberellins (GA_3) 'ProGibb 4%' and SupaGibb 4Sl' both at 1mLl-', and a mixture of benzyladenine (6-BA) plus GA4+7at 1mLl-'. Treatments were appl.ied in improving fruiting characteristics of out of season tomatoes up to three times successively when three or more flowers of an inflorescence reached anthesis. PGR's, CPPU, 1-NAA, 4-CPA, 'ProGibb', 'SupaGibb' and BA plus GA4+7, at three applications, induced higher tomato yields by increasing the truss mass. Synthetic auxins, 1-NAA and 4- CPA, increased the average fruit mass as well as the number of fruit with a diameter larger than 37 mm but also increased the percentage of malformed fruit. Three applications of the mixture BA plus G~+7 provided the most promising results by improving the yield of marketable fruit through increases in the number of fruit set, the number of fruit pe'r truss and the overall truss mass. No detrimental effects on fruit shape were associated with this treatment.

Gelmesa *et al*. (2012) reported that the objective of determining the effects of different concentrations and combinations of the plant growth regulators (PGRs) 2,4-dichlorophenoxyacetic acid (2,4-D) and gibberellic acid (GA_3) spray on fruit setting and earliness of tomato varieties. The experiment consisted of one processing (Roma VF) and one fresh market (Fetan), tomato varieties, three levels of 2,4-D (0, 5 and 10 ppm) and four levels of GA_3 (0, 10, 15 and 20 ppm) arranged in a 2 × 3 × 4 factorial combinations, in randomized completed block design with three replications. The study indicated that application of 2, 4-D at 5 and 10 ppm hastened flowering and fruiting but reduced number of fruits per cluster, fruit set percentage and final marketable fruit number per plant. However, application of GA3 extended flowering and maturity time and increased fruit number per cluster, fruit set percentage and marketable fruit number per plant over the control. In general, the study indicated that 2, 4-D is important in tomato production to induce fruit setting and earliness and GA_3 seems to extend fruit maturity and harvest period while the combined applications have intermediate effects. Therefore, it is important to further investigate the method of application and concentrations of these PGRs at different growing conditions and on different tomato cultivars to assess their role in tomato fruit setting and maturity time.

Maggio *et al*. (2010) reported that, the role of plant hormones under saline stress is critical in modulating physiological responses that will eventually lead to adaptation to an unfavorable environment. Nevertheless, the functional level of plant hormones, and their relative tissue concentration, may have a different impact on plant growth and stress tolerance at increasing salinity of the root environment. Vigorous plant growth may counteract the negative effects of salinization. In contrast, low gibberellin (GA) levels have been associated with reduced growth in response to salinity. Based on these facts and considering that the physiological basis of the cause-effect relationship between functional growth control and stress adaptation/survival is still a matter of debate, we hypothesized that exogenous applications of the plant hormone GA_3 may compensate for the salt-induced growth deficiency and consequently facilitate tomato plant adaptation to a saline environment. GA_3 application (0 or 100 mg GA_3) was compared under four salinity levels, obtained by adding equal increments of NaCl: $CaCl_2$ (2:1 molar basis) (EC = 2.5, 6.8, 11.7, 16.7 dS m^{-1}) to the nutrient solution. GA_3 treatment reduced stomatal resistance and enhanced plant water use at low salinity. These responses were associated with an increased number of fruit per plant at harvest. However, moderate and high salinity nullified these differences. The fruit carotenoid level was generally lower in GA_3-treated plants, indicating either an inhibitory effect of GA_3 treatment on carotenoid biosynthesis or a reduced perception of the stress environment by GA_3-treated tomato plants.

Abebie and Desalegn (2010) stated that, an experiment was conducted at Melkassa Agricultural Research Center, central rift valley of Ethiopia from September 2008 to January 2009 with the objective to determine the effects of different concentrations and combinations of 2,4-dichlorophenoxyacetic acid (2,4-D) and gibberellic acid (GA_3) spray on fruit yield and quality of tomato. The experiment consisted of two tomato varieties-one processing (Roma VF) and one fresh market (Fetan), three levels of 2,4-dichlorophenoxyacetic acid (2,4- D) (0, 5 and 10 mg l-1) and four levels of gibberellic acid (GA_3) (0, 10, 15 and 20 mg l-1) arranged in 2 × 3 × 4 factorial combinations, in randomized completed block design with three replications. The result showed increase in fruit length from 5.44 to 6.72 cm at 10 mg l-1 2,4-D combined with 10 mg l-1 GA_3 above the control, increased fruit weight by 13% due to 2,4-D and reduced fruit weight in single or combined application of GA3 with 2,4-D. Fruit pericarp thickness was increased by about 50% due to 2,4-D and GA_3

application above the control. Titratable acidity, total soluble solids and lycopene content were also increased due to combined application of 2,4-D and GA_3 spray. Lower fruit pH is another quality attributes of tomato affected by 2,4-D application while that of GA_3 has no effect. Final fruit yield were significantly improved above the control even though both varieties responded differently. For Roma VF, GA_3 at concentration of 10 and 15 mg l-1 resulted in maximum fruit yield of 69.50 and 67.92 ton ha-1, respectively in the absence of 2,4-D. For Fetan, maximum marketable fruit yield of 74.39 and 74.20 ton ha-1 was obtained from treatment combinations of 10 + 15 and 5 + 0 2,4-D and GA_3, respectively. Hence, yield increment of about 35% for Roma VF and 18% for Fetan were produced at 10 mg l-1 GA_3 and 10 + 15 mg l-1 2,4-D and GA_3, respectively over the control. Significant increase in fruit size and weight due to 2,4-D and increased fruit number due to GA_3 spray contributed to increased fruit yield. The results indicated that both PGRs are important in tomato production to boost yield and improve fruit quality under unfavorable climatic conditions of high temperature. Therefore, it is important to further investigate application methods and concentrations of the PGRs under concern in different growing conditions on different tomato cultivars.

Afroz *et al*. (2009) stated that, a study was conducted for developing a high frequency regeneration system in short time span using GA_3, as a pre-requisite for the genetic transformation in tomato cultivars. Effects of GA3 were investigated on regeneration efficiencies and days to maturity of three varieties of tomato Lycopersicon esculentum (using hypocotyls and leaf discs as explant source). 0.5 mg/l Indole acetic acid (IAA) and 0.5-2.5 mg/l of benzyl amino purine (BAP) were used alone or in combination with GA_3 2mg/l on MS media. Regeneration was significantly higher with different treatments used in combination with GA_3. It was increased from 57.33% to 70% in Avinash, followed by Pusa Ruby 51.66% to 67.22% and from 53.2% to 60% in case of Pant Bahr when hypocotyls were used as explant source. Same trend was followed in case of leaf disc derived regeneration, although it was less pronounced. Regeneration was increased from 68% to 73% in Avinash followed by Pusa Ruby 68.5% to 72.33 %. Inclusion of GA3 in the media also significantly reduced the days to regeneration (20-25) as against 40-45 days when GA_3 was excluded from media in all three varieties of tomato cultivars.

Balaguera-López *et al*. (2008) reported that, the high cost of seeds and seedlings of tomato long life hybrids is one of the most limiting aspects during early crop establishment, nevertheless, with the use of gibberellic acid it is possible to enhance the germination percentage, reduce the sprouting time, and equally achieve faster growth speed and less time to bring the seedlings to the field. Thus, in the first stage of the experiment, seeds of Daniela hybrid were soaked during 36 h in 0, 300, 600 or 900 mg L^{-1} GA_3 using a completely randomized design with four replicates. Four seedlings from each treatment were brought to the field during a month using the same design. In the first stage, soaking seeds in 900 mg L^{-1} GA_3 resulted in the highest germination percentage, root length, dry matter, stem and root fresh matter and leaf area, while the fastest average sprouting rate and tallest height were due to 300 mg L^{-1} GA_3 treatment. In field stage, the plant height, stem and total dry matter, leaf and root fresh matter and net assimilation showed the best response at 900 mg L^{-1} GA_3 treatment. In this way, the seed soaking with 900 mg L^{-1} GA_3 allows obtaining more vigorous tomato seedlings in less time and with a better development in field.

Vegetable growth regulators are capable of controlling the reproductive development, from flower differentiation until the last stages in fruit development. In particular, fruit set and development stage depend on the endogenous content of this substance, being possible to manipulate the beginning of fruit development by external application of hormones. We have previously evaluated the fruit set and development process in tomato cultivation in the greenhouse in response to the application of beta -NOA and GA_3 in fixed doses. Differential sensitivity was observed depending on the genotype and regulator type. Studies were conducted to establish the optimum dose and moment for the application of beta -NOA and GA_3 as ways to improve the fruit set and development of parthenocarpy fruits. Regulator types beta -NOA and GA_3 in variable doses and application dates were considered as factors. Using unpollinated ovaries as an experimental system, it was possible to conclude that the application of 40 ppm of beta -NOA at 7 days post-anthesis would offer the best advantages from a performance point of view and a lower physiologic impact, not altering the period of fruit development (Aguero *et al*., 2007).

The effect of applied gibberellin (GA_3) and auxin on fruit-set and growth has been investigated by Serrani *et al*. (2007) in tomato (*Solanum lycopersicum* L.) cv Micro-Tom. It was found that to prevent competition between developing fruits only one fruit per truss should be left on the plant. Unpollinated ovaries responded to GA_3 and to different auxins [indol-3-acetic acid, naphthaleneacetic acid, and 2,4-dichlorophenoxyacetic acid (2,4-D)], 2,4-D being the most efficient. Simultaneous application of GA_3 and 2,4-D produced parthenocarpic fruits similar to pollinated fruits, but for the absence of seeds, suggesting that both kinds of hormones are involved in the induction of fruit development upon pollination. It is concluded that Micro-Tom constitutes a convenient model system, compared to tall cultivars, to investigate the hormonal regulation of fruit development in tomato.

Khan *et al*. (2006) reported that, a pot experiment was performed according to a factorial randomized design at Aligarh to study the effect of 4 levels of gibberellic acid spray (0, 10 -8, 10 -6 and 10 -4 M GA_3) on the growth, leaf-NPK content, yield and quality parameters of 2 tomato cultivars *(Lycopersicon esculentum* Mill.), namely Hyb-SC-3 and Hyb-Himalata. Irrespective of its concentration, spray of gibberellic acid proved beneficial for most parameters, especially in the case of Hyb-SC-3.

An experiment was conducted by Rai *et al*. (2006) during the 2003 winter season in Meghalaya, India on tomato cv. Manileima to study the effect of plant growth regulators on yield. The treatments comprised 25 and 50 mg GA_3 /litre; water spray. Data were recorded for growth, flowering and fruiting characteristics, GA_3 significantly reduced the number of seeds per fruit but increased plant height and number of branches per plant.

Khan *et al.* (2006) conducted an experiment to study the effect of 4 levels of gibberellic acid spra y on the growth, leaf-NPK content, yield and quality parameters of 2 tomato cultivars (*Lycopersicon esculentum*), namely “Hyb-SC-3” and “Hyb-Himalata”. They reported that irrespective of its concentration, spray of gibberellic acid proved beneficial for most parameters, especially in the case of “Hyb-SC-3”.

Nibhavanti *et al.* (2006) carried out an experiment on the effects of gibberellic acid, NAA, 4-CPA and boron at 25 or 50 ppm on the growth and yield of tomato (cv. Dhanshree) during the summer season of 2003. Plant height was greatest with gibberellic acid at 25 and 50 ppm (74.21 cm and 75.33 cm, respectively) and 4 -CPA at 50 ppm (72.22 cm). The number of primary branches per plant did not significantly vary among the treatments. Gibberellic acid at 50 ppm resulted in the lowest number of primary branches per plant.

Sasaki *et al.* (2005) studied the effect of plant growth regulators on fruit set of tomato *(Lycopersicon esculentum* cv. Momotaro) under high temperature and in a field (Japan) under rain shelter. Tomato plants exposed to high temperature (34/20 degrees C) had reduced fruit set. Treatments of plant growth regulators reduced the fruit set inhibition by high temperature to some extent.

Kataoka *et al.* (2004) conducted an experiment on the effect of uniconazole on fruit growth in tomato cv. Severianin and reported that uniconazole (30 mg/litre) reduced fruit weight when applied to parthenocarpic fruits at approximately 0, 1 and 2 weeks after anthesis, but had no effect on fruit weight when applied at approximately *3* weeks after anthesis. To determine the antagonism between gibberellic acid (GA) and uniconazole in the regulation of fruit growth, flower clusters were treated with uniconazole (5 mg/L) and GA (5 or 50 mg/L). They reported that no notable gibberellin's activity was detected in treated fruits at *3* days to 4 weeks after treatment. The mean fresh weight of fruits at 4 weeks after treatment was lower than that of the control value. The results suggest that endogenous gibberellins in the early phase are important for fruit set and development.

Naeem *et al*. (2001) stated that, both time and concentrations had affected significantly the growth parameters of plants. Maximum days to flowering (42.67), fruit per plant (77.69), plant height (77.78 cm), fruit weight (71.15 gm), number of branches (12.33) per plant and iota! yield (26840 kg ha G1) were recorded in the plants sprayed with 60 mg/lit of gibberellic acid 10 days before transplantation, while minimum values were noted in controlled treatment. Maximum fruit drop per plant was found for control treatment and minimum for the plants treated with gibberellic acid at 60 mg/lit. It is suggested that tomato should be supplied with gibberellic acid at 60 mg/lit. 10 days before transplantation under the agroclimatic conditions of Peshawar.

Sun *et al.* (2000) reported the role of growth regulators on cold water for irrigation reduces stem elongation of plug-grown tomato seedlings. The effect of growth regulators (abscisic acid, gibberellic acid (GA), paclobutrazol, ethephon, IAA and silver thiosulfate) and cold-water irrigation at different temperatures (5, 15, 25, 35, 45 and 55 °C) on the reduction of stein elongation of plug-grown tomato seedlings was investigated. Paclobutrazol, ethephon and GA reduced the stem length of the tomatoes at several water temperatures. Cold water irrigation with the addition of 1.8 ppm GA or irrigation at room temperature could promote stem elongation. Irrigation at room temperature with the addition of 10 ppm paclobutrazol (GAs biosynthesis inhibitor) or cold-water irrigation could inhibit stem elongation. The reduction in stem elongation in plug-grown tomato seedlings was due to the relationship of GAs metabolism and sensitivity.

El-Habbasha *et al.* (1999) studied the response of tomato plants to foliar spray with some growth regulators under late summer conditions. Field experiments were carried out with tomato (cv. Castelrock) over two growing seasons (1993-94) at Shalakan, Egypt. The effects of GA_3, IAA, TPA (tolylphthalamic acid) and 4-CPA (each at 2 different concentrations) 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 with controls.

Tomar and Ramgiry (1997) found that plants treated with GA_3 showed significantly greater plant height, number of branches/plant, number of fruits/plant and yield than untreated controls. GA_3 treatment at the seedling stage offered valuable scope for obtaining higher commercial tomato yields.

El-Abd *et al.* (1995) studied the effect of plant growth regulators for improving fruit set of tomato. Two tomato cv. Alicante crops were produced in pots in the greenhouse. When the third flower of the second cluster reached anthesis, the second cluster was sprayed with IAA, GA3 or ABA at 10-4, 10-6 or 10-8 M each and ACC at 10-9, 10-10 or 10-11 M. All concentrations of IAA, GA_3, ACC and ABA induced early fruit set compared with controls sprayed with distilled water. GA_3 led to the formation of leafy clusters, with the number of leaves formed increasing with GA_3 concentration.

Wien and Zhang (1991) reported that, catfacing of tomato (Lycopersicon esculentum Mill.) fruit describes the enlarged blossom-end scar and ridged, flattened or irregular fruit shape often found on plants subjected to low temperature during ovary development. Experiments were conducted to determine if GA_3 foliar sprays could be used as a screening tool for catfacing. Concentrations of 5 to 50 µM of GA_3, applied once at transplanting, significantly increased catfacing incidence on the susceptible ‘Revolution’, whereas the resistant ‘Valerie’ was less affected. Two applications 8 days apart extended symptoms to later clusters formed on branches and may be useful for screening cultivars of a wide range of earliness. Plant apex removal may also be possible as a fruit catfacing screening tool. Chemical name used: gibberellic acid (GA_3).

Groot *et al.* (1987) reported that GA was indispensable for the development of fertile flowers and for seed germination, but only stimulated in later stages of fruit and seed development.

Sumiati (1987) reported that tomato cultivars, “Gondol”, “Meneymaker”, “Intan” and “Ratan” sprayed with 1000 ppm chlorflurenol, 100 ppm IAA, 50 ppm NAA or 10 ppm GA_3 or left untreated, compared with controls, fruit setting was hastened by 4-5 days in all cultivars following treatment with 100 ppm IAA or 10 ppm GA_3.

Leonard *et al.* (1983) observed that inflorescence development in tomato plants (cv. King plus) grown under a low light regime was promoted by GA applied directly on the inflorescence.

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

Onofeghara (1981) conducted an experiment on tomato sprayed with GA at 20-1000 ppm and NAA at 25-50 ppm. He observed that GA promoted flower primodia production and the number of primordia and NAA promoted flowering and fruiting.

Saleh and Abdul (1980) conducted an experiment with GA_3 (25 or 50 ppm) which was applied 3-time s in June or early July. The y reported that GA 3 stimulated plant growth. It reduced the total number of flowers per plant, but increased the total yield compared to the control. GA_3 also improved fruit quality.

Briant (1974) stated that, the effects of four consecutive daily sprays of gibberellic acid (GA_3) on the growth of leaves of young tomato plants cv. Potentate were studied. Total leaf weight and area were increased by GA_3. The percentage changes were larger in the younger leaves than in the older but the absolute increases of the middlle leaves accounted for most of the total response. Chlorophyll content, both total and per unit weight, was reduced by GA in the older leaves and increased in the younger; on an area basis it was reduced in all but the youngest leaves. Palisade cell length and palisade cell number per unit section length were reduced by GA_3 in the oldest leaves and increased in the youngest. There were larger intercellular spaces in both mesophyll layers and a larger transectional area of the mid-ribs of the oldest and two youngest leaves in GA_3 plants. The 'surface areas' of epidermal cells were also increased by GA_3 treatment. Leaf fresh weight per unit area was only a true index of lamina thickness in the two oldest leaves.

Literature on boron

Haleema *et al*. (2018) reported that, Effect of calcium, boron, and zinc foliar application on growth and fruit production of tomato was investigated during the year 2013 at ARI Tarnab, Peshawar to optimize calcium, boron and zinc concentration for enhancing the growth and fruit related attributes of tomato. The experiment was conducted using Randomized Complete Block (RCB) Design with 3 factors, replicated 3 times. Calcium (0, 0.3, 0.6 and 0.9%), Boron (0, 0.25, 0.5%) and Zinc (0, 0.25, 0.5%) were applied as foliar spray three times. Calcium application at 0.6% increased plant height (88.04 cm), number of primary (2.63) and secondary (7.15) branches, leaves plant^{-1} (182), leaf area (65.52 cm^2), and fruit per plant (66.15). In case of B levels, more plant height (88.14 cm), number of primary (2.61) and secondary (7.44) branches, number of leaves plant^{-1} (177), number fruits plant^{-1} (67.78) were recorded with foliar spray of B at 0.25%, while maximum leaf area was found at 0.5% B. Comparing the means for Zn concentrations, maximum plant height (86.53 cm), number of primary (2.53) and secondary (6.42) branches, leaves plant^{-1} (167), leaf area (63.33 cm^2), and fruit per plant (63.78) were higher with 0.5% foliar Zn application. The interaction between Ca, B and Zn also showed significant results for most of the attributes. Therefore, application of Ca (0.6%), B (0.25%), and Zn (0.5%) as a foliar spray can be used alone or in combination to improve growth and fruit production of tomato.

Sarangthem *et al*. (2015) stated that, it was observed from an experiment that application of vermicompost significantly influenced the yield, yield attributes and nutrient uptake of tomato. Vermicompost V_3 (20q/ha) and boron B_1 (Borax 10kg/ha) application found to be superior in vitamin C content (16.5 -20.96

mg/100gm), lycopene (40.66-45.25mg/100gm) and sugar content (4.06%-4.27%) in the pooled mean data of two years, whereas maximum dose of boron had influenced the highest uptake of boron by plant and available boron in soil but the yield was decreased. Among the combinations, minimum dose of boron and maximum dose of vermicompost B_1V_3 was found to be superior in increasing the yield and quality of the tomato fruit, particularly the size, shape, colour, smoothness, the firmness, ascorbic acid, sugar content and also reduced fruit cracking. Low boron application and highest vermicompost i.e. B_1V_3 also increased the nutrient availability and carbon status in soil and highest boron uptake by plant in both the years of experimentation. However, the application of highest boron and vermicompost (B_3V_3) also observed the higher available boron in soil during the study period.

Uraguchi *et al*. (2014) stated that, nutrient deficiency in soil poses a widespread agricultural problem. Boron (B) is an essential micronutrient in plants, and its deficiency causes defects in both vegetative and reproductive growth in various crops in the field. In *Arabidopsis thaliana*, increased expression of a major borate transporter gene *AtBOR1* or boric acid channel gene *AtNIP5;*1 improves plant growth under B-deficient conditions. In this study, we examined whether high expression of a borate transporter gene increases B accumulation in shoots and improves the growth of tomato plant, a model of fruit-bearing crops, under B-deficient conditions. We established three independent transgenic tomato plants lines expressing *AtBOR1* using *Agrobacterium*-mediated transformation of tomato (*Solanum lycopersicum* L. cv. Micro-Tom). Reverse transcription-polymerase chain reaction (RT-PCR) analysis confirmed that two lines (Line 1 and Line 2) more strongly expressed *AtBOR1* than Line 3. Wild-type plants and the transgenic plants were grown hydroponically under B-sufficient and B-deficient conditions. Wild-type and Line 3 (weakly expressing transgenic line) showed a defect in shoot growth under B-deficient conditions, especially in the development of new leaves. However, seedlings of Line 1 and Line 2, the transgenic lines showing strong *AtBOR1* expression, did not show the B-deficiency phenotype in newly developing leaves. In agreement with this phenotype, shoot biomass under low-B conditions was higher in the strongly expressing *AtBOR1* line. B concentrations in leaves or fruits were also higher in Line 2 and Line 1. The present study demonstrates that strong expression of *AtBOR1* improved growth in tomato under B-deficient conditions.

Naz *et al*. (2012) reported that, an experiment was conducted to study the effect of Boron (B) on the growth and yield of Rio Grand and Rio Figue cultivar of tomato at Horticultural Research Farm, NWFP Agricultural University, Peshawar during 2008- 2009. Different doses of B (0, 0.5, 1.0, 2.0, 3.0 and 5.0kg ha-1) with constant doses of nitrogen, phosphorus and potash was incorporated at the rate of 150, 100, 60 kg ha^{-1}. The experiment was laid out in Randomized Complete Block Design with 2 factors. Boron showed a significant effect on the growth and yield of tomato. However, 2 kg B ha^{-1} resulted in maximum number of flower clusters per plant, fruit set percentage, total yield, fruit weight loss and total soluble solid. Rio Grand cultivar of tomato showed significant effect on all parameters. Maximum number of flower clusters per plant, fruit set percentage and total yield were recorded with Rio Grand cultivar of tomato. Generally, it can be concluded that 2 kg B ha^{-1} significantly affected flowering and fruiting of Rio Grand cultivar.

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

Dursun *et al*. (2010) reported that, in many parts of the world, boron (B) levels are insufficient for potential production. Boron deficiency is also widespread in the Anatolia region of Turkey. Boron deficiency could impact production and quality of tomatoes (*Lycopersicon esculentum* L.), pepper (*Capsicum annum* L.), and cucumber (*Cucumis sativus* L.). A two-year greenhouse experiment was conducted to study yield and quality response of three vegetables to B addition (0, 1, 2, 3, and 4 kg B ha^{-1}). The optimum economic B rates (OEBR) were 2.3, 2.6, 2.4 kg B ha^{-1}, resulting in soil B concentrations of 0.33, 0.34 and 0.42 mg kg^{-1}. Independent of plant species, B application decreased tissue nitrogen (N), calcium (Ca), and magnesium (Mg) but increased tissue phosphorus (P), potassium (K), iron (Fe), manganese (Mn), zinc (Zn), and copper (Cu) concentrations. We conclude that a B addition of 2.5 kg ha^{-1} is sufficient to elevate soil B levels to nondeficient levels. Similar studies with different soils and initial soil-test B levels are needed to conclude if these critical soil test values and OEBR can be applied across the region.

Smit *et al*. (2004) stated that, insufficient fruit set of tomatoes owing to poor pollination in low cost greenhouses is a problem in South Africa, as bumblebee pollinators may not be imported. Since sub-optimum boron (B) levels may also contribute to fruit set problems, this aspect was investigated. Greenhouse tomatoes were planted in acid-washed river sand. Four nutrient solutions with only B at different levels (0.02; 0.16; 0.32 and 0.64 mg l^{-1}) were used. Leaf analyses indicated that the uptake of Ca, Mg, Na, Zn and B increased with higher B levels. At the low B level, leaves were brittle and appeared pale-green and very high flower abscission percentages were found. Fruit lacked firmness at the low B level and this problem worsened during storage. At the 0.16 mg kg^{-1} B-level, fruit set, fruit development, colour, total soluble solids, firmness and shelf life seemed to be close to optimum. The highest B-level had no detrimental effect on any of the yield and quality related parameters. However, using ‘Solubor’ as a source of B, high levels decreased soluble Mn concentrations in nutrient solutions, probably owing to the precipitation of insoluble MnO_2. This was reflected in reduced leaf-Mn concentrations.

Davis *et al*. (2003) reported that, boron deficiency in fresh-market tomatoes (*Lycopersicon esculentum* Mill.) is a widespread problem that reduces yield and fruit quality but is often not recognized by growers. Tomatoes were grown in field and hydroponic culture to compare the effects of foliar and soil applied B on plant growth, fruit yield, fruit quality, and tissue nutrient levels. Regardless of application method, B was associated with increased tomato growth and the concentration of K, Ca, and B in plant tissue. Boron application was associated with increased N uptake by tomato in field culture, but not under hydroponic culture. In field culture, foliar and/or soil applied B similarly increased fresh-market tomato plant and root dry weight, uptake, and tissue concentrations of N, Ca, K, and B, and improved fruit set, total yields, marketable yields, fruit shelf life, and fruit firmness. The similar growth and yield responses of tomato to foliar and root B application suggests that B is translocated in the phloem in tomatoes. Fruit from plants receiving foliar or root applied B contained more B, and K than fruit from plants not receiving B, indicating that B was translocated from leaves to fruit and is an important factor in the management of K nutrition in tomato.

CHAPTER III

MATERIALS AND METHODS

This chapter deals with the materials and methods that were used in carrying out the experiment. It includes a short description of location of the experiment, characteristics of soil, climate, materials used, land preparation, manuring and fertilizing, transplanting and gap filling, stalking, after care, harvesting and collection of data.

3.1 Experimental site

The experiment was conducted at the Horticulture farm of Sher-e-Bangla Agricultural University, Dhaka. The experiment was carried out during the period from October 2016 to March 2017. The geographic location of the site was 23°74" N latitude and 90°35" E longitude with an elevation of 8.2 meter from sea level.

3.2 Climate

The experimental site is located in subtropical region where climate is characterized by heavy rainfall during the months from April to September (Kharif season) and scanty rainfall during rest of the month (Rabi season). The maximum and minimum temperature, humidity rainfall and soil temperature during the study period are collected from the Sher-e-Bangla Mini weather station (Appendix I).

3.3 Soil

The soil of the experimental area belongs to the Modhupur Tract. Soil analysis report of the experimental area was collected from Khamarbari, Dhaka which was determined by SRDI, Soil testing Laboratory. The analytical data have been presented in appendix-II. The experimental site was a medium high land and pH of the soil was 5.4 to 5.6. The morphological characters of the soil as indicated by FAO (1995) are given here. AEZ No. 28

Soil series- Tejgaon General soil - Non -calcareous dark gray. The soil test report was shown in Appendix II.

3.4 Plant materials

The tomato cultivar i.e. BARI Tomato14 was used as a test crop.

3.5 Treatments of the Experiment

The experiment consisted of two factors as follows:

***Factor A:* Levels of GA_3**

a. G_0=No GA_3 spray
b. G_1=80 ppm
c. G_2=100 ppm
d. G_3=120 ppm

***Factor B:* Boron application**

a. B_0= No boron
b. B_1= 5 kg boron ha^{-1}

Treatments combinations G_0B_0, G_1B_0, G_2B_0, G_3B_0, G_0B_1, G_1B_1, G_2B_1, G_3B_1

3.6 Experimental design and layout

It was a factorial experiment. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The experimental area was divided into three equal blocks. Each block was divided into 8 plots. Every replication had eight plots where 8 treatments were allotted at random. The total number of plot was 24. The size of each plot was 2.5 m × 1.2 m. The distance between two blocks were l.0 m.

3.7 Land preparation

The selected land for the experiment was opened 5 October, 2016 with the help of a power tiller and then it was kept open to sun for 4 days prior to further ploughing. Then the land was prepared well by ploughing and cross ploughing followed by well by laddering at 9 October, 2016. Weeds and stubble were removed and the basal dosed of fertilizers were applied and mixed thoroughly with the soil before final land preparation. The unit plots were prepared by keeping l m spacing in between two plots and 50 cm drain was dug around the land. The space between two blocks and two plots were made as drain having a depth of about 30 cm.

3.8 Seed bed preparation

Tomato seedlings were raised in the seedbed situated on a relatively high land at Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka. The size of the seedbed was 3 m x l m. The soil was well prepared with the help of spade and made into loose friable and dried mass to obtain fine tilth. All weeds and stubbles were removed and 5 kg well rotten cowdung was applied during seedbed preparation. The seeds were sown on 25 October, 2016 and after sowing, seeds were covered with light soil to a depth of about 1.0 cm. Heptachlor 40 WP was applied @ 4 kg/ha around each seedbed as precautionary measure against ants and worm. The emergence of the seedlings took place within 5 to 6 days after sowing. Necessary shading by banana leaves was provided over the seed bed to protect the young seedlings from scorching sun or rain. Weeding, mulching and irrigation were done from time to time

3.9 Application of manures and fertilizers

Following doses of manures and fertilizers were recommended for tomato production fertilizer recommendation guide (2012).

Fertilizers	Doses ha^{-1}
Cowdung	10 t
Urea	550 kg
TSP	450 kg
MoP	450 kg

A common dose of cow dung @ 4 kg per pit, urea @ 10 g per pit, TSP @ 20 g per pit and MP @ 8 g per pit was applied during pit preparation in the respective plots a week before seed sowing. The boron (source: boric acid) was applied as per the treatment. The Furadan 5g was also applied during pit preparation to avoid the pest attack.

3.10 Transplanting of seedlings

Healthy and uniform 35 days old seedlings were uprooted separately from the seed bed and were transplanted in the experimental plots in the afternoon of 20^{th} October, 2016 maintaining a spacing of 60 cm x 50 cm between the rows and plants, respectively. This allowed an accommodation of 10 plants in each plot. The seedbed was watered before uprooting the seedlings from the seedbed so as to minimize damage to the roots. The seedlings were watered after transplanting. Shading was provided using banana leaf sheath for three days to protect the seedling from the hot sun and removed after seedlings were established. Seedlings were also planted around the border area of the experimental plots for gap filling.

3.11 Preparation of GA_3

GA_3 in different concentrations of 0, 80, 100 and 120 ppm were prepared following the procedure mentioned below and spraying was done by using hand sprayer. 80 ppm solution of GA_3 was prepared by dissolving 80 mg of it with distilled water then distilled water was added to make the volume 1 liter 80 ppm solution in a same way 100 and 120 ppm concentrations were made. An adhesive Tween-20 @0.1% was added to each solution. Control plots were treated only with distilled water

3.12 Intercultural operations

After transplanting the seedlings, various kinds of intercultural operations were accomplished for better growth and development of the plants, which are as follows.

3.12.1 Weeding

Weeding was done whenever necessary to keep the crop free from weeds.

3.12.2 Staking

When the seedlings were established, staking was given to each plant. Stick of dhaincha plant was given to support the growing twig.

3.12.3 Stem management

For proper growth and development of the plants the main stems were managed upward by hand and with the help of bamboo stick. So, the rainy and stormy weather could not damage the growing stems and fruits of the plants.

3.12.4 Irrigation

The experiment was done in robi season. So, irrigation was given when it is necessary. Sometimes rain was supplied sufficient water then irrigation was no need. When irrigation was supplied then it was given through drains of the plots.

3.12.5 Plant protection

Tomato is a very sensitive plant to various insect pests and diseases. So, various protection measures were taken. Melathion 57 EC and Ripcord was applied @ 2 ml against the insect pests like beetle, fruit fly, fruit borer and other. The insecticide application was made fortnightly from 10 days after seed sowing to a week before first harvesting. During cloudy and hot weather precautionary measures against viral disease was taken by spraying. Furadan 5 G was also applied @ 6 g/pit during pit preparation as soil insecticide.

3.13 Harvesting

When the green fruits were in marketable condition then they were harvested.

3.14 Data collection

Data was collected for the following parameters

I. Plant height (cm)
II. Number of branches plant^{-1}
III. Number of cluster plant^{-1}
IV. Total number of fruits plant^{-1}
V. Fruits length (cm)
VI. Fruits girth (cm)
VII. Individual fruit weight (g)
VIII. Fruit weight plant^{-1} (g)
IX. Yield ha^{-1}

3.15 Data collection procedure

3.15.1 Plant height

Plant height was taken at three times at 30 DAT, 60 DAT and at harvest and was measured in centimeter from ground level to tip of the main stem from each plant of each treatment and mean value was calculated.

3.15.2 Number of branches per plant

Total number of branches was counted at 30 DAT, 60 DAT from each plant of the treatment and mean value was calculated.

3.15.3 Number of cluster per pant

Number of cluster per plant was counted from first cluster was appearance. Number of cluster was recorded for each treatment.

3.15.5 Number of fruit per cluster

Number of fruit per cluster was counted from the each of the treatment. The total number of fruits per cluster was counted and average number of fruit was recorded.

3.15.5 Number of fruit per plant

Number of fruit was counted from first harvest stage to last harvest. The total number of fruits per plant was counted and average number of fruit was recorded.

3.15.6 Fruit length and girth

Fruit length and girth was taken by measuring tape in centimeter. Girth i.e. breath of fruit was measured at the middle portion of fruits from each plot and their average was taken. Average length of same fruits was also taken.

3.15.7 Yield of fruits

To estimate yield, all the six plants in every plot and all the fruits in every harvest were considered. Thus, the average yield per plot was measured. The yield per hectare was calculated considering the area covered by the six plants.

3.16 Statistical analysis

The recorded data on different parameters were statistically analyzed using Statistix 10 software and mean separation was done by LSD test at 5% level of probability by Gomez and Gomez (1984).

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to study the growth and yield of tomato (*Lycopersicon esculentum* Mill.) as influenced by GA_3 and boron. Data on different growth and other parameter, yield attributes and yield were recorded. The analyses of variance (ANOVA) of the data on different parameters are presented in Appendix section. The results have been presented with the help of graphs and tables and possible interpretations given under the following headings.

4.1 Plant height

Application of different levels of GA_3 showed significant difference on plant height (Figure 1 and Appendix III). However, at 30 DAT, the longest plant (59.03 cm) was observed in G_2 (100 ppm) whereas the shortest plant was observed in control condition. The longest plant (94.94 cm) was recorded from G_2 and the shortest plant (86.13 cm) was found from G_0 at 60 DAT. Again, the longest plant 101.31 cm was observed in G_2 (100 ppm) while the shortest plant 91.10 cm was found in G_0 (control). Akand *et al*. (2016), Mignolli *et al*. (2016) observed similar trend of results.

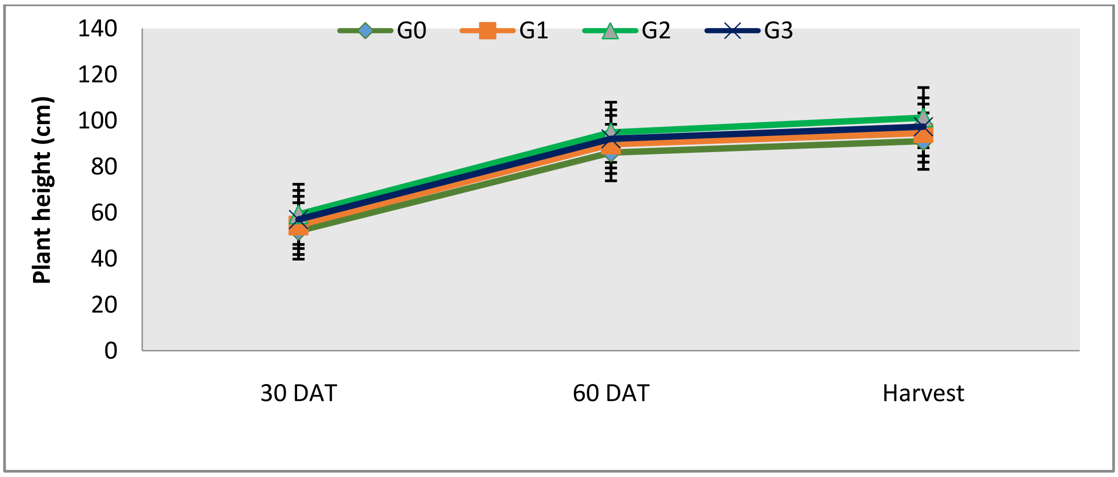

Figure 1. Effect of GA_3 on plant height

G_0: Control, G_1: 80 ppm, G_2: 100 ppm, G_3: 120 ppm

Vertical bars represented at 5% level of probability

Application of different levels of boron performed significant difference on plant height (Figure 2 and Appendix III). The longest plant (111.15 cm) was performed by B_1 (5 kg boron ha^{-1}) at harvest while control treatment gave the shortest plant all observed. This might be due to that boron helped in proper vegetative growth in tomato. The present finding is agreed with the finding of Haleema *et al*. (2018), Sarangthem *et al*. (2015).

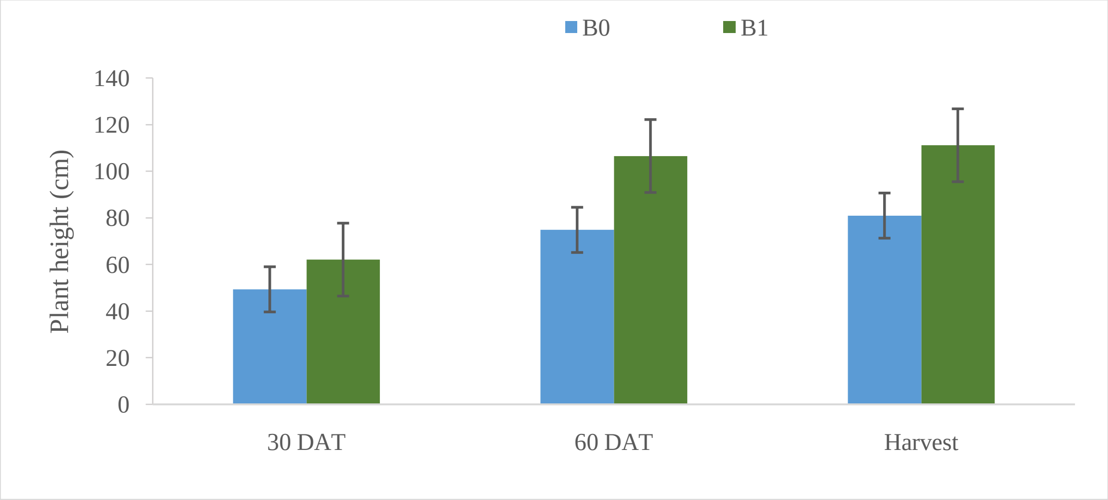

Figure 2. Effect of boron on plant height
B_0: Control, B_1: 5 kg boron ha^{-1}

Vertical bars represented at 5% level of probability

In case of combine effect of different levels of GA_3 and boron showed significant on plant height (Table 1 and Appendix III). At 30 DAT the tallest plant (66.07 cm) was obtained from G_2B_1 and the shortest plant (45.52 cm) was found from the control (G_0B_0) combination. At 60 DAT the longest plant (111.52 cm) was recorded from G_2B_1 whereas the shortest plant (71.32 cm) was found from the control treatment combination. The tallest plant (116.39 cm) was found in G_2B_1 and shortest plant was obtained from G_2B_1 and the shortest plant (76.15 cm) was recorded from control treatment combination.

Table 1. Combine effect of GA_3 and boron on plant height

Treatments	Plant height (cm) at		
	30 DAT	60 DAT	Harvest
G_0B_0	45.523 h	71.32 h	76.15 h
G_1B_0	48.832 g	73.62 g	79.89 g
G_2B_0	52.533 e	78.36 e	86.23 e
G_3B_0	50.587 f	76.16 f	81.69 f
G_0B_1	58.657 d	100.94 d	106.05 d
G_1B_1	60.160 c	105.71 c	109.27 c
G_2B_1	66.077 a	111.52 a	116.39 a
G_3B_1	63.587 b	107.98 b	112.89 b
LSD	2.36	1.54	2.34
CV (%)	8.67	9.92	7.99

In a column, means with similar letter (s) are not significantly different by LSD at 5% level of significance.
G_0: Control, G_1: 80 ppm, G_2: 100 ppm, G_3: 120 ppm
B_0: Control, B_1: 5 kg boron ha^{-1}

4.2 Number of branches plant^{-1}

The number of branches plant^{-1} showed significant difference due to application of GA3. The maximum number of branches (6.01) was found from G_2 while minimum number of branches (2.81) was counted from G_0 at 30 DAT. On the other hand, the highest number of branches (9.18) was observed in G_2 while the minimum number of branches (5.85) was found from control treatment (Figure 3 and Appendix IV). Pratibha *et al*. (2015) and Van Tonder *et al*. (2013) found similar result.

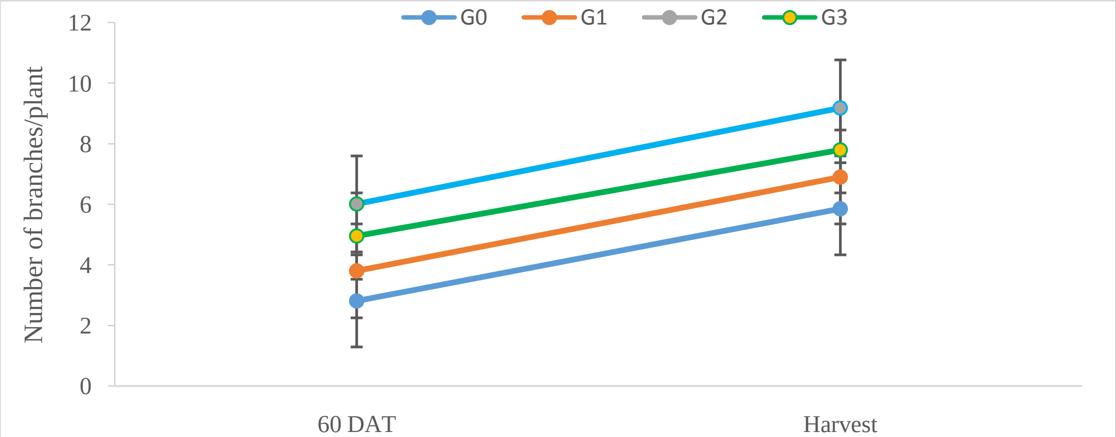

Figure 3. Effect of GA_3 on number of branches plant^{-1}
G_0: Control, G_1: 80 ppm, G_2: 100 ppm, G_3: 120 ppm

Vertical bars represented at 5% level of probability

Application of boron showed significant variations on number of branches plant^{-1} (Figure 4 and Appendix IV). The maximum number of branches (4.81) was found in B_1 while minimum number of branches (3.97) was recorded in B_0 treatment at 60 DAT. On the other hand, the maximum number of branches (8.89) was found in B_1 treatment and minimum number of branches (5.97) was recorded from control treatment (B_0).

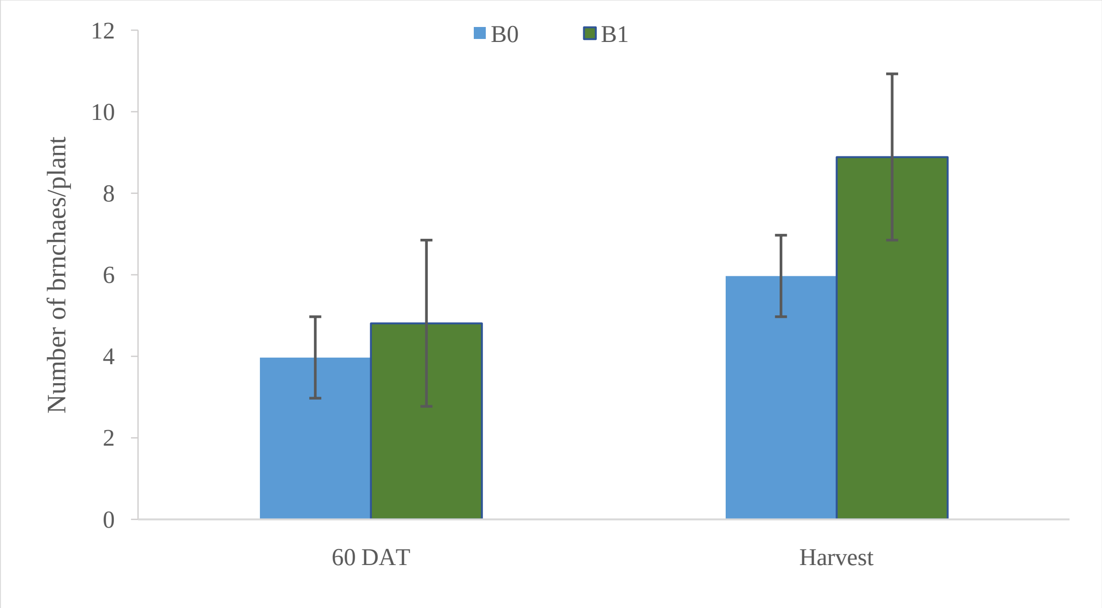

Figure 4. Effect of boron on number of branches plant^{-1}
B_0: Control, B_1: 5 kg boron ha^{-1}

Vertical bars represented at 5% level of probability

The combine effect of GA_3 and boron performed wide range of variations on number of branches plant^{-1} (Table 2 and Appendix IV). The highest number of branch (6.46) was counted from G_2B_1 while the minimum number of branches plant^{-1} (2.43) was found from G_0B_0 at 60 DAT. However, the maximum number of branches (10.56) was obtained from G_2B_1 the lowest (4.36) was recorded from G_0B_0.

Table 2. Combine effect of GA_3 and boron on number of branches

Treatments	Number of branches at	
	60 DAT	Harvest
G_0B_0	2.43	4.36
G_1B_0	3.33	5.50
G_2B_0	5.56	7.80
G_3B_0	4.56	6.23
G_0B_1	3.20	7.33
G_1B_1	4.26	8.30
G_2B_1	6.46	10.56
G_3B_1	5.33	9.36
$LSD_{(0.05)}$	4.22	6.39
CV (%)	8.22	8.67

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

G_0: Control, G_1: 80 ppm, G_2: 100 ppm, G_3: 120 ppm
B_0: Control, B_1: 5 kg boron ha^{-1}

4.3 Number of cluster

Due to application of GA_3 number of cluster plant^{-1} showed significant difference (Table 3 and Appendix V). The number of cluster plant^{-1} ranges from 10.43 to 14.47. The maximum number of cluster plant^{-1} (14.47) was recorded in G_2 treatment and the minimum number of cluster plant^{-1} (10.43) was observed in G_0 treatment. This might be due to that G_3 treatment facilitated better reproductive development of plant. Pramanik *et al*. (2017), Gamel *et al*. (2017), Akand *et al*. (2016), Mignolli *et al*. (2016), Rahman *et al*. (2015) and Patidar (2015) also reported that similar result.

The number of cluster plant^{-1} showed statistically significant impact due to different doses boron application in tomato cultivation (Table 3 and Appendix V). Due to influence of boron the maximum number of cluster plant^{-1} (14.10) was recorded in B_1 while the minimum number of cluster plant^{-1} (10.25) was in B_0. This might be due to that boron helped in proper reproductive development in tomato. The present finding agreed with the findings of Uraguchi *et al*. (2014), Naz *et al*. (2012), Cervilla *et al*. (2012), Dursun *et al*. (2010), Smit *et al*. (2004) and Davis *et al*. (2003).

Table 3. Effect of GA_3 and boron on number of cluster $plant^{-1}$

Treatments	Number of cluster $plant^{-1}$
Effect of GA_3	
G_0	10.43 d
G_1	11.36 c
G_2	14.47 a
G_3	12.45 b
$LSD_{(0.05)}$	0.16
Effect of Boron	
B_0	10.25 b
B_1	14.10 a
$LSD_{(0.05)}$	0.11
CV(%)	7.29

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

G_0: Control, G_1: 80 ppm, G_2: 100 ppm, G_3: 120 ppm
B_0: Control, B_1: 5 kg boron ha^{-1}

Combine effect of GA_3 and boron produced statistically non-significant number of cluster $plant^{-1}$ (Table 4 and Appendix V). For combine effect the number of cluster $plant^{-1}$ ranges from 8.53 to 16.34. The maximum number of cluster $plant^{-1}$ (16.34) was found in G_2B_1 and the number of cluster $plant^{-1}$ (8.53) was found in G_0B_0 combination compared to the others combination.

Table 4. Combine effect of GA_3 and boron on number of cluster $plant^{-1}$

Treatments	Number of cluster $plant^{-1}$
G_0B_0	8.53
G_1B_0	9.43
G_2B_0	12.60
G_3B_0	10.46
G_0B_1	12.33
G_1B_1	13.29
G_2B_1	16.34
G_3B_1	14.43
$LSD_{(0.05)}$	6.90
CV (%)	7.29

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

G_0: Control, G_1: 80 ppm, G_2: 100 ppm, G_3: 120 ppm
B_0: Control, B_1: 5 kg boron ha^{-1}

4.4 Number of fruits plant^{-1}

The number of fruits plant^{-1} showed significant difference for different doses of GA_3 application (Table 5 and Appendix VI). Due to application of different levels of GA_3, the maximum number of fruits plant^{-1} (33.79) was recorded in G_2 while the minimum number of fruits plant^{-1} (26.22) was recorded in G_0. This might be due to that G_3 treatment facilitated better reproductive development of plant. Akand *et al*. (2016), Rahman *et al*. (2015), Patidar (2015), Akand *et al*. (2015), Pratibha *et al*. (2015), Kumar *et al*. (2014), Mehraj *et al*. (2014), Van Tonder *et al*. (2013), Gelmesa *et al*. (2012) and Maggio *et al*. (2010) also reported similar statement of the present study.

Application of boron on tomato showed significant effect on number of fruits plant^{-1} (Table 5 and Appendix VI). The maximum number of fruits plant^{-1} (35.42) was found in B_1 while the minimum number of fruits plant^{-1} (24.85) was recorded in B_0 treatment. This might be due to application of boron helped to the maximum number fruits set in tomato Plants. The present finding is agreed with the statement of Haleema *et al*. (2018), Sarangthem *et al*. (2015), Uraguchi *et al*. (2014), Naz *et al*. (2012), Cervilla *et al*. (2012), Dursun *et al*. (2010), Smit *et al*. (2004) and Davis *et al*. (2003).

Table 5. Effect of GA_3 and boron on number of fruits plant^{-1}

Treatments	Number of fruits plant^{-1}
Effect of GA_3	
G_0	26.22 d
G_1	29.10 c
G_2	33.79 a
G_3	31.44 b
$LSD_{(0.05)}$	0.24
Effect of Boron	
B_0	24.85 b
B_1	35.42 a
$LSD_{(0.05)}$	0.17
CV (%)	8.13

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

G_0: Control, G_1: 80 ppm, G_2: 100 ppm, G_3: 120 ppm

B_0: Control, B_1: 5 kg boron ha^{-1}

Due to the combine effect of GA_3 and boron showed non-significant results on number of fruits plant^{-1} (Table 6 and Appendix VI). The number of fruits plant^{-}

^{1} ranges from 21.21 to 39.30. The maximum number of fruits plant^{-1} (39.30) was produced from the treatment combination G_2B_1 and the minimum number of fruits plant^{-1} (21.21) was produced from the control treatment combination (G_0B_0).

Table 6. Combine effect of GA_3 and boron on number of fruits plant^{-1}

Treatments	Number of fruits plant^{-1}
G_0B_0	21.21
G_1B_0	23.62
G_2B_0	28.28
G_3B_0	26.30
G_0B_1	31.24
G_1B_1	34.59
G_2B_1	39.30
G_3B_1	36.58
$LSD_{(0.05)}$	1.22
CV (%)	8.13

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

G_0: Control, G_1: 80 ppm, G_2: 100 ppm, G_3: 120 ppm

B_0: Control, B_1: 5 kg boron ha^{-1}

4.5 Fruit length

Due to application of GA3 fruit length showed significant differences (Table 7 and Appendix VII). The highest fruit length (4.55 cm) was recorded in G_2 treatment and the lowest fruit length (3.60 cm) was recorded in G_0 treatment. This might be due to that G_2 treatment facilitated to enhance the length of fruits. Pramanik *et al*. (2017), Gamel *et al*. (2017), Akand *et al*. (2016), Van Tonder *et al*. (2013), Groot *et al.* (1987) and Onofeghara (1981) also reported that similar trend of results.

Fruit length showed statistically significant influenced due to different levels of boron of tomato cultivation (Table 7 and Appendix VII). The highest fruit length (4.51 cm) was recorded in B_1 while the lowest fruit length (3.60 cm) was in B_0. The fruit length ranges from 3.60 cm to 4.51 cm. This might be due to that boron helped in proper fruit sizes in tomato. The present finding is agreed with the finding of Haleema *et al*. (2018), Sarangthem *et al*. (2015), Uraguchi *et al*. (2014), Naz *et al*. (2012), Cervilla *et al*. (2012), Dursun *et al*. (2010), Smit *et al*. (2004) and Davis *et al*. (2003).

Table 7. Effect of GA_3 and boron on fruit length

Treatments	Fruit length (cm)
Effect of GA_3	
G_0	3.60 d
G_1	3.95 c
G_2	4.55 a
G_3	4.15 b
$LSD_{(0.05)}$	0.22
Effect of Boron	
B_0	3.60 b
B_1	4.51 a
$LSD_{(0.05)}$	1.03
CV (%)	9.60

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

G_0: Control, G_1: 80 ppm, G_2: 100 ppm, G_3: 120 ppm

B_0: Control, B_1: 5 kg boron ha^{-1}

Combine effect of GA_3 and boron produced statistically significant fruit length of tomato (Table 8 and Appendix VII). The highest fruit length (5.16 cm) was found in G_2B_1 and the lowest of fruit length (3.20 cm) was found in G_0B_0.

Table 8. Combine effect of GA_3 and boron on fruits length

Treatments	Fruit length (cm)
G_0B_0	3.20 f
G_1B_0	3.60 e
G_2B_0	3.93 d
G_3B_0	3.70 e
G_0B_1	4.00 d
G_1B_1	4.30 c
G_2B_1	5.16 a
G_3B_1	4.60 b
$LSD_{(0.05)}$	0.04
CV (%)	9.60

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

G_0: Control, G_1: 80 ppm, G_2: 100 ppm, G_3: 120 ppm

B_0: Control, B_1: 5 kg boron ha^{-1}

4.6 Fruit girth

The fruit girth showed significant difference due to application of different levels of GA_3 application (Table 9 and Appendix VIII). Due to application of different levels of GA_3, the range of fruit girth was found 3.60 cm to 4.50 cm. The highest fruit girth (4.50 cm) was recorded in G_2 while the lowest fruit girth (3.60 cm) was recorded in G_0. This might be due to that G_3 treatment facilitated to increase the fruit girth in tomato. Akand *et al*. (2016), Khan *et al*. (2006), Rai *et al*. (2006), Nibhavanti *et al.* (2006), Sasaki *et al.* (2005), Kataoka *et al.* (2004), Naeem *et al*. (2001) and Sun *et al.* (2000) also observed the same trends of results.

Application impact of boron on tomato showed significant effect on fruit girth of tomato (Table 9 and Appendix VIII). The highest value of fruit girth (4.46 cm) was found in B_1 while the lowest value of fruit girth (3.60 cm) was recorded in B_0 treatment. The present finding is agreed with the finding of Haleema *et al*. (2018), Sarangthem *et al*. (2015), Uraguchi *et al*. (2014), Naz *et al*. (2012).

Table 9. Effect of GA_3 and boron on fruit girth

Treatments	Fruit girth (cm)
Effect of GA_3	
G_0	3.60 d
G_1	3.98 c
G_2	4.50 a
G_3	4.11 b
$LSD_{(0.05)}$	0.21
Effect of Boron	
B_0	3.63 b
B_1	4.46 a
$LSD_{(0.05)}$	0.76
CV (%)	7.72

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

G_0: Control, G_1: 80 ppm, G_2: 100 ppm, G_3: 120 ppm

B_0: Control, B_1: 5 kg boron ha^{-1}

Combine effect of GA_3 and boron showed positively significant variation on fruit girth (Table 10 and Appendix VIII). The highest fruit girth (5.00 cm) was found in G_2B_1 and the lowest fruit girth (3.10 cm) was produced by the G_0B_0 treatment.

Table 10. Combine effect of GA_3 and boron on fruits girth

Treatments	Fruit girth (cm)
G_0B_0	3.10 f
G_1B_0	3.70 e
G_2B_0	4.00 d
G_3B_0	3.73 e
G_0B_1	4.10 d
G_1B_1	4.26 c
G_2B_1	5.00 a
G_3B_1	4.50 b
$LSD_{(0.05)}$	0.03
CV (%)	8.17

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

G_0: Control, G_1: 80 ppm, G_2: 100 ppm, G_3: 120 ppm
B_0: Control, B_1: 5 kg boron ha^{-1}

4.7 Individual fruit weight

Due to application of GA_3 the individual fruit weight showed positively significant result (Table 11 and Appendix IX). The highest individual fruit weight (60.68 g) was recorded in G_2 treatment and the lowest individual fruit weight (51.30 g) was recorded in G_0 treatment. This might be due to that G_3 treatment facilitated better reproductive development of plant. Patidar (2015), Akand *et al*. (2015), Groot *et al.* (1987), Sumiati (1987), Leonard *et al.* (1983), Wu *et al.* (1983), Onofeghara (1981), Saleh and Abdul (1980) and Briant (1974) also reported that similar results.

The individual fruit weight showed statistically significant variations due to different doses of boron application for tomato cultivation (Table 11 and Appendix IX). The significant influence of boron facilitated highest value of individual fruit weight (64.76 g) in B_1 while the lowest value of individual fruit weight (46.77 g) was in B_0. This might be due to that boron influenced the increase of fruit weight in tomato. The present finding is agreed with the finding of Haleema *et al*. (2018), Sarangthem *et al*. (2015), Uraguchi *et al*.

(2014), Naz *et al*. (2012), Cervilla *et al*. (2012), Dursun *et al*. (2010), Smit *et al*. (2004) and Davis *et al*. (2003).

Table 11. Effect of GA_3 and boron on individual fruit weight

Treatments	Individual fruit weight (g)
Effect of GA_3	
G_0	51.30 d
G_1	53.91 c
G_2	60.68 a
G_3	57.17 b
$LSD_{(0.05)}$	1.03
Effect of Boron	
B_0	46.77
B_1	64.76
$LSD_{(0.05)}$	8.86
CV (%)	4.97

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

G_0: Control, G_1: 80 ppm, G_2: 100 ppm, G_3: 120 ppm
B_0: Control, B_1: 5 kg boron ha^{-1}

Combine effect of GA_3 and boron produced statistically significant individual fruit weight (Table 12 and Appendix IX). The highest individual fruit weight (67.98 g) was found in G_2B_1 and the lowest individual fruit weight (41.30 g) was found in G_0B_0 combination compared to the others combination.

Table 12. Combine effect of GA_3 and boron on individual fruits weight

Treatments	Individual fruit weight (g)
G_0B_0	41.30 h
G_1B_0	44.41 g
G_2B_0	53.38 e
G_3B_0	48.00 f
G_0B_1	61.31 d
G_1B_1	63.42 c
G_2B_1	67.98 a
G_3B_1	66.34 b
$LSD_{(0.05)}$	2.13
CV (%)	8.99

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

G_0: Control, G_1: 80 ppm, G_2: 100 ppm, G_3: 120 ppm
B_0: Control, B_1: 5 kg boron ha^{-1}

4.8 Yield plant^{-1}

Due to application of GA_3 the yield plant^{-1} showed positively significant impact (Table 13 and Appendix X). The yield plant^{-1} ranges from 1468.8 g to 1710.4 g. The highest yield plant^{-1} (1710.40 g) was recorded in G_2 treatment and the lowest yield plant^{-1} (1468.80 g) was recorded in G_0 treatment. This might be due to that G_3 treatment facilitated better reproductive development of plant. Tomar and Ramgiry (1997), El-Abd *et al.* (1995), Wien and Zhang (1991), Groot *et al.* (1987), Sumiati (1987), Leonard *et al.* (1983), Wu *et al.* (1983), Onofeghara (1981), Saleh and Abdul (1980) and Briant (1974) also reported that similar trends of result.

The yield plant^{-1} showed statistically significant impact due to different boron doses of boron application for tomato cultivation (Table 13 and Appendix X). The highest yield plant^{-1} (1691.20 g) was recorded in B_1 while the lowest yield plant^{-1} (1484.40 g) was in B_0. The yield plant^{-1} ranges from 1484.4 g to 1691.2 g. This might be due to that boron helped in proper reproductive development in tomato. The present finding is agreed with the finding of Haleema *et al*. (2018), Sarangthem *et al*. (2015), Uraguchi *et al*. (2014), Naz *et al*. (2012), Cervilla *et al*. (2012), Dursun *et al*. (2010), Smit *et al*. (2004) and Davis *et al*. (2003).

Table 13. Effect of GA_3 and boron on yield plant^{-1}

Treatments	Yield plant^{-1} (g)
Effect of GA_3	
G_0	1468.8 d
G_1	1549.8 c
G_2	1710.4 a
G_3	1622.2 b
$LSD_{(0.05)}$	15.26
Effect of boron	
B_0	1484.4 b
B_1	1691.2 a
$LSD_{(0.05)}$	9.26
CV (%)	8.88

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

G_0: Control, G_1: 80 ppm, G_2: 100 ppm, G_3: 120 ppm

B_0: Control, B_1: 5 kg boron ha^{-1}

Combine effect of GA_3 and boron produced statistically significant values of yield plant^{-1} (Table 14 and Appendix X). For combine effect, the yield plant^{-1} ranges from 1356.0 g to 1804.9 g. The highest yield plant^{-1} was found (1804.90 g) in G_2B_1 and the lowest yield plant^{-1} was found (1356.00 g) in G_0B_0 combination compared to the others combination.

Table 14. Combine effect of GA_3 and boron on yield plant^{-1}

Treatments	Yield plant^{-1} (g)
G_0B_0	1356.0 h
G_1B_0	1425.3 g
G_2B_0	1615.9 d
G_3B_0	1540.5 f
G_0B_1	1581.6 e
G_1B_1	1674.3 c
G_2B_1	1804.9 a
G_3B_1	1703.9 b
$LSD_{(0.05)}$	0.94
CV (%)	9.92

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

G_0: Control, G_1: 80 ppm, G_2: 100 ppm, G_3: 120 ppm

B_0: Control, B_1: 5 kg boron ha^{-1}

4.9 Yield ha^{-1}

The yield of tomato showed significant difference at different doses of GA_3 application (Figure 5 and Appendix XI). Due to application of different levels of GA_3, the highest yield (68.41 t ha^{-1}) was recorded in G_2 while the lowest yield (58.75 t ha^{-1}) was recorded in G_0. This might be due to application of GA_3 treatment facilitated which influenced to increase the yield in tomato. Pramanik *et al*. (2017), Gamel *et al*. (2017), Akand *et al.* (2016), Mignolli *et al.* (2016), Rahman *et al*. (2015), Patidar (2015), Akand *et al*. (2015), Pratibha *et al.* (2015), Kumar *et al*. (2014), Mehraj *et al*. (2014) and Van Tonder *et al*. (2013) also reported that similar results.

Application of boron on tomato showed significant effect for yield of tomato (Figure 6 and Appendix XI). Due to the effect of boron on fruit yield of tomato, the highest value of yield (67.64 t ha^{-1}) was found in B_2 while the lowest fruit yield (59.73 t ha^{-1}) was recorded in B_0 treatment. The fruit yield ranges from 59.37 t ha^{-1} to 67.64 t ha^{-1}. This might be due to that boron helped in proper reproductive development in tomato. The present finding is agreed with the finding of Haleema *et al*. (2018), Sarangthem *et al*. (2015), Uraguchi *et al*. (2014), Naz *et al*. (2012), Cervilla *et al*. (2012), Dursun *et al*. (2010), Smit *et al*. (2004) and Davis *et al*. (2003).

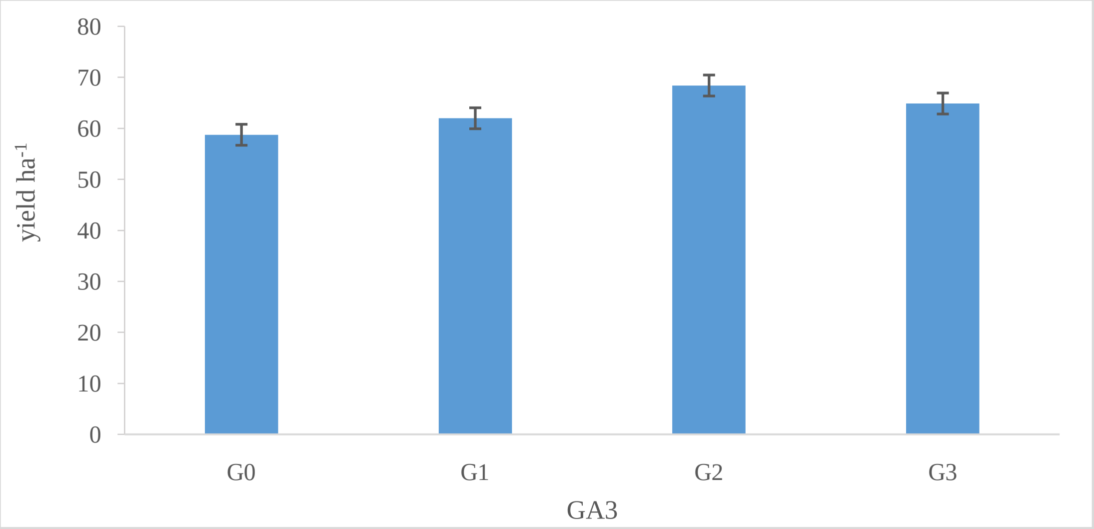

Figure 5. Effect of GA_3 on number fruit yield
G_0: Control, G_1: 80 ppm, G_2: 100 ppm
Vertical bars represented at 5% level of probability

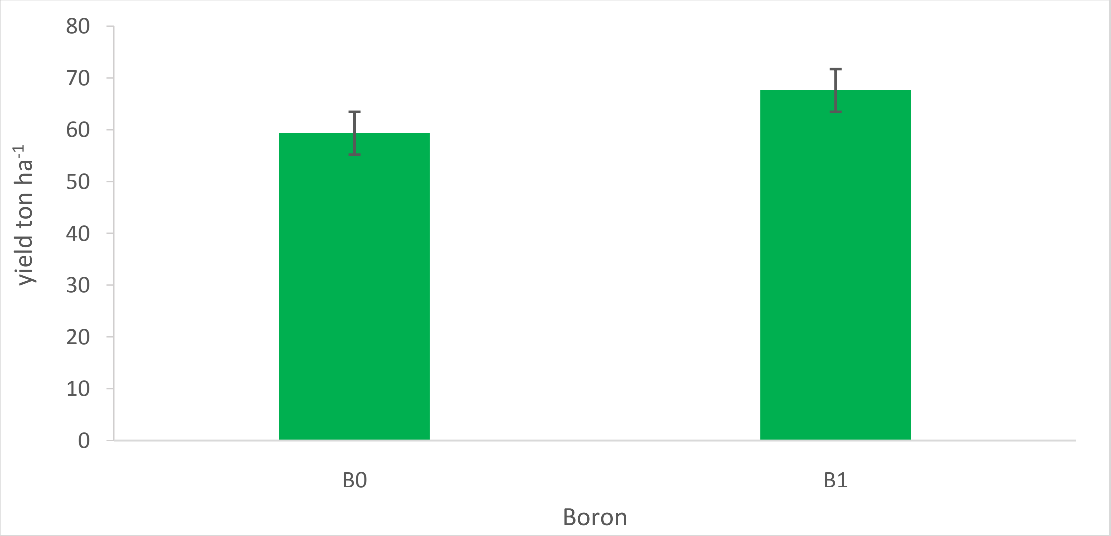

Figure 6. Effect of boron on number fruit yield
B_0: Control, B_1: 5 kg boron ha^{-1}
Vertical bars represented at 5% level of significance

Combine effect of GA_3 and boron showed positively significant impact on yield of tomato (Table 15 and Appendix XI). The treatment G_2B_1 produced the highest fruit yield (72.19 t ha^{-1}) and G_0B_0 produced lowest value of fruit yield (54.24 t ha^{-1}).

Table 15. Combine effect of GA_3 and boron on yield ha^{-1}

Treatments	Yield ha^{-1}
G_0B_0	54.24 h
G_1B_0	57.01 g
G_2B_0	64.63 d
G_3B_0	61.62 f
G_0B_1	63.26 e
G_1B_1	66.97 c
G_2B_1	72.19 a
G_3B_1	68.15 b
$LSD_{(0.05)}$	1.98
CV (%)	7.72

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

G_0: Control, G_1: 80 ppm, G_2: 100 ppm, G_3: 120 ppm

B_0: Control, B_1: 5 kg boron ha^{-1}

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at the Farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh during the period from October 2016 to March 2017 to study the growth and yield of tomato (*Lycopersicon esculentum* Mill.) as influenced by GA_3 and boron. The experiment comprised as two factors, Factor A: Different GA_3 doses i.e. G_0=No GA_3 spray, G_1=80 ppm, G_2=100 ppm, G_3=120 ppm; and two level of boron i.e. B_0 =No boron application, B_1= 5 kg boron ha^{-1} (Sources: boric acid). The experiment was laid out RCBD with three replications. Data on different growth parameters, yield attributes and yield were recorded and analyzed.

Plant height range from 52.09 cm to 59.30 cm, 86.13 to 94.94 cm and 91.10 cm to 101.31 cm at 30 DAT, 60 DAT and harvest time, respectively while showed the increasing trend up to 60 DAT and the decreasing trend. The tallest plant was recorded in G_3 treatment and shortest plant was recorded in G_1 treatment. The tallest plant was recorded in B_1 while shortest plant was in B_0. The plant height ranges from 49.36 cm to 62.12 cm, 74.86 cm to 106.54 cm and 80.99 cm to 111.15 cm at 30 DAT, 60 DAT and harvest time, respectively. For combine effect plant height ranges from 45.52 cm to 66.07 cm, 71.32 cm to 111.52 cm and 76.15 cm to 116.36 cm at 30 DAT, 60 DAT and harvest time, respectively. The tallest plant was found in G_2B_1 and shortest plant was found in G_0B_0 combination at all sampling dates compared to the others combination.

Due to application of different levels of GA_3, the range of number of branches $plant^{-1}$ was found 2.81 to 6.01, 5.85 to 9.18 at 60 DAT and harvest time, respectively. The highest number of branches $plant^{-1}$ was recorded in G_2 while lowest number of branches $plant^{-1}$ was recorded in G_0. The maximum number of branches was found in B_1 while minimum number of branches was recorded in B_0 treatment. The number of branches ranges from 3.97 to 4.81 and 5.97 to

8.89 at 30 DAT, 60 DAT and harvest time, respectively. Number of branches plant^{-1} ranges from 2.43 to 6.46 and 4.36 to 10.56 at 60 DAT and harvest time, respectively while G_2B_1 produced the maximum number of branches and G_0B_0 produced minimum number of branches.

The number of cluster plant^{-1} ranges from 10.43 to 14.47. The maximum number of cluster plant^{-1} was recorded in G_2 treatment and the minimum number of cluster plant^{-1} was recorded in G_0 treatment. Due to influence of boron the maximum number of cluster plant^{-1} was recorded in B_1 while minimum number of cluster plant^{-1} was in B_0. The number of cluster plant^{-1} ranges from 10.25 to 14.10. For combine effect number of cluster plant^{-1} ranges from 8.53 to 16.34. The maximum number of cluster plant^{-1} was found in G_2B_1 and the number of cluster plant^{-1} was found in G_0B_0 combination compared to the others combination.

Due to application of different levels of GA_3, the range of number of fruits plant^{-1} was found 26.22 to 33.79. The maximum number of fruits plant^{-1} was recorded in G_2 while the minimum number of fruits plant^{-1} was recorded in G_0. The maximum number of fruits plant^{-1} was found in B_1 while the minimum number of fruits plant^{-1} was recorded in B_0 treatment. The number of fruits plant^{-1} ranges from 24.85 to 35.42. The number of fruits plant^{-1} ranges from 21.21 to 39.30 while G_2B_0 produced the maximum number of fruits plant^{-1} and G_0B_0 produced the minimum number of fruits plant^{-1}.

The fruit length ranges from 3.60 cm to 4.55 cm. The highest value of fruit length was recorded in G_2 treatment and the lowest values of fruit length was recorded in G_0 treatment. The highest value of fruit length was recorded in B_1 while the lowest value of fruit length was in B_0. The fruit length ranges from 3.60 cm to 4.51 cm. For combine effect the value of fruit length ranges from 3.20 cm to 5.16 cm. The highest value of fruit length was found in G_2B_1 and the lowest value of fruit length was found in G_0B_0 combination compared to the others combination.

Due to application of different levels of GA_3, the range of fruit girth was found 3.60 cm to 4.50 cm. The highest fruit girth was recorded in G_2 while the lowest fruit girth was recorded in G_0. The highest value of fruit girth was found in B_1 while the lowest value of fruit girth was recorded in B_0 treatment. The value of fruit girth ranges from 3.63 cm to 4.46 cm. The fruit girth ranges from 3.10 cm to 5.00 cm while G_2B_1 produced the highest fruit girth and G_0B_0 produced the lowest fruit girth.

The individual fruit weight ranges from 51.30 g to 60.68 g. The highest individual fruit weight was recorded in G_2 treatment and the lowest individual fruit weight was recorded in G_0 treatment. The significant influence of boron facilitated highest value of individual fruit weight in B_1 while the lowest value of individual fruit weight was in B_0. The individual fruit weight ranges from 46.77 g to 64.76 g. For combine effect the individual fruit weight ranges from 41.30 g to 67.42 g. The highest individual fruit weight was found in G_2B_1 and the lowest individual fruit weight was found in G_0B_0 combination compared to the others combination.

The yield plant^{-1} ranges from 1468.8 g to 1710.4 g. The highest yield plant^{-1} was recorded in G_2 treatment and the lowest yield plant^{-1} was recorded in G_0 treatment. The highest yield plant^{-1} was recorded in B_1 while the lowest yield plant^{-1} was in B_0. The yield plant^{-1} ranges from 1484.4 g to 1691.2 g. For combine effect, the yield plant^{-1} ranges from 1356.0 g to 1804.9 g. The highest yield plant^{-1} was found in G_2B_1 and the lowest yield plant^{-1} was found in G_0B_0 combination compared to the others combination.

Due to application of different levels of GA_3, the range of yield of tomato was found 58.75 t ha^{-1} to 68.41 t ha^{-1}. The highest yield was recorded in G_2 while lowest yield was recorded in G_0. Due to the effect of boron on fruit yield of tomato, the highest value of yield was found in B_2 while the lowest fruit yield was recorded in S_0 treatment. The fruit yield ranges from 59.37 t ha^{-1} to 67.64 t ha^{-1}. The yield of tomato ranges from 54.24 t ha^{-1} to 72.19 t ha^{-1} while G_2B_1 produced the highest fruit yield and G_0B_0 produced lowest value of fruit yield.

Recommendations

The present experiment was conducted only one season even in a single location. So, it is difficult to recommend this finding without further study. By considering the results of the present experiment, further studies in the following areas are suggested below:

I. Studies of similar nature could be carried out in different agro-ecological zones (AEZ) in different seasons of Bangladesh for the evaluation of regional adaptability.

II. In this study, few levels of GA_3 and boron were used, it is recommended to increase the GA_3 levels and boron doses to get accurate result.

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APPENDIX

Appendix I. Monthly recorded the average air temperature, rainfall, relative humidity and sunshine of the experimental site during the period from October 2016 to March 2017.

Month	Air temperature (^{0}C)		Relative humidity (%)	Total rainfall (mm)	Sunshine (hr)
	Maximum	Minimum			
October, 2016	26.4	14.1	69	12.8	5.5
November, 2016	25.4	12.7	68	7.7	5.6
December, 2016	24.1	15.5	67	28.9	5.5
January, 2017	32.5	20.4	64	65.8	5.2
February, 2017	33.9	23.6	70	76.4	5.7
March, 2017	36.5	24.5	75	80.6	5.8

Source: Sher-e-Bangla Agricultural University Weather Station

Appendix II. Physical and chemical soil properties of experimental plot

Characteristics	Value
% Sand	27
% Silt	43
% clay	30
Textural class	silty-clay
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	45

Source: Soil Resources Development Institute (SRDI)

Appendix III. Factorial ANOVA for plant height at 30 DAT

Sources of variations	DF	SS	MS	F	P
Replication	2	4.94	2.472		
GA_3	3	176.35	58.785	297.40	0.0000
Boron	1	975.54	975.545	4935.49	0.0000
GA_3 × Boron	3	4.29	1.431	7.24	0.0036
Error	14	2.77	0.198		

Appendix IV. Factorial ANOVA for plant height at 60 DAT

Sources of variations	DF	SS	MS	F	P
Replication	2	10.91	5.46		
GA_3	3	250.65	83.55	189.07	0.0000
Boron	1	6020.47	6020.47	13623.59	0.0000
GA_3 × Boron	3	9.97	3.32	7.52	0.0031
Error	14	6.19	0.44		

Appendix V. Factorial ANOVA for plant height at harvest

Sources of variations	DF	SS	MS	F	P
Replication	2	14.72	7.36		
GA_3	3	334.95	111.65	613.07	0.0000
Boron	1	5457.45	5457.45	29966.89	0.0000
GA_3 × Boron	3	2.62	0.87	4.80	0.0168
Error	14	2.55	0.18		

Appendix VI. Factorial ANOVA for number of branches at 60 DAT

Sources of variations	DF	SS	MS	F	P
Replication	2	2.2108	1.1054		
GA_3	3	34.6979	11.5660	409.07	0.0000
Boron	1	4.2504	4.2504	150.33	0.0000
GA_3 × Boron	3	0.0346	0.0115	0.41	0.7499
Error	14	0.3958	0.0283		

Appendix VII. Factorial ANOVA for number of branches at harvest

Sources of variations	DF	SS	MS	F	P
Replication	2	2.5033	1.2517		
GA_3	3	35.9300	11.9767	212.24	0.0000
Boron	1	51.0417	51.0417	904.54	0.0000
GA_3 × Boron	3	0.1283	0.0428	0.76	0.5360
Error	14	0.7900	0.0564		

Appendix VIII. Factorial ANOVA for number of cluster plant^{-1}

Sources of variations	DF	SS	MS	F	P
Replication	2	2.426	1.2132		
GA_3	3	54.209	18.0696	226.12	0.0000
Boron	1	88.550	88.5504	1108.10	0.0000
GA_3 × Boron	3	0.042	0.0140	0.18	0.9113
Error	14	1.119	0.0799		

Appendix IX. Factorial ANOVA for number of fruits plant^{-1}

Sources of variations	DF	SS	MS	F	P
Replication	2	14.986	7.493		
GA_3	3	188.440	62.813	341.29	0.0000
Boron	1	670.455	670.455	3642.82	0.0000
GA_3 × Boron	3	1.113	0.371	2.02	0.1580
Error	14	2.577	0.184		

Appendix X. Factorial ANOVA for fruit length

Sources of variations	DF	SS	MS	F	P
Replication	2	0.16750	0.08375		
GA_3	3	2.83125	0.94375	288.27	0.0000
Boron	1	4.95042	4.95042	1512.13	0.0000
GA_3 × Boron	3	0.24125	0.08042	24.56	0.0000
Error	14	0.04583	0.00327		

Appendix XI. Factorial ANOVA for fruit girth

Sources of variations	DF	SS	MS	F	P
Replication	2	0.14581	0.07290		
GA_3	3	2.49235	0.83078	363.56	0.0000
Boron	1	4.15834	4.15834	1819.75	0.0000
GA_3 × Boron	3	0.19501	0.06500	28.45	0.0000
Error	14	0.03199	0.00229		

Appendix XII. Factorial ANOVA for fruit weight

Source of variations	DF	SS	MS	F	P
Replication	2	22.34	11.17		
GA_3	3	296.88	98.96	766.96	0.0000
Boron	1	1941.84	1941.84	15049.76	0.0000
GA_3 × Boron	3	25.10	8.37	64.83	0.0000
Error	14	1.81	0.13		

Appendix XIII. Factorial ANOVA for yield plant^{-1}

Sources of variations	DF	SS	MS	F	P
Replication	2	444	222		
Boron	1	256401	256401	191510.01	0.0000
GA_3	3	190908	63636	47530.85	0.0000
GA_3 × Boron	3	6503	2168	1619.08	0.0000
Error	14	19	1		

Appendix XIV. Factorial ANOVA for yield ton ha^{-1}

Sources of variations	DF	SS	MS	F	P
Replication	2	0.710	0.355		
Boron	1	410.242	410.242	191510.01	0.0000
GA_3	3	305.454	101.818	47530.85	0.0000
GA_3 × Boron	3	10.405	3.468	1619.08	0.0000
Error	14	0.030	0.002		