EFFECT OF GIBBERELLIC ACID AND BORON ON THE GROWTH AND YIELD OF TOMATO

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CERTIFICATE

This is to certify that thesis entitled, "**EFFECT OF GIBBERELLIC ACID AND BORON ON THE GROWTH AND YIELD OF TOMATO**" submitted to the Department of Horticulture, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (MS)** in **HORTICULTURE,** embodies the result of a piece of *bona fide* research work carried out by **MST. URME ISLAM**, **Reg. No. 08-03135** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma in any institute.

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

Dated: June, 2015

Place: Dhaka, Bangladesh

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ABSTRACT

A field experiment was conducted at the Horticultural Farm of Sher-e-Bangla Agricultural University, Dhaka from November, 2014 to March, 2015 to study the effect of GA_3 and boron on the growth and yield of tomato, (CV- BARI Tomato-14). There were four concentrations of GA_3 viz. G_0:0 ppm, G_1:70 ppm, G_2:90 ppm and $G_{3:}$ 110 ppm and three levels of boron viz. B_0:0, B_1:10 and B_2:15 kg ha^{-1}. The experiment was laid out in a Randomized Complete Block Design with 3 replications and there were altogether 36 plots. Application of GA_3 and boron significantly influenced the growth, yield and size of tomato. The highest yield (68.67 t/ha) was found from G_1 and the lowest yield (53.63 t/ha) was obtained from G_0. Due to application of boron, the highest yield (67.32 t/ha) was obtained from B_1 and lowest yield (56.69 t/ha) was recorded from B_0. In case of combined effect, the highest yield (77.61 t/ha) was found from G_1B_1 and lowest yield (34.72 t/ha) was found from G_0B_0. Economic analysis raveled that G_1B_1 gave the maximum benefit cost ratio (2.67). So, application of 70ppm GA_3 along with 10 kg boron /ha was the best for growth and yield of tomato.

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LIST OF ACRONYMS

ABBREVIATIONS	ELABORATIONS
%	Percent
@	At the rate
AEZ	Agro –Ecological Zone
Agric.	Agriculture
Agril.	Agricultural
Agron.	Agronomy
ANOVA	Analysis of variance
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
BD	Bangladesh
cm	Centi-meter
Cult.	Culture
CV%	Percentage of coefficient of variance
df	Degrees Of Freedom
DMRT	Duncan's Multiple Range Test
EC	Emulsifiable concentration
et al.	and others
etc.	Etcetera
FAO	Food And Agriculture Organization of United Nations
GA	Gibberellic Acid
hr.	Hours
Hort.	Horticulture

j.	Journal
Kg/ha	Kilograms per hectare
Kg	Kilogram
m	Meter
m^2	Meter square
MoA	Ministry of Agriculture
MSE	Mean square of the error
no.	Number
ppm	Parts per million
RCBD	Randomized Complete Block Design
Rep.	Replication
Res.	Research
SAU	Sher-e- Bangla Agricultural University
Sc.	Science
SE	Standard Error
TSS	Total Soluble Solid
Univ.	University
var.	Variety

CHAPTER I

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.), under the family Solanaceae is one of the most popular and important vegetable crops grown in Bangladesh. It ranks third in the world's vegetable production, next to potato and sweet potato, placing itself first as processing crop among the vegetables (Choudhury, 1979). It has a great demand throughout the year and generally grown in both winter and summer seasons. In Bangladesh, it is cultivated due to its adaptability to wide range of soil and climate (Ahmed, 1995). It is originated in tropical America (Salunkhe *et al*., 1987) which includes Peru, Ecuador, Bolivia areas of Andes (Kallo, 1986). However, in spite of its broad adaption, production is concentrated in a few area and rather dry area. The present leading tomato producing countries of the world are China, United States of America, India, Egypt, Turkey, Iran, Italy, Mexico, Brazil and Indonesia (FAO 2002).

The soil and climate conditions of winter season of Bangladesh are congenial for tomato cultivation. Among the winter vegetable crops grown in Bangladesh, tomato ranks second in respect of production next to potatoes and third in respect of area (BBS, 2004). In Bangladesh tomato has great demand throughout the year but its production is mainly concentrated during the winter season. The recent statistics shows that in Bangladesh tomato was grown in 9,646.77 hectares of land and the total production was approximately 146,000 metric tons during the year 2009-2010 (BBS, 2010).

The popularity of tomato and its different products are increasing day by day. It is a nutritious and delicious vegetable used in salads, soups and processed into stable products like ketchup, sauce, marmalade, chutney and juice. They are extensively used in the canning industry for canning. Food value of tomato is very rich and highly nutritious because 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, B and vitamin C including calcium and carotene (Bose and Som, 1990). Therefore, it can meet up some degree of vitamin A and C requirement, adds flavor to the foods, rich in medicinal value and also can contribute to solve malnutrition problem.

Fruit set in tomato can be increased by applying plant growth regulators to compensate the deficiency of natural growth substances required for its development (Akand *et al*., 2015). GA_3 is known to promote fruit development in pollinated ovaries that undergo dormancy due to high temperature (Gelmesa *et al*., 2012). GA_3 is also an important factor for tomato good yield. The application of gibberellic acid had significantly increased the number of fruits per plant than the untreated control. Tomar and Ramgiry (1997) reported that GA_3 @ 55 ppm sprayed on flower cluster resulted an increase in fruit weight. Therefore, it is necessary to find out the effective dose of growth regulators, viz. GA_3 in promoting the fruit set that will eventually lead to enhance increasing yield of tomato even in high temperature that prevails in the later part of the growing season under Bangladesh conditions. However, high temperature before and after the short winter season inhabits the flower and fruit development, use of plant growth regulators viz. gibberellin and auxin has been reported to be very effective to overcome the problems of flower and fruit development in tomato (Adlakha and Verma, 1964; Groot *et al*.,1987).

Boron plays an important role directly and indirectly in improving the yield and quality of tomato in addition to checking various diseases and physiological disorders (Magalhaes *et al.*, 1980). Boron affects the quality of tomato fruit, particularly size and shape, color, smoothness, firmness, keeping quality and chemical composition. Demoranville and Deubert (1987) reported that fruit shape, yield and shelf life of tomato were also affected by boron nutrition. In order to improve the quality of tomato, there should have the technologies which will eventually fulfill the grower's as well as consumer's need. Studies on management practices, particularly on the management of boron would help increasing quality of tomato.

The increase in vegetative growth of tomato could be attribute to physiological role of boron and its involvement in the metabolism of protein, synthesis of pectin, maintaining the correct water relation within the plant, resynthesis of adenosine triphosphate (ATP) and translocation of sugar at development of the flowering and fruiting stages (Bose and Tripathi, 1996). Boron has different functions in plant. It plays a vital role in the physiological processes of plants such as maturation, cell elongation and cell division, carbohydrate, protein and nucleic acid metabolisms, cytokinin synthesis, auxin and phenol metabolisms (Lewis, 1980). Adequate B levels help to maintain leaf K levels in tomato during fruit development (Sperry, 1995). Blevins *et al*. (1993) reported that B has major influence on the plasma membrane of plant cells and ion transport and those B amendments increased K, Ca and Mg levels in soybean.

Boron also has effect on many functions of the plant such as hormone movement, active salt absorption, flowering and fruiting process, pollen germination, carbohydrates, nitrogen metabolism and water relations in the plants. Boron deficiency causes reduced root growth, brittle leaves and necrosis of shoot apex. Boron affects the cambium and phloem tissues of storage root or stem, apical meristems of leaves vascular cambia (Singh and Gangwar, 1991). The improvement in quality parameters of tomato fruit due to boron application could be the result of overall growth and development of the crop (Naresh, 2002).

GA_3 and boron are important factors to increase yield and to get early production and better quality fruit, and attempt was made to study effects of GA_3 and Boron on plant growth and yield of tomato with the following objectives-

- To find out the optimum level of GA_3 for growth and yield of tomato.
- To find out the optimum level of boron for growth and yield of tomato.
- To determine the suitable combination of GA_3 and boron for ensuring the maximum growth and higher yield of tomato.

CHAPTER II

REVIEW OF LITERATURE

Tomato is one of the most popular and widely grown vegetables of the world and also important vegetable crops in Bangladesh, which received much attention to the researcher throughout the world. Among various research works, investigations have been made in various parts of the world to determine the optimum dose of GA_3 and boron fertilizer that have marked effects on tomato production. An attempt has been made in this chapter to present relevant review of literature on the research works performed till to date in Bangladesh and other part of the world in relation to the effects of growth regulators GA_3 and boron on growth and yield of tomato.

2.1 Effect of GA_3 on the growth and yield of tomato

Akash *et al*. (2014) conducted a 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.

Desai *et al*. (2012) conducted an experiment to find out the effect of different plant growth regulators and micronutrient on fruit characters and yield of tomato cv. GUJARAT TOMATO-3 (GT-3) at Horticulture Farm, Junagadh Agricultural University, Junagadh, Gujarat, India during 10 December, 2010 to 10 April, 2011. Eleven different treatments consisted of four plant growth regulators and three micronutrients were used, *viz.*, T_1= gibberellic acid @ 50 ppm, T_2= gibberellic acid @ 75 ppm, T_3= naphthalene acetic acid @ 50 ppm, T_4= naphthalene acetic acid @ 75 ppm, T_5= boron 50 ppm, T_6= boron 75 ppm, T_7= zinc 0.5per cent, T_8= zinc 1per cent, T_9=iron 100 ppm, T_{10}= iron 150 ppm and T_{11}= Control (No application of plant growth regulator and micronutrients) in the study. The fruit characters and yield parameters in plant significantly differed due to different plant growth regulators and micronutrient on tomato. The maximum fruit length (7.57 cm), girth (6.47 cm) and pulp-seed ratio (12.93)was found in T_2= gibberellic acid @ 75 ppm, whereas fruit weight (57 g), yield plant-1 (2.47 kg) and yield hectare-1 (913.258 q/ha) were found in treatment T_4= naphthalene acetic acid @ 75 ppm and the minimum for all the parameters were found in control treatment.

Khan *et al*. (2006) conducted an experiment to study the effect of 4 level of gibberellic acid spray on the growth, leaf NPK content, yield and quality parameters of 2tomato cultivars (*Lycopersicon esculentum* Mill.) , 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 effect of gibberellic acid, NAA, 4-CPA and boron at 25 or 50ppm on the growth and yield of tomato (cv. Dhanshree) during the summer season of 2003. Plant height was greatest with gibberellic acid at 25 or 50ppm (74.21cm and 75. 33 cm, respectively) and 4-CPA at 50ppm (72.22 cm). The number of primary branches per plant did not among the treatments. Gibberellic acid at 50ppm resulted in the lowest number of primary branches per plant.

Rai *et al*. (2006) conducted an experiment during the 2003 winter season in Meghalaya, India on tomato cv. Manileima of to study the effect 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.

Kataoka *et al*. (2003) 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_3) and uniconazole in the regulation of fruit growth, flower clusters were treated with uniconazole (5mg/L) and GA_3(5or 50 mg/L).They reported that no notable gibberellin's activity was detected in treated fruits at 3 days to 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.

El-Habbasha *et al*. (1999) studied the response of tomato plants to foliar spray with some growth regulator under late summer conditions. Field experiments were carried out with tomato (cv.Castelrock) over two growing seasons (1993-94) at shalakan, Egypt. The effect of GA_3, IAA, TPA (tolyphthalamic 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.

Gulnaz *et al*. (1999) reported that seeds of wheat treated with to 10ppm of GA_3 resulted in 36-43% increase in dry weight at 13.11dSm^{-1}.

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

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.

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

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

Gurdev and Saxsena (1991) observed that the growth regulators (GA_3 at 10^{-5} M) increased total dry matter of wheat. Application of 10^{-5} M GA_3 on mustard at 40 or 60 days after sowing significantly increased total dry matter (Khan *et al*. 1998).

Groot *et al*. (1987) reported that GA_3 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 1000ppm chlorflurenol,100ppm IAA, 50ppm NAA or 10ppm GA_3 or left untreated ,compared with controls, fruit setting was hastened by 4-5 days in all cultivars following treatment with 100ppm IAA or 10ppm GA_3.

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

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

Leonard *et al*. (1983) observed that inflorescence development in tomato plants (cv.King plus) grown under a low light regime was promoted by GA_3 applied directly on the inflorescence.

Onofeghara (1983) conducted an experiment on tomato sprayed with GA_3 at 20-1000 ppm and NAA at 25-50 ppm. He observed that GA_3 promoted flower primordia production and the number of primordia and NAA promoted flowering and fruiting.

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

Saleh and Abdul (1980) performed an experiment with GA_3 (25 or 50ppm) which was applied 3 times in June or early July. They reported that GA_3stimulated 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.

Mehta and Mathi (1975) reported that treatments with NAA at 0.1 or 0.2 ppm improved the yield of tomato irrespective of planting date. Maximum fruit set, early and total yield, fruit number and weight were obtained in response to 4-D at 5 ppm followed by NAA at 0.2 ppm. He also reported that GA_3 treatments at 10 or 25 ppm improved the yield of tomato cv. Pusa Ruby irrespective of planting date.GA_3 gave earlier setting and maturity.

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

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

Kaushik *et al*. (1974) carried out experiment with the application of GA_3 at 1, 10 or 100 mg/L on tomato plants at 2 leaf stages and at weekly interval until 5 leaf stages. They reported that GA_3 increased the number and weight of fruits per plant at higher concentration.

Choudhury and Faruque (1972) reported that the percentage of seedless fruit increased with an increase in GA_3 concentration from 50 ppm to 100 ppm and 120 ppm. However, the fruit weight was found to decrease by GA_3 effects.

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

Jansen (1970) reported that tomato plants treated with GA_3 neither increased the yield nor accelerated fruit ripening. He also mentioned that increasing concentration of GA3reduced both the number and size of fruits.

Bora and selman (1969) working with tomato demonstrated that four foliar sprays of GA_3 (0, 5, 50 or 500 ppm) applied at 7, 17, 22,27or 37^0 C increased the leaf area, weight and height of tomato plants. The best treatment was 5ppm GA_3 at 22^0C.

Adlakha and Verma (1965) observed that when the first four clusters of tomato plants were sprayed three times at unspecified intervals with GA_3 at 50 and 100 ppm, the fruit setting, fruit weight and total yield increased by 5,35 and 23% respectively with the higher concentration than the lower.

Adlakha and Verma (1964) sprayed of GA_3 in concentration of 50 and 100 ppm on flower cluster at anthesis and noted that the application of GA_3 at 100 ppm could appreciably increase fruit size, weight, protein sugar and ascorbic acid contents.

Gustafson (1960) worked with different concentration of GA_3 and observed that when35 and 70 ppm GA_3 were sprayed to the flowers and flower buds of the first three clusters, percentage of fruits set increased but there was a decrease in the total weight. When only the first cluster was sprayed, the number of fruit set and the total weight per cluster was increased, but this response did not occur in subsequent clusters.

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

2.2 Effect of boron on the growth and yield of tomato

Gurmani *et al*. (2012) designed a glasshouse pot experiment, with two tomato cultivars VCT-1 and Riogrande, to assess the effects of four levels of soil application of B (0, 0.5, 1.0 and 1.5 mg kg^{-1}) in the form of borax on plant growth, biochemical content, antioxidant activity and fruit yield. Higher plant growth and fruit yield in both cultivars were achieved by the B 1.0 and 1.5 mg kg^{-1} soil application respectively. Application of 0.5 mg B kg-1 had lower dry matter production as well as fruit yield when compared with B 1.0 and 1.5 mg kg^{-1}. The percent increase of fruit yield at 0.5 mg B kg-1 was 12 and 10, in VCT-1 and Riogrande respectively. In the same cultivars, B application @ 1.0 mg B kg^{-1} caused the fruit yield by 23 and 21% while 1.5 mg B kg^{-1} enhanced by 22 and 20% respectively. Boron concentration in leaf, fruit and root increased with the increasing level of B. Boron application at 1.0 and 1.5 mg kg^{-1} significantly increased chlorophyll, sugar and protein content in both cultivars. Superoxide dismutase and catalase activity was significantly increased by the soil application of 1.5 mg B kg^{-1} in both cultivars of tomato. The study results showed that soil application of 1.0 mg B kg^{-1} soil have positive effect on plant growth, yield and biochemical.

Luis *et al.* (2012) conducted a study to evaluate the effect of boron on two variety of tomato. The objective of this research was to study the how B toxicity (0.5 and 2 m MB) 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 m MB, 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 (O2 and anthocyanins 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 ($r>0.8$). Their results indicate that these parameters could be used to evaluate the stress level as well as to develop models that could help to prevent the damage inflicted by B toxicity in tomato plants.

Sakamoto (2012) conducted a study to demonstrate the only role of B in plants as the structural maintenance of cell wall. The author stated that soil B, as boric acid, is acquired through roots and then distributed around the plant via the passive and active transport pathway. To adapt variations in the environmental B status, the active B transport system is tightly regulated at the molecular level in plants. In agriculture, both deficient and excess levels of soil B impair plant growth, resulting in the reduction of quantity and quality of crops. The major causes of B toxicity in plants contain oxidative stress, metabolism alteration and deoxyribonucleic acid damage.

Ejaz *et al.* (2011) conducted a study to investigate the efficacy of micronutrient of foliar application on tomato. The present research project was executed during 2008–2009, to evaluate the effect of Zn, B (micronutrients) in combination with N (macro-nutrient) for the tomato grown under high tunnel. Macro/micro-nutrients solutions were provided by 4B Group of Fertilizers, Pakistan. The experiment was arranged in Completely Randomized Design (CRD) with five treatments and four replications. Foliar application of individual nutrients such as N (2%), B (5%) and Zn (6%) were used along with their combined mixture. In addition, a control treatment was also run as check. After the statistical analysis it was found that individual application of nutrient provide better results as compared to control but their combined effect (Zn = 6%, B = 5%, N = 2%) provided substantial results in plant heights, no. of leaves, no of flowers, no of fruits, average fruit weight and yield per plant. It is confirmed from the results that combination of macro-nutrients and micro-nutrients as foliar application has the ability to enhance the growth and yield of tomato positively.

Farzaneh *et al.* (2011) conducted a completely randomized factorial experiment with 16 treatments and three replicates to study the effect of nitrogen and boron on yield, shoot and root dry weights and leaf concentration of nutrient elements in hydroponically grown tomato in greenhouse of Agricultural College of Zanjan University in 2000. In this experiment, tomato seed of Rio Grande Ug was selected and simple and interaction effect of four levels of N (100, 200, 300 and 400 mg/L) and four levels of B (0.5, 1.0, 1.5 and 2.0 mg/L) on tomato yield, shoot and root dry weights and leaf concentration of nutrient elements was investigated. The results indicated that the simple and interaction effect of nitrogen and boron on yield and tomato shoot and root dry weights were significant. Te highest yield and root dry weights were obtained in N200B1.0 treatment and the highest shoot dry weight was obtained in N300B1.0 treatment. By increasing the nitrogen level in the nutrient solution, leaf N and Mn concentration increased while B, Fe and Zn concentration of leaves decreased significantly. In contrast, by increasing the boron levels, leaf N, B and Zn concentration increased and Fe and Mn concentration of leaves decreased significantly. With respect to the results of this study, applications of 200 mg/L N and 1.0 mg/L B of nutrient solution are recommended to obtain higher yield and better quality for tomato in hydroponic culture.

Nada *et al*. (2010) conducted a study to clarify a critical concentration of excess boron (B) in nutrient solution for hydroponically cultured tomato. The study also investigated the influences of excess B on growth, photosynthesis and fruit maturity. In tomato topped at the first truss, B concentrations higher than 2 ppm in nutrient solution resulted in a significant increase in leaf B concentration. At the fruit developmental stage, fresh weights of leaf and fruit were suppressed at 8 ppm and 4 ppm B in nutrient solution, respectively. Photosynthetic rate, respiration rate and stomatal conductance decreased with excess B at 4 ppm or higher concentration from the first truss flowering stage to fruit developmental stage. When tomato was topped at the second truss and limited to two fruits in each truss, excess B did not affect fruit growth or maturation in the first truss. However, fruit size and Brix were reduced in the second truss. These may be caused by decrease in the photosynthate distribution to fruit in the second truss because of the decrease in photosynthetic activity. Furthermore, excess B could promote fruit maturity in the second truss because of production of ethylene with increase in injured leaves. Based on these results, the authors suggest that the critical concentration of B in nutrient solution is 4 ppm for long-term hydroponic cultivation of tomatoes.

Salam *et al.* (2010) conducted a study at the Vegetable Research Farm of the Horticulture Research Centre, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur to investigate the effects of boron and zinc in presence of different levels of NPK fertilizers on quality of tomato. There were twelve treatment combinations which comprised four levels of boron and zinc viz., i) B_0Zn_0= 0 kg B + 0 kg Zn/ha, ii) $B_{1.5}Zn_{2.0}$= 1.5 kg B + 2.0 kg Zn/ha, iii) $B_{2.0}Zn_{4.0}$ = 2.0 kg B + 4.0 kg Zn/ha , iv) $B_{2.5}Zn_{6.0}$=2.5 kg B + 6.0 kg Zn/ha and three levels of NPK fertilizers viz., i) 50% less than the recommended NPK fertilizer dose (50% <RD), ii) Recommended NPK fertilizer dose (RD), iii) 50% more than the recommended NPK fertilizer dose (50% >RD). The highest pulp weight (88.14%), dry matter content (5.34%), TSS (4.50%), acidity (0.47%), ascorbic acid (10.95 mg/100g), lycopene content (112.00 μg/100g), chlorophyll-a (41.00μg/100g), chlorophyll-b (56.00

μg/100g), marketable fruits at 30 days after storage (67.48%) and shelf life (16 days) were recorded with the combination of 2.5 kg B+ 6 kg Zn/ha and recommended dose of NPK fertilizers.

Hossein (2008) conducted a field experiment at Horticultural farm, BAU, Mymensingh during 2007-2008 to evaluate the effect of Zn and B on the growth and yield of Tomato. The treatments were four levels of Zn (0, 0.5, 1.0 and 1.8 kg ha^{-1}) and four levels of B (0, 0.1, 0.3 and 0.6 kg ha^{-1}). The highest fruit yield (74.88 t ha^{-1}) was obtained due to the application of 1.8 kg Zn and 0.1kg B ha^{-1}.

Jyolsna and Mathew (2008) conducted a pot culture experiment to study the effects of 0, 0.5, 1.0, and 1.5 kg B ha^{-1} with recommended doses of chemical fertilizers (75:40:25 N, P_2O_5 and K_2O kg ha^{-1}; RDF) and RDF + farmyard manure (FYM; 25 tons ha^{-1}) on growth, yield, and quality of tomato as well as the B status of a lateritic soil in southern Kerala. Boron significantly increased plant height and number of primary branches. It also reduced the days to flowering and increased fruit set (12.5 to 20% more at the highest level) both with and without FYM. Benefit–cost ratio was 40% greater for the highest level of B when applied in conjunction with RDF compared with RDF alone (no B). Quality parameters like reducing sugars, total sugars, vitamin C, and lycopene concentrations also improved following B application. Nevertheless, B availability in these soils attained sufficiency levels (2 mg kg^{-1}) at 0.5 kg ha^{-1} of applied B, implying the need to exercise caution especially when applying higher doses.

Kamruzzaman (2007) conducted a field experiment on tomato at the field laboratory of Crop Botany Department, BAU, Mymensingh during 2006-07. The experiment comprised of four levels of boron viz. @ 0, 0.4, 0.6 and 0.8 kg B ha^{-1} as foliar application. Application of standard dose of boron Ca. 0.4 kg B ha^{-1} was found to produce highest fruit yield (2166.6 kg ha^{-1}).

Sathya (2006) conducted an experiment to evaluate the various levels of B on yield of PKM1 tomato. The results revealed that the highest fruit yield of 33 t ha^{-1} was recorded in treatment that received borax @ 20 kg ha^{-1} and was found to be significantly superior to rest of the treatments (0, 5, 10, 15 and 25 kg ha^{-1}). The yield increase was about 33.6 per cent over control.

Shah (2006) conducted a field experiment at the Horticulture farm, BAU, Mymensingh during the rabi season, 2005-06. There were 5 levels of NPKS and B fertilizers *viz*. i) N (0, 190, 253 and 317 kg ha^{-1}); ii) P (0, 66, 88 and 110 kg ha^{-1}); iii) K (0, 94, 125 and 154 kg ha^{-1}); iv) S (0, 15, 20 and 25 kg ha^{-1}) and v) B (0, 1.5, 2 and 2.5 kg ha^{-1}) in the 17 selected treatments. The different combinations of NPKS and B exhibited significant variation in respect of all the characters. The maximum number of flowers and matured fruits per plant were obtained from the treatment (N253P88K125S20B2 kg ha-1). Importantly the plants fertilized with the same treatment gave the maximum fruit yield (62.69 ton ha^{-1}).

Yadav *et al.* (2006) evaluated the effects of boron (0.0, 0.10, 0.15, 0.02, 0.25, 0.30 or 0.35%), applied to foliage after transplanting, on the yield of tomato cv. DVRT-1 in Allahabad, Uttar Pradesh, India, during 2003-04. The highest number of fruits per plant (44.0), number of fruits per plot (704.0), yield per plant (0.79kg), yield per plot (12.78kg) and yield ha-1 (319.50

quintal) were obtained with 0.20% boron, whereas the greatest fruit weight (27.27g) was recorded for 0.10% boron.

Bhatt and Srivastava (2005) investigated the effects of the foliar applications of boron (boric acid), zinc (zinc sulfate), molybdenum (ammonium molybdate), copper (copper sulfate), iron (ferrous sulfate), manganese (sulfate), mixture of these nutrients, and Multiplex (a commercial micronutrient formulation) on the nutrient uptake and yield of tomato (Pusa hybrid-1) in Pantnagar, Uttaranchal, India, during the summer of 2002 and 2003. Zinc, iron, copper, boron and manganese were applied at 1000 ppm each, whereas molybdenum was applied at 50 ppm. Foliar spraying was conducted at 40, 50 and 60 days after transplanting. All treatments significantly enhanced dry matter yield, fruit yield and nutrient uptake over the control. The mixture of the micronutrients was superior in terms of dry matter yield of shoot (53.25 g ha^{-1}); dry matter content of shoot (27.25%); nitrogen (152.38 kg ha^{-1}), phosphorus (47.49 kg ha^{-1}), potassium (157.48 kg ha^{-1}), sulfur (64.87 kg ha^{-1}), zinc (123.70 g ha^{-1}), iron (940.36 g ha^{-1}), copper (72.70 g ha^{-1}), manganese (359.17 g ha^{-1}) and boron (206.58 g ha^{-1}) uptake by shoots; total fruit yield (266.60 kg ha^{-1}); dry matter yield of fruit (1698 kg ha^{-1}); manganese (34.08 g ha^{-1}) and boron (95.23 g ha^{-1}) uptake by fruits.

The effect of micronutrient boron application on dry matter yield, uptake and distribution in the plant parts of two tomato verities (Roma VF and Dandino) were studied by Oyinlola (2004) in a rainfed trial. Results showed variations in boron distribution among plant parts. The concentration of boron (B) ranged from 6.0-109.0, 5.8-18.3 and 3.1-13.6mg/kg, in leaves, stem and roots, respectively. The effect of boron rates on the DMY, B concentration and uptake was highly significant (P 0.010) on the leaves and stem, but not on the roots. The concentration of boron (B) in both varieties was more in the leaves, than in the stem. The roots had the least B concentration. Among the varieties “Dandino” recorded higher B concentration in the various plant parts than RomaVF.Application of B increased fruit yield of tomato fruit by 233 and 192% relative to the control for “Roma VF” and “Dandino” varieties, respectively.

Oyinlola and Chude (2004) studied the effects of 0, I, 2, 3, 4 and 5 kg B/ha on the yield and biochemical properties of tomato cultivars Roma VF and Dandino. Matured ripe fruits were analyzed for biochemical properties such as ascorbic acid, reducing sugar and total soluble solid content and titratable acidity. Boron rates significantly ($P<0.01$) increased the yield and yield attributes of the crop such as number of fruits and average weight of fruits, as well improved the biochemical properties of the fruits. In both years, the yield attributes of the crop such as number of fruits and average weight of fruits, as well improved the biochemical properties of the fruits. In both years, the highest fruit yield and best fruit quality were obtained at 2 kg B/ha. Fruit yield increased by 121 and 72% relative to the control in 1992/93 and 1993/94, respectively. Cultivar Dandino recorded higher ascorbic acid, total soluble solids, titratable acidity, reducing sugars and yield compared to cv. Roma VF, whereas cv. Roma VF flowered earlier than Dandino. Fruit yield correlated with all the yield attributes and biochemical properties determined for both years.

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

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

Naresh (2002) conducted an experiment to find out the response of foliar application of boron on vegetative growth, fruit yield and quality of tomato. Significant improvement in yield attributes of the experimental tomato crop due to boron application ultimately might have resulted in increased fruit yield of the crop. Significant and positive correlation between fruit yield and number of fruit per plant (0. 961 and 0.969) as well as average fruit weight (0.985 g and 0.980) also subscribe the aforesaid contention. The improvement in quality parameters of tomato fruit due to boron application could be the result of overall growth and development of the crop.

A greenhouse study was conducted by Alpaslan and Gunes (2001) to determine interactive affects of NaCl salinity and B on the growth, sodium (Na) chloride (Cl) boron (B) potassium (K) concentration and membrane permeability of salt resistant tomato (*Lycopersicon esculentum* cv. Lale F_1). Plants were grown in a factorial combination of NaCl (0 and 30 mM for cucumber and 0 and 40 mM for tomato) and B (0, 5, 10 and 20 mg/kg soil). Boron toxicity symptoms appeared at 5mg/kg treatments in both plants. Salinity caused an increased in leaf injury due to B toxicity, but it was more severe in cucumber. Dry weights of the plants decreased with the increasing levels of applied B in non saline conditions, but the decrease in dry weights due to B toxicity was more pronounced in saline condition especially in cucumber.

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

Chude and Oyinloda (2001) concluded that plant responses to soil and applied boron vary widely among species and among genotypes within a species. This assertion was verified by comparing the differential responses of Roma VF and Dandino tomato cultivars to a range of boron levels in field trials at Kadawa (11 degrees 39' N, 8 degrees 2' E) and Samaru (11 degrees 12', 7 degrees 3 7` E) in Sudan and northern Guinea savanna, respectively, in Nigeria. Boron levels were 0, 0.5, 1.0, 1.50, 2.0 and 2.5 kg/ha replicated three times in a randomized complete block design. Treatment effects were evaluated on fruit yield and nutritional qualities of the two tomato cultivars at harvest. There was a highly significant (P=0.01) interaction between B rates and cultivars, with Dandino producing higher yields than Roma VF in both years and locations. Total soluble solids, titratable acidity and reducing sugar contents of the two cultivars differed significantly (P=0.05). Dandino contained higher amounts of these indexes than Roma VF. This cultivars seems to be more B efficient than Roma VF even at low external B level.

Yadav *et al.* (2001) designed a study during 1990 and 1991, in Hisar, Haryana, India, to evaluate the effect of different concentrations of zinc and boron on the vegetative growth, flowering and fruiting of tomato. The treatments comprised five levels of zinc (0, 2.5, 5.0, 7.5 and 10.0 ppm) and four levels of boron (0, 0.50, 0.75 and 1.0 ppm) as soil application, as well as 0.5% zinc and 0.3% boron as foliar application. The highest fruit length, fruit breadth and fruit number were obtained with the application of 7.5 ppm zinc and 1.0 ppm boron.

Bose and Tripathi (1996) carried out an experiment to find the physiological role of boron and its involvement in the metabolism of proteins and found that the increase in vegetative growth of tomato could be attributed to physiological role of boron and its involvement in the metabolism of proteins, synthesis of pectin, maintaining the correct water relation within the plant, resynthesis of adenosine triphosphate (ATP) and translocation of sugar at development of the flowering and fruiting stages. Boron also plays an important role in flowering and fruit formation.

Singh and Gangwar (1991) carried out an experiment to find out the boron effect on tomato plants and found that boron had effects on many functions of the plant, such as hormone movement, active salt absorption, flowering and fruiting process, pollen germination, carbohydrates, nitrogen metabolism and water relations in the plants. Boron deficiency occurs in vegetable crops having high boron requirements when grown on alkaline soils with free lime and on sandy soils with low organic matter content. Boron deficiency causes reduced root growth, brittle leaves and necrosis of shoot apex. Cracking of surface of tomato fruit results in large losses.

CHAPTER III

MATERIALS AND METHODS

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

3.1 Experimental site

The field experiment was conducted in the Horticulture farm of Sher-e-Bangla Agricultural University, Dhaka-1207. The location of the experimental site was at 23.75^0N latitude and 90.34^0E longitudes with an elevation of 8.45 meter from the sea level.

3.2 Experimental period

The experiment was carried out during the Rabi season from October 2014 to March 2015. Seeds was sown on 25 October, 2014, seedling transplanting was done on 01 December, 2014 and harvested upto 15 March, 2015.

3.3 Soil type

The experimental site was situated in the subtropical zone. The Soil of the experimental site lies in Agro-Ecological Zone of "Madhupur Tract" (AEZ-28). Its top soil is clay loam in texture and olive grey with common fine to medium distinct dark yellowish brown mottles. The pH 5.8-6.5, ECE 25.28 and organic carbon contents is 0.82.

3.4 Weather

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

3.5 Materials used for experiment

The tomato variety BARI Tomato-14 was used in the experiment. It was a high yielding, heat tolerant and indeterminate type variety. Seed was collected from Bangladesh Agricultural Research Institute, Joydebpur, Gazipur.

3.6 Raising of seedling

Tomato seedlings were raised in two seed beds of 3 m x l m and size. The soil was well prepared and converted into loose friable condition in obtaining good tilth. All weeds, stubble, sand, dead roots were removed. Twenty grams of seed were sown in each seed bed. The seeds were sown in seed bed on 25 October 2014. Seed were then covered with finished light soil and shading was provided by bamboo mat (chatai) to protect young seedlings from scorching sunshine and rainfall. Light watering weeding and mulching were done as and when necessary to provide seedlings with good condition for growth.

3.7 Experimental treatments

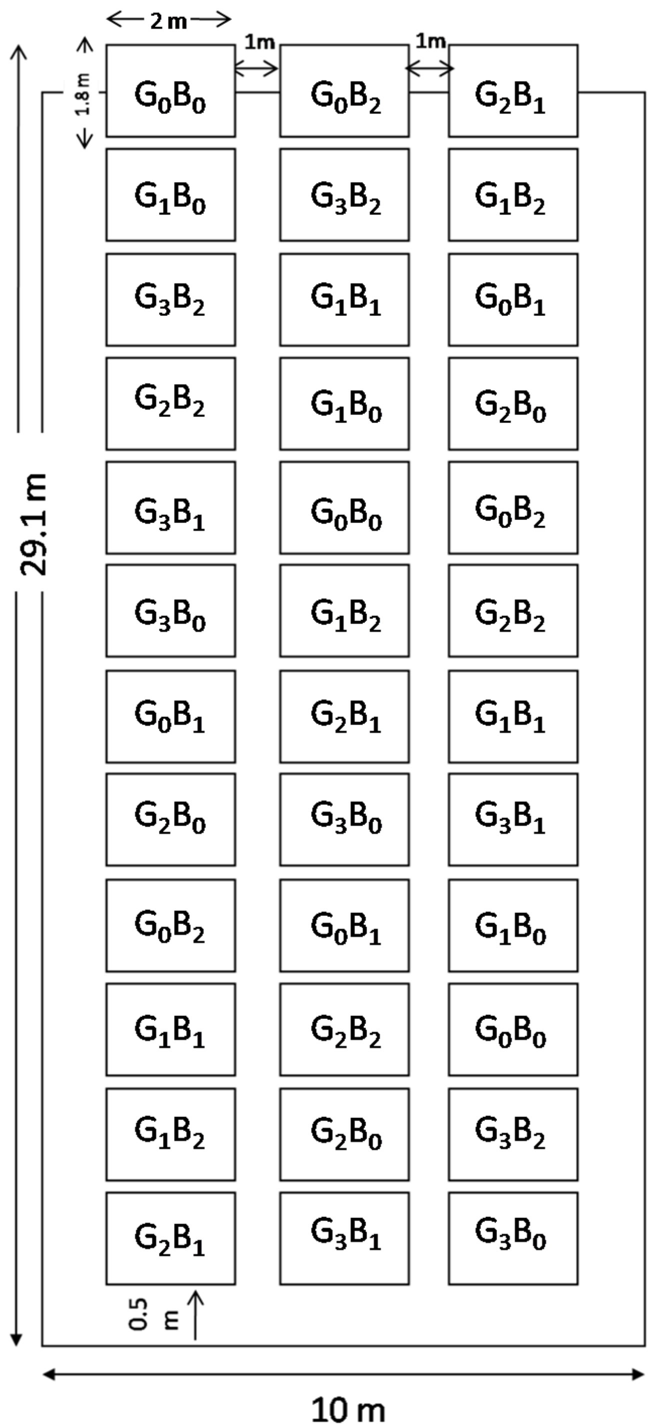
The two factor experiment consisted of four levels of GA_3 (Factor A) and three levels of boron (Factor B). The factors were as follows:

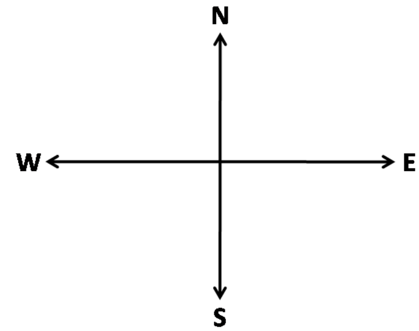
Factor A: Level of GA_3	**Factor B: Level of boron**
G_0= 0ppm	B_0= 0 kg/ ha
G_1= 70ppm	B_1= 10 kg/h
G_2= 90ppm	B_2= 15 kg/ha
G_3= 110ppm	

There were all together 12 treatments combination used in each block were: G_0B_0, G_0B_1, G_0B_2, G_1B_0, G_1B_1, G_1B_2, G_2B_0, G_2B_1, G_2B_2, G_3B_0, G_3B_1, G_3B_2

3.8 Experimental Design and layout

Field layout was done after final land preparation. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The whole plot was divided into three blocks each containing twelve 12 plot of 2 m x1.8 m size, giving 36 unit plots. The space was kept 1m between replications. Row to row and plant to plant distance were 60 cm and 50cm, respectively. The layout of the experiment is shown in Figure 1.





Plot size: 2m × 1.8 m
Plot spacing: 50 cm
Spacing Between replication : 1.0m
Plant spacing: 60 × 50 cm

Factor A: Gibberellic acid (GA_3)
G_0= 0ppm G_1= 70ppm G_2= 90ppm G_3= 110ppm

Factor B: Boron (B)
B_0= 0 kg/ ha B_1= 10 kg/ ha B_2= 15 kg/ ha

Figure 1: Experimental layout

3.9 Plot preparation/land preparation

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

3.10 Application of manure and fertilizers

Well-rotten cow dung @ 15 ton/ha was applied properly during final land preparation. The sources of N, P_2O_5, K_2O as urea, TSP, MOP were applied, respectively throughout this experiment. The entire amount of TSP was applied during the final land preparation. Urea was applied in three equal installments at 10, 25 and 40 days after seedling transplanting. On the other hand, 38.46% MOP was applied as basal dose and rest of the MOP was applied in two equal installments at 25 and 40 days after transplanting. As a treatment 50% boron fertilizer was applied during the final land preparation and rest of the boron was applied in three equal installments at 30, 45 and 60 days after transplanting. The fertilizer were applied on both sides of plants rows and mixed well with the soil.

Table 1: Fertilizer and manure applied for the experimental field preparation. Manure and fertilizer were used as recommended by Krishi Projukti Hatboi, BARI (2014)

Manure/ fertilizers	**Rate/ha**	**Application (%)**						
		Basal	10 DAT	25 DAT	35 DAT	40 DAT	45 DAT	60 DAT
Cow dung	10 ton	100	-	-	-	-	-	-
Urea	450 kg	-	33.33	33.33	-	33.33	-	-
TSP	250 kg	100	-	-	-	-	-	-
MOP	260 kg	38.46	-	30.77	-	30.77	-	-
Boron	(As treatment)	50	-	-	16.66	-	16.66	16.66

3.11 Preparation and application of GA_3

The stock solution of 1000 ppm of GA_3 with small amount of ethanol to dilute and then mixed in 1 litre of water turn as per requirement of 70 ppm, 90 ppm, 110 ppm solution of GA_3.70 , 90 and 110 ml of stock solution were mixed with 1 litre of water. Application of GA_3 at 15 days interval was done at 25, 40, and 55days after transplanting.

3.12 Transplanting of seedlings

Healthy and uniform 35 days old seedlings were uprooted separately from the seedbed and were transplanted in the experimental plots in the afternoon of 01 December, 2014 maintaining a spacing of 60cm x 50cm between the rows and plants respectively. This allowed an accommodation of 15 plants in each plot. The seedbed was watered before uprooting the seedlings from the seedbed so as to minimize damage of the roots. The seedlings were watered after transplanting. Shading was provided using banana leaf sheath for three days to protect the seedlings from the hot sun and remove after seedlings were established. Seedlings were also planted around the border area of the experimental plots for gap filling.

3.13 Gap filling

Gap filling was done as and when needed.

3.14 Intercultural operation

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

3.14.1 Irrigation and drainage

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

3.14.2 Staking

When the plants were well established, Staking was given to each plant by bamboo sticks to keep them erect. Within a few days of staking as plants grew up, the plants were pruned as per the treatments.

3.14.3 Weeding

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

3.14.4 Earthening up

Earthening up operation was done immediately after top-dressing with nitrogen fertilizer.

3.14.5 Control of pest and disease

Malathion 57EC was applied @ 2ml/l against the insect pest like cutworm, leaf hopper, fruit borer and others. The insecticide application was made fortnightly for a week before first harvesting. Furadan 10 G was also applied during final land preparation as soil insecticide. During foggy weather precautionary measured against disease infection of tomato was taken by spraying Dithane M-45 fortnightly @ 2g/l, at the early vegetative stage. Ridomil Gold MZ was also applied @ 2g/l against blight disease of tomato.

3.15 Harvesting

Fruit were harvested at 3 day intervals during early ripe stage when they attained slightly red color. Harvesting was started from 10 March, 2015 and was continued up to 30 March, 2015.

3.16 Collection of data

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

3.16.1 Plant height

Plant height was measured from the sample plants in centimeter from the ground level to the tip of the longest stem and means value was calculated. Plant height was recorded at 20, 35, 50, 65 days after planting to observe the growth rate.

3.16.2 Number of leaves per plant

Number of leaves was measured from the sample plants in centimeter from the ground level to the tip of the longest stem and means value was calculated. Number of leaves was recorded 20, 35, 50, 65 days after planting to observe the growth rate.

3.16.3 Number of branches per plant

Number of branches was measured from the sample plants in centimeter from the ground level to the tip of the longest stem and means value was calculated. Number of branches was recorded 20, 35, 50, 65 days after planting to observe the growth rate.

3.16.4 Number of flower clusters per plant

The number of flower clusters was counted from the sample plants periodically at 50 and 65 DAT, and the average number of flower clusters produced per plant was calculated.

3.16.5 Number of flowers per cluster

The number of flowers per cluster was taken from sample plants at 50 and 65 DAT, and was calculated as follow:

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

3.16.6 Number of flowers per plant

The total number of flower was counted from the sample plants periodically at 50 and 65 DAT, and the average number of flower produced per plant was calculated.

3.16.7 Number of fruit clusters per plant

The number of fruit cluster was recorded from the five sample plants at 65 and 80 DAT, and the average number of fruit clusters produced per plant was recorded.

3.16.8 Number of fruits per cluster

The number of fruits per cluster was taken from sample plants at 65 and 80 DAT, was calculated as follow:

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

3.16.9 Number of fruits per plant

The total number of fruit was recorded from the five sample plants at 50, 65 and 80 DAT, and the average number of fruit produced per plant was recorded.

3.16.10 Weight of individual fruit (g)

Among the total number of fruit during the period from first to final harvest the fruits, expect the first and final harvest, was considered for determining the individual fruit weight by the following formula:

$$\text{Weight of individual fruit} = \frac{\text{Total weight of fruits}}{\text{Total number of fruit}}$$

3.16.11 Fruit Diameter

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

3.16.12 % Dry matter content in leaves

After harvesting, randomly selected 100g plant leaf sample previously sliced into very thin pieces were put into envelop and placed in oven maintained at 60^{o} C for72 hours. The sample was then transferred into desiccators and allowed to cool down at room temperature. The final weight of the sample was taken. The dry matter contents of leaf were computed by following formula:

$$\%\ \text{Dry matter content in leaf} = \frac{\text{Dry weight of leaf (g)}}{\text{Fresh weight of leaf (g)}} \times 100$$

3.16.13 % Dry matter content in fruit

After harvesting, randomly selected 100g plant fruit sample previously sliced into very thin pieces were put into envelop and placed in oven maintained at 60^{o} C for 72 hours. The sample was then transferred into desiccators and allowed to cool down at room temperature. The final weight of the sample was taken. The dry matter contents of fruit were computed by simple calculation from the weight recorded by the following formula:

$$\%\ \text{Dry matter content in fruit} = \frac{\text{Dry weight of fruit (g)}}{\text{Fresh weight of fruit (g)}} \times 100$$

3.16.14 Fruit yield per plant

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

3.16.15 Fruit yield per plot

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

3.16.16 Fruit yield per hectare

It was measured by the following formula:

$$\text{Fruit yield per hectare (ton)} = \frac{\text{Fruit yield per plot kg x10000 m}^2}{\text{Area of plot in square meter (m2) x 1000 kg}}$$

3.17 Statistical Analysis of Data

The data obtained for different characteristics in respect of growth, yield contributing characters of tomato and yield were statistically analyzed to find out the statistical significance. The means for all the treatments were calculated and the analysis of variance for all the characters was performed by “F” (variance ratio) test. The significance of the difference among the means was evaluated by Duncan’s Multiple Range Test (DMRT) according to Gomez and Gomez (1984) for interpretation of the result at 5% level of probability.

3.18 Economic Analysis

The cost of production was analyzed in order to find out the most economic treatment of GA_3 and boron. All input cost included the cost for lease of land and interest on running capital in computing the cost of production. The interest was calculated @ 13% in simple interest rate. The market price of tomato was considered for estimating the cost and return. Analyses were done according to the procedure determining by Alam *et al*. (1989). The benefit cost ratio (BCR) was calculated as follows:

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

CHAPTER IV

RESULTS AND DISCUSSION

The chapter comprises the presentation and discussion of the results obtained from the effect of GA_3 and boron on the growth and yield of tomato. The effects due to different levels of GA_3 and boron and their interaction on the growth, yield contributing attributes and yield have been presented in Tables 2 to 14 and Figures 2 to 4. The results of each parameter studied in the experiment have been presented and discussed under the following headings.

4.1 Plant height

Plant height of tomato varied significantly due to the application of different concentrations of GA_3 at 20, 35, 50 and 65 DAT (Appendix II). At 20 DAT, the longest plant (21.42 cm) was observed in G_2 (90ppm GA_3) which was statistically similar to G_1 (20.02 cm) and G_3 (19.91 cm) whereas the shortest plant (18.98 cm) was found in G_0 (0ppm GA_3). The longest plant (48.69 cm) was recorded from G_1 while the shortest plant (41.93 cm) was recorded from G_0 at 35 DAT. At 50 DAT, the longest plant (79.73 cm) was also recorded from G_1 and the shortest plant (73.76 cm) was found in G_0. At 65 DAT, the longest plant (117.3 cm) was found from G_1 and the shortest plant (108.3 cm) was recorded from G_0 (Table 2). Roy and Nasiruddin (2011) found highest plant height @ 75 ppm GA_3 application in cabbage. GA_3 induce cell division, cell elongation, cell enlargement and ultimately leads to better growth of plants. Chaudhary (2004), Shittu and Adeleke (1999) and Sanyal *et al.* (1995) reported similar results in their experiment.

Plant height of tomato varied significantly due to the application of different levels of boron at 35, 50 and 65 DAT except 20 DAT (Appendix II). At 20 DAT, the highest plant height (20.67 cm) was observed in B_1 (10 kg boron ha^{-1}) and control treatment (B_0) gave the shortest plant (19.50 cm). The longest plant (48.87 cm) was recorded from B_1 while the shortest plant (42.08 cm) was recorded from B_0 at 35 DAT. AT 50 DAT, the highest plant height (82.13 cm) was also observed in B_1 and the lowest plant height (72.42 cm) was observed in B_0. At 65 DAT, the longest (123.0 cm) and the shortest (109.2 cm) plant were recorded from B_1 and B_0 respectively (Table 2). Sakamoto (2012) illustrated that in agriculture, both deficient and excess levels of soil boron impair plant growth, resulting in the reduction of quantity and quality of crops. Deficiency of boron in tomato and several other crops is responsible for stunted growth (Gupta and Cutcliffe, 1985; Nelson *et al*., 1977).

Due to combined effect of GA_3 and boron showed statistically significant variation on plant height at 20, 35, 50 and 65 DAT (Appendix II). At 20 DAT, the longest plant (21.93 cm) was obtained from G_2B_1 (90ppm GA_3 with 10 kg boron ha^{-1}) while the shortest plant (18.00 cm) was obtained from G_3B_0 (110ppm GA_3 with 0 kg boron ha^{-1}). At 35 DAT, the highest plant height (55.20 cm) was observed in G_1B_1 which was statistically identical to G_1B_2 (50.07 cm) and the lowest plant height (39.53 cm) was observed in G_0B_0. The longest plant (90.40 cm) was recorded from G_1B_1 while the shortest plant (61.80 cm) was recorded from G_0B_0 at 50 DAT. At 65 DAT, the longest plant (139.9 cm) was recorded from G_1B_1 whereas the shortest plant (98.55 cm) was recorded from G_0B_0 (Table 3).

Table 2: The effect of different levels of GA_3 and boron on the plant height (cm) of tomato at different days after transplanting

Treatments	**Plant height (cm)**			
	20 DAT	**35 DAT**	**50 DAT**	**65 DAT**
GA_3				
G_0	18.98 b	41.93 b	73.76	108.3 b
G_1	20.02 ab	48.69 a	79.73 a	117.3 a
G_2	21.42 a	45.16 b	76.13 ab	116.7 ab
G_3	19.91 ab	43.80 b	74.87 ab	116.5 ab
LSD (0.05)	1.809	1.182	5.494	8.245
Boron				
B_0	19.50 a	42.08 b	72.42 b	109.2 b
B_1	20.67 a	48.87 a	82.13 a	123.0 a
B_2	20.08 a	43.73 b	73.82 b	111.9 b
LSD (0.05)	1.567	3.003	4.758	7.141
% CV	9.21	7.90	7.38	7.35

G_0 = 0 ppm GA_3 B_0 = 0 kg B ha^{-1}
G_1 = 70 ppm GA_3 B_1 = 10 kg B ha^{-1}
G_2 = 90 ppm GA_3 B_2 = 15 kg B ha^{-1}
G_3 = 11 0ppm GA_3

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

Table 3: The combined effect of different levels of GA_3 and boron on the plant height (cm) of tomato at different days after transplanting

Treatments	Plant height (cm)			
	20 DAT	**35 DAT**	**50 DAT**	**65 DAT**
G_0B_0	18.33 ab	39.53 d	61.80 d	98.55 d
G_0B_1	20.80 ab	45.33 bcd	75.60 c	109.2 bc
G_0B_2	19.73 ab	43.27 cd	71.80 c	111.9 bc
G_1B_0	19.87 ab	46.53 bc	75.47 c	111.1 bc
G_1B_1	21.27 ab	55.20 a	90.40 a	139.9 a
G_1B_2	21.80 a	50.07 ab	86.87 ab	123.0 b
G_2B_0	20.53 ab	42.00 cd	76.73 bc	109.4 bc
G_2B_1	21.93 a	45.53 bcd	79.40 bc	111.1 bc
G_2B_2	20.13 ab	46.93 bc	74.07 c	113.3 bc
G_3B_0	18.00 b	41.47 cd	71.73 c	102.4 c
G_3B_1	20.20 ab	41.80 cd	77.20 bc	108.9 bc
G_3B_2	18.40 ab	41.07 cd	72.40 c	106.6 bc
LSD (0.05)	3.134	6.007	9.517	14.28
% CV	9.21	7.90	7.38	7.35

G_0 = 0 ppm GA_3 B_0 = 0 kg B ha^{-1}
G_1 = 70 ppm GA_3 B_1 = 10 kg B ha^{-1}
G_2 = 90 ppm GA_3 B_2 = 15 kg B ha^{-1}
G_3 = 110 ppm GA_3

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

4.2 Number of leaves per plant

Number of leaves per plant of tomato varied significantly due to the application of different levels of GA_3 at 20, 35, 50 and 65 DAT (Appendix II). At 20 DAT, the maximum number of leaves per plant (6.60) was observed in G_1 (70ppm GA_3) while the minimum number of leaves (5.42) was observed in G_0 (0ppm GA_3) which was statistically identical to G_2 (5.86) and G_3 (5.64). At 35 DAT, the maximum number of leaves per plant (13.87) was also found in G_1 and the minimum number of leaves per plant (10.58) was found in G_0. At 50 DAT, the maximum number of leaves per plant (38.18) was obtained from G_1 while the minimum (32.73) was obtained from G_0. At 65 DAT, the highest number of leaves per plant (43.87) was observed in G_1 and the lowest number of leaves (39.66) was observed in G_0 (Table 4). Briant (1974) found that total leaves and weight were increased by GA_3 in young tomato plant. Although GA_3 regulates growth, applications of very low concentrations can have a profound effect while too much will have the opposite effect (Wikipedia, 2016); it might be for that GA_3 higher concentration (110 ppm) gave the lowest number of leaves in tomato.

Number of leaves per plant of tomato varied significantly due to the application of different levels of boron at 20, 35, 50 and 65 DAT (Appendix II). At 20 DAT, the maximum number of leaves per plant (6.47) was found in B_1 (10 kg boron ha^{-1}) while the minimum leaf number (5.43) was observed in B_2 (15 kg boron ha^{-1}) which was statistically similar with B_0 (5.76). At 35 DAT, the highest leaf number per plant (12.70) was obtained from B_1 which was statistically similar to B_2 (12.65) and the lowest (10.05) from B_0. At 50 DAT, the highest leaf number per plant (38.51) was counted from B1 whereas, the lowest (31.60) was from B_0. At 65 DAT, the highest leaf number per plant (44.91) was recorded from B_1 and the lowest number of leaf (39.88) was counted from B_0 (Table 4). Oyinlola (2004) reported that application of boron significantly increased the number of leaves on tomato plant compared to control.

Combined effect of GA_3 and boron illustrated statistically significant differences on number of leaves per plant at 20, 35, 50 and 65 DAT (Appendix II). At 20 DAT, the maximum number of leaves per plant (7.60) was found in G_1B_2 (70ppm GA_3 with 15 kg boron ha^{-1}) while the minimum leaf number per plant (3.60) was observed in G_0B_0 (0ppm GA_3 with 0 kg boron ha^{-1}). At 35 DAT, the maximum number of leaves per plant (16.60) was found in G_1B_1 followed by G_2B_1 (14.53) and the minimum number of leaves per plant (8.07) was found in G_0B_0. At 50 DAT, the highest leaf number per plant (46.13) was obtained from G_1B_1 whereas, the lowest leaf number (29.67) was obtained from G_0B_0. At 65 DAT, the maximum (51.31) and minimum (32.32) leaf numbers per plant were observed in G_1B_1 and G_0B_0 respectively (Table 5).

Table 4: The effect of different levels of GA_3 and boron on number of leaves per plant of tomato at different days after transplanting

Treatments	Number of leaves per plant			
	20 DAT	**35DAT**	**50 DAT**	**65 DAT**
GA_3				
G_0	5.42 b	10.58 c	32.73 b	39.66 b
G_1	6.60 a	13.87 a	38.18 a	43.87 a
G_2	5.86 b	11.02 bc	34.14 b	42.40 ab
G_3	5.64 b	11.73 b	33.09 b	41.85 ab
LSD (0.05)	0.536	0.975	2.494	2.901
Boron				
B_0	5.76 b	10.05 b	31.60 b	39.88 b
B_1	6.47 a	12.70 a	38.51 a	44.91 a
B_2	5.43 b	12.65 a	33.50 b	41.05 b
LSD (0.05)	0.465	0.845	2.160	2.512
%CV	9.33	8.45	7.39	7.07

G_0 = 0 ppm GA_3 B_0 = 0 kg B ha^{-1}
G_1 = 70 ppm GA_3 B_1 = 10 kg B ha^{-1}
G_2 = 90 ppm GA_3 B_2 = 15 kg B ha^{-1}
G_3 = 110 ppm GA_3

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

Table 5: The combined effect of different levels of GA_3 and boron on number of leaves per plant of tomato at different days after transplanting

Treatments	Number of leaves per plant			
	20 DAT	**35 DAT**	**50 DAT**	**65 DAT**
G_0B_0	3.60 e	8.07 g	29.67 d	32.32 d
G_0B_1	6.73 ab	10.47 ef	32.60 cd	40.55 bc
G_0B_2	5.07 cd	10.93 def	29.80 d	37.00 cd
G_1B_0	4.33 de	10.33 ef	34.47 cd	42.76 b
G_1B_1	7.07 a	16.60 a	46.13 a	51.31 a
G_1B_2	7.60 a	12.93 bc	40.17 b	43.89 b
G_2B_0	5.67 c	10.93 def	34.00 cd	40.55 bc
G_2B_1	6.97 ab	14.53 b	35.00 c	46.11 b
G_2B_2	6.80 ab	12.73 cd	35.47 c	42.78 b
G_3B_0	3.80 e	9.73 fg	32.73 cd	41.11 bc
G_3B_1	6.93 ab	11.93 cde	32.93 cd	43.31 b
G_3B_2	6.00 bc	12.40 cd	31.47cd	41.67 bc
LSD (0.05)	0.929	1.689	4.319	5.024
% CV	9.33	8.45	7.39	7.07

G_0 = 0 ppm GA_3 B_0 = 0 kg B ha^{-1}
G_1 = 70 ppm GA_3 B_1 = 10 kg B ha^{-1}
G_2 = 90 ppm GA_3 B_2 = 15 kg B ha^{-1}
G_3 = 110 ppm GA_3

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

4.3 Number of branches per plant

A significant variation in the number of branches per plant was observed due to effect of different concentrations of GA_3 at 35, 50 and 65 DAT (Appendix II). At 35 DAT, the highest number of branches per plant (1.49) was counted in G_1 (70ppm GA_3) while the lowest number of branches per plant (1.18) was found in G_0 (0ppm GA_3). At 50 DAT, the maximum number of branches (5.28) was also found in G_1 and the minimum (4.33) in G_0. The maximum number of branches per plant (6.24) was obtained from G_1 and the minimum number of branches per plant (5.13) was observed in G_0 at 65 DAT (Table 6). Tomar and Ramgiry (1997) also reported that tomato plant treated with GA_3 showed significantly greater number of branches per plant than untreated control. Rai *et al*. (2006) also found the similar result.

The variation in number of branches per plant at different levels of boron was also significant at 35, 50 and 65 DAT. At 35 DAT, the maximum number of branches per plant (1.88) was observed in B_1 (10 kg boron ha^{-1}) and the minimum number of branches (1.03) was found in B_0 (0 kg boron ha^{-1}) which was statistically identical to B_2 (1.07). At 50 DAT, the highest number of branches per plant (5.48) was counted from B_1 whereas, the lowest number (4.15) was counted from B_0. At 65 DAT, the highest (6.21) and lowest (5.48) number of branches were also obtained from B_1 and B_0, respectively (Table 6). Amarchandra and Verma (2003) found similar findings.

There was statistically significant differences among the treatment combinations in respect of number of branches per plant at 35, 50 and 65 DAT. The highest number of branches per plant (2.20) was obtained from G_1B_1 (70ppm GA_3 with 10 kg boron ha^{-1}) which was statistically identical to

G_2B_1 (2.03) while the lowest number of branches per plant (0.80) was obtained from G_0B_0 (0ppm GA_3 with 0 kg boron ha^{-1}) at 35 DAT. At 50 DAT, the highest number of branches per plant (6.17) was recorded from G_1B_1 whereas, the lowest number of branches per plant (3.10) was found in G_0B_0. At 65 DAT, the maximum number of branches per plant (7.30) was also counted in G_1B_1 and the minimum (4.73) was observed in G_0B_0 (Table7).

Table 6: The effect of different levels of GA_3 and boron on number of branches per plant of tomato at different days after transplanting

Treatments	Number of branches per plant		
	35DAT	**50DAT**	**65DAT**
GA_3			
G_0	1.18 c	4.33 c	5.13 b
G_1	1.49 a	5.28 a	6.24 a
G_2	1.34 b	4.80 b	5.99 a
G_3	1.29 b	4.59 bc	6.00 a
LSD (0.05)	0.107	0.366	0.402
Boron			
B_0	1.03 b	4.15 c	5.48 c
B_1	1.88 a	5.48 a	6.21 a
B_2	1.07 b	4.62 b	5.83 b
LSD (0.05)	0.093	0.317	0.348
% CV	8.10	7.89	7.04

G_0 = 0 ppm GA_3 B_0 = 0 kg B ha^{-1}
G_1 = 70 ppm GA_3 B_1 = 10 kg B ha^{-1}
G_2 = 90 ppm GA_3 B_2 = 15 kg B ha^{-1}
G_3 = 110 ppm GA_3

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

Table 7: The combined effect of different levels of GA_3 and boron on number of branches per plant of tomato at different days after transplanting

Treatments	Number Of branches per plant		
	35DAT	**50DAT**	**65DAT**
G_0B_0	0.80 f	3.10 e	4.73 f
G_0B_1	1.07 de	3.50 e	6.13 bc
G_0B_2	1.07 de	4.20 d	5.00 ef
G_1B_0	1.20 d	4.87 bcd	5.33def
G_1B_1	2.20 a	6.17 a	7.30 a
G_1B_2	1.73 b	5.37 b	6.43 b
G_2B_0	1.07 de	4.80 bcd	5.33 ef
G_2B_1	2.03 a	5.33 b	6.43 b
G_2B_2	1.20 d	5.07 bc	6.20 bc
G_3B_0	0.93 ef	4.53 cd	6.10 bcd
G_3B_1	1.53 c	5.13 bc	5.43 cdef
G_3B_2	1.07 de	4.93 bc	5.67 bcde
LSD (0.05)	0.186	0.634	0.696
% CV	8.10	7.89	7.04

G_0 = 0 ppm GA_3 B_0 = 0 kg B ha^{-1}
G_1 = 70 ppm GA_3 B_1 = 10 kg B ha^{-1}
G_2 = 90 ppm GA_3 B_2 = 15 kg B ha^{-1}
G_3 = 110 ppm GA_3

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

4.4 Number of flower clusters per plant

Number of flower clusters per plant of tomato varied significantly due to the application of different levels of GA_3 at 50 and 65 DAT (Appendix II). AT 50 DAT, the maximum number of flower clusters per plant (4.53) was obtained from G_1 and the minimum (4.00) was from G_0. At 65 DAT, the highest number of flower clusters per plant (12.96) was recorded from G_1 and the lowest (11.60) was from G_0 (Table 8). Onofeghara (1983) also found similar result.

Number of flower cluster per plant of tomato also varied significantly due to the application of different levels of boron at 50 and 65 DAT. At 50 DAT, the highest number (4.60) of flower clusters per plant was recorded from B_1 whereas, the lowest (4.02) was recorded from B_0 which was statistically similar to B_2 (4.10). At 65 DAT, the maximum number (13.57) of flower clusters per plant was obtained from B_1 which was statistically identical to B_2 (12.68) and the minimum number (11.30) of flower clusters per plant was observed in B_0 (Table 8). Naz *et al*., (2012) also found higher flower cluster per plant in boron treated tomato plant than untreated control.

Number of flower clusters per plant varied significantly due to the combined effect of GA_3 and boron at 50 and 65 DAT. At 50 DAT, the highest number (5.13) of flower clusters per plant was obtained from G_1B_1 whereas, the lowest number (3.67) was obtained from G_0B_0. At 65 DAT, the highest number (15.13) of flower clusters per plant was obtained from G_1B_1 which was statistically similar with G_1B_2 (13.53) and the lowest number (8.97) of flower clusters per plant was recorded from G_0B_0 (Table 9).

4.5 Number of flowers per cluster

Number of flowers per cluster of tomato showed significant variation due to the application of different levels of GA_3 at 50 and 65 DAT (Appendix II). At 50 DAT, the highest number (3.79) of flowers per cluster was observed in G_1 (70ppm GA_3) while the lowest number (3.47) was counted from G_0 (0ppm GA_3). The highest number (4.49) of flowers per cluster was found in G_1 and the lowest number (3.96) was found in G_0 at 65 DAT (Table 8). Saleh and abdul (1980) also agreed the findings of present study.

Number of flowers per cluster of tomato also showed significant differences due to the application of different doses of boron at 50 and 65 DAT. At 50 DAT, the highest number (3.84) of flowers per cluster was recorded from B_1 (10 kg boron ha^{-1}) which was statistically identical to B_2 (3.67) whereas, the lowest number (3.41) was found in B_0 (0 kg boron ha^{-1}). At 65 DAT, the highest (4.34) and lowest (4.01) number of flowers per cluster were obtained from B_1 and B_0, respectively (Table 8). Suganiya and Kumuthini (2015) reported that boron increased the number of flowers per cluster than control treatment in brinjal plant.

Combined effect of different levels of GA_3 and boron illustrated significance differences for number of flowers per cluster at 50 and 65 DAT. At 50 DAT, the highest number (4.07) of flowers per cluster was recorded from G_1B_1 (70ppm GA_3 with 10 kg boron ha^{-1}) and the lowest number (2.87) was recorded from G_0B_0 (0ppm GA_3 with 0 kg boron ha^{-1}). At 65 DAT, the highest number (6.20) of flowers per cluster was also observed in G_1B_1 followed by G_1B_2 (5.00) whereas, the lowest number (3.17) was counted in G_0B_0 (Table 9).

4.6 Number of flowers per plant

Number of flowers per plant of tomato varied significantly due to the application of different concentrations of GA_3 at 50 and 65 DAT (Appendix II). The maximum number (17.20) of flowers per plant was counted from G_1 (70ppm GA_3) which was statistically similar with G_2 (16.64) whereas, the minimum number (14.09) was counted from G_0 (0ppm GA_3) at 50 DAT. At 65 DAT, the highest number (62.00) of flowers per plant was also found in G_1 and the lowest number (47.44) was found in G_0 (Table 8). Onofeghara (1983) also illustrated similar result.

Number of flowers per plant of tomato also varied significantly due to the application of different levels of boron at 50 and 65 DAT. At 50 DAT, the highest number of flowers per plant (17.13) was recorded from B_1 (10 kg boron ha^{-1}) and the lowest number (14.25) was obtained from B_0 (0 kg boron ha^{-1}). At 65 DAT, the maximum number (61.43) of flowers per plant was counted in B_1 which was statistically identical to B_2 (57.54) and the minimum number (42.67) was observed in B_0 (Table 8). Naresh (2002) observed that boron also had positive effects on number of flowers per plant resulting in an increase in the number of fruits per plant and total yield.

Number of flowers per plant varied significantly due to the combined effect of different levels of GA_3 and boron at 50 and 65 DAT (Appendix II). At 50 DAT, the highest number (20.07) of flowers per plant was counted from G_1B_1 (70ppm GA_3 with 10 kg boron ha^{-1}) which was statistically similar with G_2B_1 (18.27) while the lowest number (11.00) was counted from G_0B_0 (0ppm GA_3 with 0 kg boron ha^{-1}). At 65 DAT, the highest number (85.97) of flowers per plant was also recorded from G_1B_1 followed by G_1B_2 (68.83) and the lowest number (31.67) was obtained from G_0B_0 (Table 9).

.**Table 8: The effect of different levels of GA_3 and boron on yield contributing characters and yield of tomato at different days after transplanting**

Treatments	Number of flower clusters per plant		Number of flowers per cluster		Number of flowers per plant	
	50 DAT	**65 DAT**	**50 DAT**	**65 DAT**	**50 DAT**	**65 DAT**
GA_3						
G_0	4.00 c	11.60 b	3.47 b	3.96 b	14.09 b	47.44 c
G_1	4.53 a	12.96 a	3.79 a	4.49 a	17.20 a	62.00 a
G_2	4.38 ab	12.74 a	3.63 ab	4.34 b	16.64 a	51.94 bc
G_3	4.04 bc	12.77 a	3.67 ab	3.99 b	15.02 b	54.13 b
LSD (0.05)	0.344	0.965	0.282	0.318	1.161	5.256
Boron						
B_0	4.02 b	11.30 b	3.41 b	4.01 b	14.25 c	42.67 b
B_1	4.60 a	13.57 a	3.84 a	4.34 a	17.13 a	61.43 a
B_2	4.10 b	12.68 a	3.67 a	4.23 ab	15.83 b	57.54 a
LSD (0.05)	0.298	0.836	0.244	0.276	1.006	4.552
% CV	8.31	7.89	7.90	7.77	7.55	9.98

G_0 = 0 ppm GA_3
G_1 = 70 ppm GA_3
G_2 = 90 ppm GA_3
G_3 = 110 ppm GA_3

B_0 = 0 kg B ha^{-1}
B_1 = 10 kg B ha^{-1}
B_2 = 15 kg B ha^{-1}

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

Table 9: The combined effect of different levels of GA_3 and boron on yield contributing characters and yield of tomato at different days after transplanting

Treatments	Number of flower clusters per plant		Number of flowers per cluster		Number of flowers per plant	
	50 DAT	65 DAT	50 DAT	65 DAT	50 DAT	65 DAT
G_0B_0	3.67 d	8.97 d	2.87 e	3.17 d	11.00 e	31.67 e
G_0B_1	4.07 cd	12.57 bc	3.63 abcd	3.70 cd	16.40 bcd	45.67 cd
G_0B_2	4.27 cd	11.50 c	3.43 cd	3.67 cd	14.73 d	51.23 cd
G_1B_0	4.07 cd	13.13 bc	3.73 abcd	4.07 c	15.13 cd	47.43 cd
G_1B_1	5.13 a	15.13 a	4.07 a	6.20 a	20.07 a	85.97a
G_1B_2	4.93 ab	13.53 ab	3.93 abc	5.00 b	16.20 bcd	68.83 b
G_2B_0	4.07 cd	12.67 bc	3.83 abcd	3.77 cd	14.87 cd	45.77 cd
G_2B_1	4.40 bc	13.27 bc	4.00 ab	4.77 b	18.27 ab	65.33 b
G_2B_2	4.27 cd	13.20 bc	3.90 abc	4.03 c	17.13 bc	66.57b
G_3B_0	3.80 cd	12.23 bc	3.44 cd	3.57 cd	14.67 d	41.23 d
G_3B_1	4.13 cd	11.57 c	3.50 bcd	4.70 b	15.33 cd	54.10 c
G_3B_2	4.07 cd	12.43 bc	3.33 cd	3.70 cd	15.07 cd	43.67d
LSD (0.05)	0.596	1.672	0.488	0.551	2.011	9.104
% CV	8.31	7.89	7.90	7.77	7.55	9.98

G_0 = 0 ppm GA_3 B_0 = 0 kg B ha^{-1}
G_1 = 70 ppm GA_3 B_1 = 10 kg B ha^{-1}
G_2 = 90 ppm GA_3 B_2 = 15 kg B ha^{-1}
G_3 = 110 ppm GA_3

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

4.7 Number of fruit clusters per plant

The number of fruit clusters per plant at different levels of GA_3 was found to be significant at 65 and 80 DAT (Appendix II). At 65 DAT, the maximum number of fruit clusters per plant (4.95) was produced by GA_3 level of 70ppm whereas, the control treatment (0ppm GA_3) produced the minimum number of fruit cluster per plant (3.81). AT 80 DAT, the highest (7.15) and lowest (6.32) number of fruit clusters per plant were obtained from G_1 and G_0, respectively (Table 10). Saleh and Abdul (1980) also found similar trend of result which is support to the present findings.

The number of fruit clusters per plant at different levels of boron was also varied significantly at 65 and 80 DAT. The highest number of fruit clusters per plant (5.02) was recorded from B_1 (10 kg boron ha^{-1}) while the lowest (3.85) was counted from B_0 (0 kg boron ha^{-1}) at 65 DAT. At 80 DAT, the maximum (7.30) and minimum (6.41) fruit clusters per plant were recorded from B_1 and B_0, respectively (Table 10). Ejaz *et al.* (2011) also reported the similar results.

There was significant combined effect between different levels of GA_3 and boron in case of number of fruit clusters per plant at 65 and 80 DAT. AT 65 DAT, GA_3 level 70ppm with 10 kg boron ha^{-1} produced the maximum number of fruit clusters (6.19) and those of GA_3 level 0ppm with 0 kg boron ha^{-1} produced the minimum number of fruit cluster (2.55) per plant. At 80 DAT, the highest number of fruit clusters per plant (8.61) was counted from G_1B_1 which was statistically identical to G_2B_1 (7.72) whereas, the lowest number of fruit clusters per plant (5.03) were found in G_0B_0 (Table 11).

4.8 Number of fruits per cluster

Significant variation was recorded for the number of fruits per cluster of tomato due the application of different levels of GA_3 at 65 and 80 DAT (Appendix II). At 65 DAT, the highest number of fruits per cluster (5.47) was observed in G_1 (70ppm GA_3) and the lowest number (4.88) was found in G_0 (0ppm GA_3). At 80 DAT, the highest (5.18) and lowest (4.76) number of fruits per cluster were also obtained from G_1 and G_0, respectively (Table 10). Gelmesa *et al.*, (2012) showed similar results i.e., GA_3 increased fruit number per cluster, fruit set percentage and marketable fruit number per plant over the control.

There was also significant differences among the different boron levels on the number of fruits per cluster at 65 and 80 DAT. At 65 DAT, the highest number of fruits per cluster (5.24) was counted in B_1 (10 kg boron ha^{-1}) while the lowest number (4.65) was observed in B_0 (0 kg boron ha^{-1}). At 80 DAT, the maximum number of fruits per cluster (5.37) was also observed in B_1 and the lowest number (4.86) was recorded from B_0 (Table 10). Haque (2007) also found higher number of fruits per cluster with the application of boron than control in tomato plant. Ullah *et al*. (2015) also showed similar results.

Combined effect of GA_3 and boron differed significantly for number of fruits per cluster at 65 and 80 DAT. The highest number of fruits per cluster (6.37) was counted from G_1B_1 (70ppm GA_3 with 10 kg boron ha^{-1}) and the lowest number (4.23) was counted from G_0B_0 (0ppm GA_3 with 0 kg boron ha^{-1}) at 65 DAT. At 80 DAT, the maximum number of fruits per cluster (5.70) was observed in G_1B_1 while the minimum number (4.27) was obtained from control treatment (G_0B_0) (Table 11).

4.9 Number of fruits per plant

Number of fruits per plant of tomato showed significant variations for the application of different GA_3 levels at 50, 65 and 80 DAT (Appendix II). At 50 DAT, the maximum (2.24) and minimum (1.22) fruits per plant were observed in G_1 (70ppm GA_3) and G_0 (0ppm GA_3), respectively. At 65 and 80 DAT the similar trends of results was found on number of fruits per plant due to application of different levels of GA_3 (Table 10). Kaushik *et al.* (1974) reported that GA_3 increased the number of fruits per plant in tomato while Jansen (1970) mentioned that increasing concentration of GA_3 reduced both the number and size of fruits.

Significant variation was also recorded on number of fruits per plant of tomato due to the application of different levels of boron at 50, 65 and 80 DAT. At all three different DATs, the highest and lowest number of fruits per plant were recorded from B_1 (10 kg boron ha^{-1}) and B_0 (0 kg boron ha^{-1}), respectively. The maximum fruits number per plant (3.13, 26.63 and 38.76) and the minimum fruits number per plant (0.65, 17.32 and 30.81) were counted from 50, 65 and 80 DAT, respectively (Table 10). Ejaz *et al.* (2011) also reported that application of boron provide better results in number of fruits per plant of tomato as compared to control. This may be because boron takes part in active photosynthesis, which ultimately help towards increase in number and weight of fruits per plant (Kumar and Sen, 2005).

Number of fruits per plant varied significantly due to the combined effect of different levels of GA_3 and boron at 50, 65 and 80 DAT. AT 50 DAT, the highest number of fruits per plant (3.87) was obtained from G_1B_1 (70ppm GA_3 with 10 kg boron ha^{-1}) followed by G_2B_1 (3.47) while the lowest number (0.07) was attained in G_0B_0 (0ppm GA_3 with 0 kg boron ha^{-1}). At 65 DAT, the highest number of fruits per plant (34.97) was observed in G_1B_1 followed by G_1B_2 (26.67) whereas, the lowest number (12.83) was found in G_0B_0. At 80 DAT, the maximum number of fruits per plant (46.17) was also counted from G_1B_1 followed by G_1B_2 (40.67) and the minimum number of fruits per plant (24.87) was recorded from G_0B_0 (Table 11).

Table 10: The effect of different levels of GA_3 and boron on yield contributing characters and yield of tomato at different days after transplanting

Treatments	Number of fruit clusters per plant		Number of fruits per cluster		Number of fruits per plant		
	65 DAT	80 DAT	65 DAT	80 DAT	50 DAT	65 DAT	80 DAT
GA_3							
G_0	3.81 c	6.32 b	4.88 b	4.76 b	1.22 c	20.32 b	29.83 b
G_1	4.95 a	7.15 a	5.47 a	5.18 a	2.24 a	22.44 a	36.94 a
G_2	4.53 c	6.22 ab	5.15 a	5.11 ab	1.64 b	21.13 ab	34.66 a
G_3	4.22 c	6.90 a	5.10 a	5.09 ab	1.64 b	20.94 ab	34.01 a
LSD (0.05)	4.055	0.530	0.573	0.368	0.188	1.590	3.066
Boron							
B_0	3.85 c	6.41 b	4.65 b	4.86 b	0.65 c	17.27 c	30.81 b
B_1	5.02 a	7.30 a	5.24 a	5.37 a	3.13 a	26.67 a	38.76 a
B_2	4.28 b	6.53 b	4.97 b	4.88 b	1.28 b	19.68 b	32.02 b
LSD (0.05)	0.351	0.459	0.496	0.319	0.163	1.377	2.655
% CV	9.47	8.03	11.37	7.50	11.42	7.67	9.26

G_0 = 0 ppm GA_3 B_0 = 0 kg B ha^{-1}
G_1 = 70 ppm GA_3 B_1 = 10 kg B ha^{-1}
G_2 = 90 ppm GA_3 B_2 = 15 kg B ha^{-1}
G_3 = 110 ppm GA_3

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

Table 11: The combined effect of different levels of GA_3 and boron on yield contributing characters and yield of tomato at different days after transplanting

Treatments	Number of fruit clusters per plant		Number of fruits per cluster		Number of fruits per plant		
	65 DAT	80 DAT	65 DAT	80 DAT	50 DAT	65 DAT	80 DAT
G_0B_0	2.55 f	5.03 d	4.23 d	4.27 c	0.07 h	12.83 g	24.87 e
G_0B_1	4.00 de	6.72 bc	5.17 bcd	5.07 ab	1.47 e	19.53 de	33.20 cd
G_0B_2	4.11 d	6.22 c	4.53 cd	4.83 bc	0.47 g	17.03 f	35.23 bc
G_1B_0	4.55 cd	6.67 c	5.13 bcd	4.97 bc	1.40 e	19.68 de	32.10 cd
G_1B_1	6.19 a	8.61 a	6.37 a	5.70 a	3.87 a	34.97 a	46.17 a
G_1B_2	4.89 bc	6.76 bc	6.20 ab	5.47 ab	3.00 c	26.67 b	40.67 b
G_2B_0	4.33 cd	6.66 c	4.50 cd	5.07 ab	1.93 d	17.27 ef	31.47 cd
G_2B_1	5.55 ab	7.72 ab	5.57 abc	5.17 ab	3.47 b	22.40 cd	35.67 bc
G_2B_2	4.94 bc	6.77 bc	5.57 abc	5.13 ab	2.20 d	24.47 bc	34.77 c
G_3B_0	3.78 de	6.54 c	4.73 cd	4.73 bc	0.33 gh	16.00 f	31.13 cd
G_3B_1	4.33 cd	6.66 c	5.23 bcd	4.87 bc	0.93 f	19.77 de	32.53 cd
G_3B_2	3.33 e	6.54 c	4.60 cd	5.13 ab	1.13 ef	16.53 f	28.53 de
LSD (0.05)	0.702	0.918	0.992	0.638	0.236	2.753	5.310
% CV	9.47	8.03	11.37	7.50	11.42	7.67	9.26

G_0 = 0 ppm GA_3 B_0 = 0 kg B ha^{-1}
G_1 = 70 ppm GA_3 B_1 = 10 kg B ha^{-1}
G_2 = 90 ppm GA_3 B_2 = 15 kg B ha^{-1}
G_3 = 110 ppm GA_3

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

4.10 Fruit diameter

The variation in fruit diameter among the different concentrations of GA_3 was found to be statistically significant (Appendix II). The maximum diameter of fruit (6.52 cm) was obtained from 70 ppm GA_3 whereas, the minimum fruit diameter (4.82 cm) was obtained from control plants (Table 12). Desai *et al*. (2012) found the maximum fruit length and girth in gibberellic acid @ 75 ppm. Sawhnuy and Greyson (1972) also reported the similar findings.

Diameter of tomato fruit also varied significantly due to the application of different doses of boron. The highest diameter of fruit (6.13 cm) was recorded from B_1 (10 kg boron ha^{-1}) which was statistically identical to B_2 (5.84 cm). The lowest diameter (5.11) was recorded from B_0 (0 kg boron ha^{-1}) (Table 12). Yadav *et al.* (2001) also found similar results.

Different levels of GA_3 and boron significantly influenced the diameter of fruit for their combined effect. The highest diameter of fruit (7.58 cm) was obtained from the treatment combination of 70 ppm GA_3 and 10 kg boron ha^{-1} while the lowest diameter of fruit (4.50 cm) was obtained from G_0B_0 (0ppm GA_3 with 0 kg boron ha^{-1}) (Table 13).

4.11 Weight of fruits per plants

The weight of fruits per plant was significantly influenced by different levels of GA_3 (Appendix II). The maximum weight (2130 g) was found from G_1 (70ppm GA_3) and the minimum weight (1608 g) was obtained from G_0 (0ppm GA_3) (Table 12). Lilov and Donchev (1984) also found similar results by the application of GA_3.

It was noticed that different levels of boron exhibited significant effect on the weight of fruits per plant. The plant fertilized with 10 kg boron ha^{-1} produced the maximum weight (1989 g) of fruits per plant which was statistically identical to B_2 (1871 g) and the minimum weight (1733 g) was obtained from control treatment (0 kg boron ha^{-1}) (Table 12). Similar effects of different boron levels in respect of fruit weight per plant have been reported by Singh and Gangwar (1991).

There was significant combined effect of different levels of GA_3 and boron on the weight of fruits per plant (Appendix II). The maximum fruit weight per plant (2412 g) was observed in the treatment combination of 70 ppm GA_3 and 10 kg boron ha^{-1} which was statistically similar with treatment combination of 70 ppm GA_3 and 15 kg boron ha^{-1} (2158 g). The lowest (1039 g) in this respect was found from the treatment combination 0 ppm GA_3 and 0 kg boron ha^{-1} (Table 13).

4.12 Individual fruit weight

Weight of individual fruit of tomato varied significantly due to the application of different levels of GA_3 (Appendix II). The highest weight of individual fruit (77.39 g) was found from G_1 (70ppm GA_3) followed by G_3 (65.05 g) and G_2 (59.05 g). The lowest individual fruit weight (57.15 g) was observed from G_0 (0ppm GA_3) (Table 12). Lilov and Donchev (1984) also showed similar results.

Application of different levels of boron also showed significant differences for weight of individual fruit. The highest individual fruit weight (71.42 g) was found from B_1 (10 kg boron ha^{-1}) while the lowest individual fruit weight (59.07) was obtained from B_0 (no boron application) (Table 12). Oyinlola and Chude (2004) also found the similar results.

Significant variation was recorded due to the combined effect of different levels of GA_3 and boron for weight of individual fruit. The highest individual fruit weight (84.43 g) was recorded from G_1B_1 (70 ppm GA_3 with 10 kg boron ha^{-1}) was statistically identical to G_1B_2 (76.93 g) and G_2B_1 (75.95) whereas, the lowest individual fruit weight (44.02 g) was observed from control treatment (0 ppm GA_3 with 0 kg boron ha^{-1}) (Table 13).

4.13 Dry matter content in leaves

A statistical significant variation was recorded on dry matter content in leaf due to effect of different concentrations of GA_3 (Appendix II). The highest dry matter content in leaves (13.17%) was obtained from G_1 (70 ppm GA_3) whereas, the lowest dry matter content in leaves (9.72%) was observed in control (G_0) condition (Table 12). Gabal *et al.* (1990) and Takano *et. al*. (1995) reported similar results.

Statistically significant variation was recorded on dry matter content in leaves due to the application of different levels of boron. The highest dry matter content in leaves (12.49%) was obtained from B_1 (10 kg boron ha^{-1}) and the lowest dry matter content in leaves (10.29%) was found in B_0 i.e., control treatment (Table 12). Farzaneh *et al.* (2011) also reported similar results.

Combination effect of different levels of GA_3 and boron illustrated statistically significant variation on dry matter content in leaves. The maximum dry matter content in leaves (14.40%) was found in G_1B_1 (70 ppm GA_3 with 10 kg boron ha^{-1}) which was statistically similar with G_2B_1

(13.50%) and G_1B_2 (13.47%). On the other hand, the lowest dry matter content in leaves (7.01%) was obtained from G_0B_0 (0 ppm GA_3 with 0 kg boron ha^{-1}) (Table 13).

4.14 Dry matter content in fruits

A statistically significant variation was recorded for dry matter content in fruits due to different concentrations of GA_3 (Appendix II). The highest dry matter content in fruits (10.52%) was observed in G_1 (70 ppm GA_3) which was statistically identical to G_2 (10.35%). The lowest dry matter content (8.27%) was found in control treatment (Table 12). Gabal *et al*. (1990) also found similar results.

Statistically significant variation was recorded on dry matter content in fruits due to effect of different levels of boron. The highest (9.95%) and lowest (9.11%) dry matter content of fruit were obtained from B_1 (10 kg boron ha^{-1}) and B_0 (0 kg boron ha^{-1}), respectively (Table 12). Salam *et al*. (2011) also showed that dry matter content of tomato fruits increased with the application of boron than control treatment.

Combination effect of GA_3 and boron showed statistically significant variation for dry matter content in fruits. The highest dry matter content in fruits (12.65%) was observed in G_1B_1 (70 ppm GA_3 with 10 kg boron ha^{-1}) whereas, the lowest (6.53%) was observed in G_0B_0 (0 ppm GA_3 with 0 kg boron ha^{-1}) (Table 13).

Table 12: The effect of different levels of GA_3 and boron on yield contributing characters and yield of tomato at different days after transplanting

Treatments	Fruit diameter (cm)	Weight of fruits/plant (g)	Individual fruit weight (g)	Dry matter of leaf (%)	Dry matter of fruit (%)
GA_3					
G_0	4.82 c	1608 c	57.15 c	9.72 c	8.27
G_1	6.52 a	2130 a	77.39 a	13.17 a	10.52 a
G_2	5.56 b	1883 b	59.05 bc	11.42 b	10.35 a
G_3	5.88 b	1837 b	65.05 b	11.01 b	9.22 b
LSD (0.05)	0.532	153.8	6.205	0.966	0.713
Boron					
B_0	5.11 b	1733 b	59.07 b	10.29 c	9.11 b
B_1	6.13 a	1989 a	71.42 a	12.49 a	9.95 a
B_2	5.84 a	1871 a	63.49 b	11.21 b	9.72 ab
LSD (0.05)	0.461	133.2	5.373	0.836	0.618
% CV	9.56	8.43	9.82	8.72	7.60

G_0 = 0 ppm GA_3
G_1 = 70 ppm GA_3
G_2 = 90 ppm GA_3
G_3 = 110 ppm GA_3

B_0 = 0 kg B ha^{-1}
B_1 = 10 kg B ha^{-1}
B_2 = 15 kg B ha^{-1}

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

Table 13: The combined effect of different levels of GA_3 and boron on yield contributing characters and yield of tomato at different days after transplanting

Treatments	Fruit diameter (cm)	Weight of fruits/plant (g)	Individual fruit weight (g)	Dry matter of leaf (%)	Dry matter of fruit (%)
G_0B_0	4.50 e	1039 f	44.02 f	7.01 g	6.53 g
G_0B_1	5.94 bcd	1967 bcd	60.11 cde	10.11 def	9.90 cde
G_0B_2	5.36 cde	1864 bcde	61.35 cde	9.65 ef	9.49 de
G_1B_0	5.40 cde	2060 bc	69.54 bcd	12.44 bc	9.41 de
G_1B_1	7.58 a	2412 a	84.43 a	14.40 a	12.65 a
G_1B_2	6.34 bc	2158 ab	76.93 ab	13.47 ab	11.12 bc
G_2B_0	6.30 bc	1639 e	59.10 cde	11.61cd	9.07 e
G_2B_1	6.57 b	2114 bc	75.95 ab	13.50 ab	10.57 bcd
G_2B_2	5.35 cde	1939 bcd	70.80 bc	11.27 cde	11.34 b
G_3B_0	4.65 e	1622 e	55.78 e	9.40 f	7.71 fg
G_3B_1	5.31 cde	1847 cde	60.04 cde	10.54 def	8.70 ef
G_3B_2	5.03 de	1714 de	57.90 de	12.55 bc	8.60 ef
LSD (0.05)	0.921	266.3	10.75	1.673	1.235
% CV	9.56	8.43	9.82	8.72	7.60

G_0 = 0 ppm GA_3 | B_0 = 0 kg B ha^{-1}
G_1 = 70 ppm GA_3 | B_1 = 10 kg B ha^{-1}
G_2 = 90 ppm GA_3 | B_2 = 15 kg B ha^{-1}
G_3 = 110 ppm GA_3

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

4.15 Fruit yield per hectare

The fruit yield of tomato per hectare was also significantly influenced by different levels of GA_3 (Appendix II). The highest yield (68.67 t/ha) was obtained from G_1 (70 ppm GA_3) followed by G_2 (65.57 ton/ha) and G_3 (61.07 ton/ha) while the lowest yield (53.63 t/ha) was obtained from G_0 (control treatment) (Figure 2). Prasad *et al.*, (2013) reported that fruit yield/ha significantly increased with the application of GA_3 compared to control. It is due to the fact that application of GA_3 check the flowers and fruit drop and ultimately increase the percent of fruit set. Kaushik *et al.*, (1974) supported these findings.

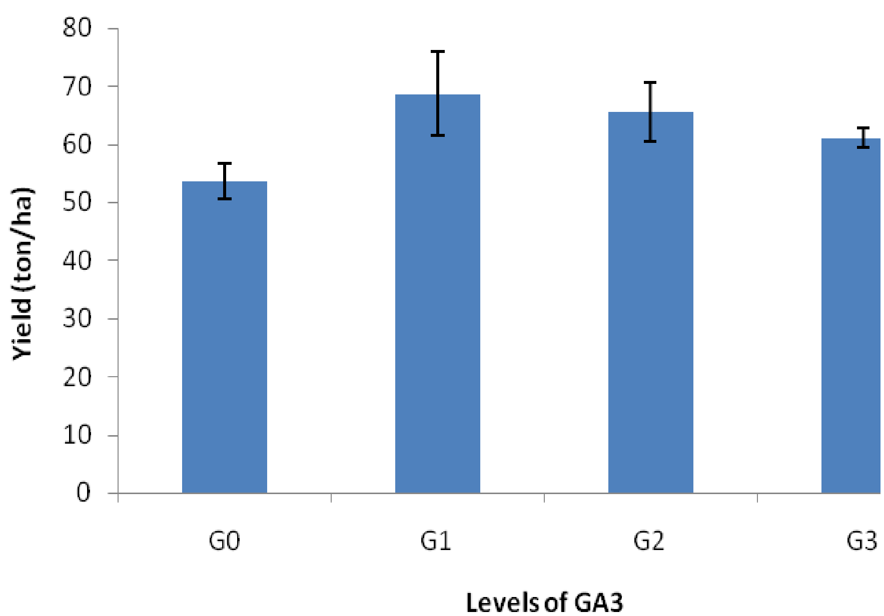


Figure 2: Effect of different levels of GA_3 on the yield of tomato

Different levels of boron also significantly influenced on the yield of fruit per hectare (Appendix II). The highest yield (67.32 t/ha) was produced due to the application of 10 kg boron ha^{-1} (B_1). On the other hand, the lowest yield (56.69 t/ha) was produced in control treatment (B_0). Rahman *et al*., (2013) reported that 6-10 kg boron fertilizer per hectare is needed to fulfill the demand of boron in tomato plant for higher yield (Figure 3). Ullah *et al.* (2015) also showed that application of boron gave higher yield per hectare than untreated control in tomato.

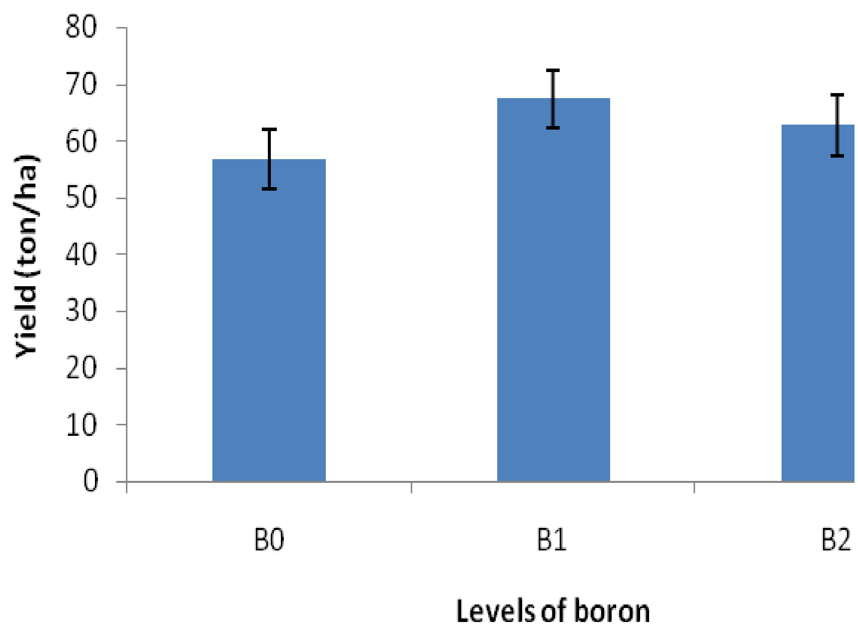


Figure 3: Effect of different levels of boron on the yield of tomato

Due to combined effect of different levels of GA3 and boron performed significant effect on yield per hectare (Appendix II). The treatment combination of 70 ppm GA_3 and 10 kg boron ha^{-1} gave the maximum yield (77.61 t/ha) of tomato followed by the treatment combination of 70 ppm GA_3 + 15 kg boron ha^{-1} (72.43 t/ha) and 70 ppm GA_3 + 0 kg boron ha^{-1} (71.46 ton/ha). On the other hand, the minimum yield (34.72 t/ha) was found from the treatment combination of no GA_3 and no boron (Figure 4).

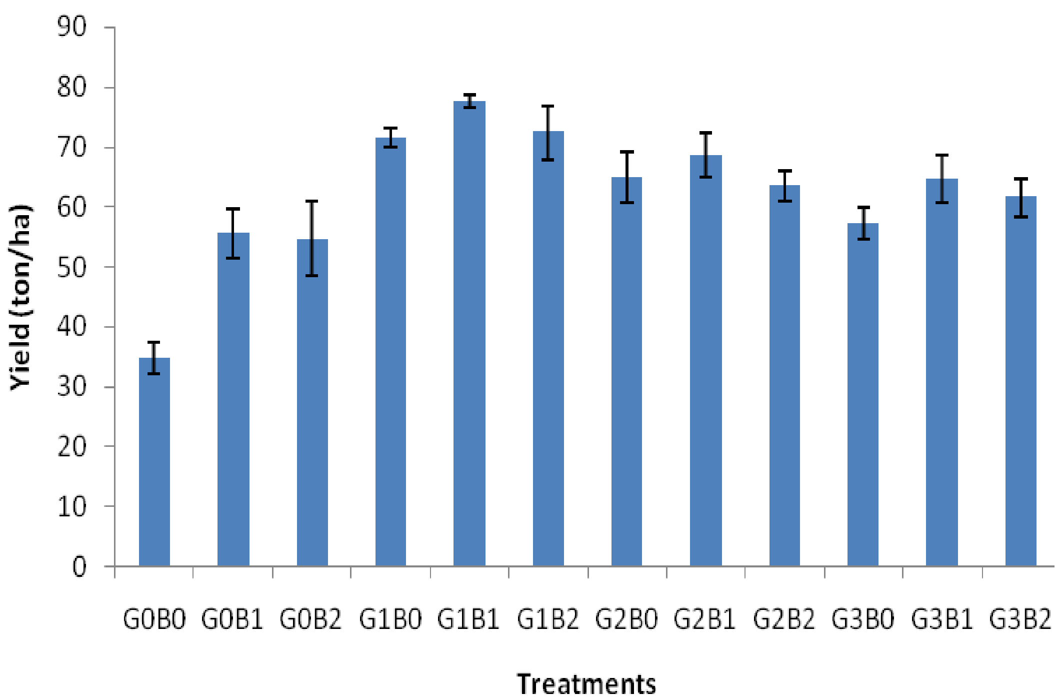


Figure 4: Combination effect of GA_3 and boron on the yield of tomato

4.16 Economic analysis

Input cost for land preparation, seed cost, fertilizer & manure cost and man power required for all the operations from transplanting of seedling to harvesting of tomato were recorded for unit plot and converted into cost per hectare. Prices of tomato were considered in market rate basis. The economic analysis was done to find out the gross and net return and the benefit cost ratio in the present experiment and presented under following headings-

4.16.1 Gross return

In the combination of GA_3 and boron showed different gross return under the trial. The highest gross return (Tk. 582075/ha) was obtained from G_1B_1 (70 ppm GA_3 with 10 kg boron ha^{-1}) and the second highest gross return (Tk. 543225/ha) was obtained from G_1B_2 (70 ppm GA_3 with 15 kg boron ha^{-1}). On the other hand, the lowest gross return (Tk. 260400/ha) was calculated from G_0B_0 (0 ppm GA_3 with 0 kg boron ha^{-1}) (Table 14).

4.16.2 Net return

In case of net return, different treatment combinations showed different results. The highest (Tk. 364101/ha) and second highest (Tk. 324245/ha) net return were obtained from G_1B_1 and G_1B_2, respectively. The lowest net return (Tk. 47794/ha) was obtained from G_0B_0 (Table 14).

4.16.3 Benefit cost ratio (BCR)

The combination of GA_3 and boron for benefit cost ratio was different in all treatment combination (Table 14). The highest benefit cost ratio (2.67) was obtained from G_1B_1 and the second highest benefit cost ratio (2.48) was estimated from both G_1B_2 and G_1B_2 whereas the lowest benefit cost ratio

(1.22) was obtained from G_0B_0. From the economic point of view, it is apparent that G_1B_1 treatment combination (70 ppm GA_3 with 10 kg boron ha^{-1}) was the most profitable than rest of the treatment combinations under the study.

Table 14: Cost and return of tomato cultivation as influenced by GA_3 and boron

Treatments	Cost of production (Tk./ha)	Yield of tomato (t/ha)	Gross return (Tk./ha)	Net return (Tk./ha)	Benefit cost ratio
G_0B_0	212606	34.72	260400	47794	1.22
G_0B_1	214613	55.61	417075	202462	1.94
G_0B_2	215625	54.62	409650	194025	1.90
G_1B_0	215961	71.46	535950	319989	2.48
G_1B_1	217974	77.61	582075	364101	2.67
G_1B_2	218980	72.43	543225	324245	2.48
G_2B_0	217079	64.98	487350	270271	2.25
G_2B_1	219092	68.68	515100	296008	2.35
G_2B_2	220099	63.43	475725	255626	2.16
G_3B_0	218197	57.13	428475	210275	1.93
G_3B_1	220210	64.62	484650	264440	2.20
G_3B_2	221217	61.56	461700	240483	2.08

Cost of tomato@Tk.7500/ton

CHAPTER V

SUMMARY AND CONCLUSION

This experiment was conducted in the Horticultural Farm of Sher-e-Bangla Agricultural University Dhaka 1207, (Tejgaon series under AEZ No.28) from October 2014 to March 2015, to study the effect of different levels of GA_3 and different levels of boron on the growth and yield of tomato. The texture of soil was silty clay loam in having pH 5.71 and organic carbon content of 0.68%. Four concentrations of GA_3 (0, 70 ppm, 90 ppm and 110 ppm) and three levels of boron (0 kg ha^{-1}, 10 kg ha^{-1} and 15 kg ha^{-1}) were used in the study. Levels of these two nutrient elements make 12 treatment combinations. The experiment was carried out in Randomized Complete Block Design (RCBD) with three replications. The unit plot size was 2 m x 1.8 m which accommodated 15 plants. The crop was harvested from 10 March to 30 March, 2015.

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

At 65 days after transplantation GA_3 had a significant effect on plant height. Plants grown with 70 ppm GA_3 showed maximum plant height (117.3 cm) while the shortest (108.3 cm) plant was observed from 0 ppm GA_3 (control). In case of boron, the tallest plant (123.0 cm) was produced by 10 kg boron ha^{-1} and the shortest plant (109.2 cm) was shown by control plant (0 kg boron ha^{-1}). The treatment combinations demonstrated significant variation in plant height at 20, 35, 50 and 65 DAT. At 65 DAT, the longest plant (139.9 cm) was produced by 70ppm GA_3 with 10 kg boron ha^{-1} whereas, the shortest (98.55 cm) was shown from treatment combination of 0ppm GA_3 and 0 kg boron ha^{-1}.

At 65 DAT, different levels of GA_3 showed significant effect on total number of leaves of tomato. The maximum value (43.87) of this character was found at the 70ppm GA_3 and the minimum value (39.66) was obtained from control treatment (0ppm GA_3). On the other hand, this parameter was also significantly influenced by different levels of boron. The maximum number of leaves (44.91) was produced by 10 kg boron ha^{-1} while the minimum leaf number (39.88) was produced by control plots at 65 DAT. At 65 DAT, the highest number of leaves (51.31) was given by the treatment combination of 70 ppm GA_3 and 10 kg boron ha^{-1} and the lowest (32.32) was observed from 0 ppm GA_3 and 0 kg boron ha^{-1}.

A significant variation in the number of branches per plant was observed due to effect of different levels of GA_3. At 65 DAT, 70 ppm GA_3 showed the maximum number of branches per plant (6.24) and control treatment (0 ppm GA_3) showed minimum number of branches per plant (5.13). In case of boron, at 65 DAT, the maximum number of branches per plant (6.21) was recorded from 10 kg boron ha^{-1} and minimum (5.48) was recorded from 0 kg boron ha^{-1}. Statistically significant difference among the treatment combinations was observed in respect of number of branches per plant at 35, 50 and 65 DAT. At 65 DAT, the maximum number of branches per plant (7.30) was produced by 70ppm GA_3 with 10 kg boron ha^{-1} while the minimum (4.73) was produced by treatment combination of 0ppm GA_3 and 0 kg boron ha^{-1}.

Significant variation was observed in respect of the number of flower clusters per plant, flowers per clusters and flowers per plant as influenced by different levels of GA_3 and boron. At 65 DAT, the highest values of these characters were obtained from 70 ppm GA_3, and the lowest were obtained from the control (0 ppm GA_3) treatment. In case of boron application the maximum values of these characters were found from the 10 kg boron ha^{-1} but the minimum values were obtained from 0 kg boron ha^{-1}. On the other hand, in case of interaction effect of GA_3 and boron the highest number of flower clusters per plant (15.13), flowers per cluster (6.20) and flowers per plant (85.97) were produced by the treatment combination of 70ppm GA_3 and 10 kg boron ha^{-1} whereas, the lowest number of flower clusters per plant (8.97), flowers per cluster (3.17) and flowers per plant (31.67) were produced by the control treatment (0ppm GA_3 with 0 kg boron ha^{-1}) at 65 DAT.

At 80 DAT, different levels of GA_3 and boron showed significant effect on number of fruit clusters per plant, fruits per cluster and fruits per plant. The highest values of these characters were obtained from 70 ppm GA_3 and the lowest were obtained from the control (0 ppm GA_3) treatment. In case of boron application the highest values of these characters were obtained from the 10 kg boron ha^{-1} while the lowest values were obtained from 0 kg boron ha^{-1}. In case of interaction effect of GA_3 and boron, the highest number of fruit clusters per plant (8.61), fruits per cluster (5.70), fruits per plant (46.17) were produced by the treatment combination of 70ppm GA_3 and 10 kg boron ha^{-1}. On the other hand, the lowest number of fruit clusters per plant (5.03), fruits per cluster (4.27) and fruits per plant (24.87) were produced by the control treatment (0ppm GA_3 with 0 kg boron ha^{-1}).

Different concentrations of GA_3 showed significant effect on percent of dry matter content in leaf and fruit. The maximum values of these characters were found at 70 ppm GA_3 and the minimum values were obtained from control treatment (0 ppm GA_3). On the other hand, these parameters were also significantly influenced by different levels of boron. The values of these characters were the maximum in 10 kg boron ha^{-1}, but the minimum in control (0 kg boron ha^{-1}) plants. The maximum dry matter content in leaf (14.40 %) and dry matter content in fruit (12.65 %) were given by the combination of 70 ppm GA_3 and 10 kg boron ha^{-1} whereas the minimum dry matter content in leaf (7.01 %) and dry matter content in fruit (6.53 %) were found in G_0B_0 (control treatment).

Different levels of GA_3 showed significant effect on fruit yield per hectare. The maximum value (68.67 t/ha) of this character was found from 70ppm GA_3 and the minimum value (53.63 t/ha) was obtained from control (0ppm GA_3) treatment. On the other hand, this parameter was also significantly influenced by different levels of boron. The values of this character was maximum (67.32 t/ha) in 10 kg boron ha^{-1}, but the minimum (56.69 t/ha) was from control (0 kg boron ha^{-1}). The treatment combination of 70 ppm GA_3 with 10 kg boron ha^{-1} gave the maximum yield (77.61 t/ha) whereas, the minimum yield (34.72 t/ha) was found from the control treatment.

The highest gross return (Tk. 582075/ha), net return (Tk. 364101/ha), benefit cost ratio (2.67), was recorded from the treatment combination of 70 ppm GA_3 with 10 kg boron ha^{-1} whereas, the lowest gross return (Tk. 260400/ha), net return (Tk. 47794/ha) and benefit cost ratio (1.22) was recorded from the combination of 0ppm GA_3 and 0 kg boron ha^{-1}.

The overall results obtained from the study facilitated to draw the following conclusions:

- The plants was produced the maximum growth and yield of tomato due to the application of 70 ppm GA_3.
- Boron played an important role on the growth, fruit formation and fruit yield of tomato. In respect of all the yield attributes and yield, 10 kg boron per hectare showed better performance.
- It may be drown the conclusion from above fact 70 ppm GA_3 and 10 kg boron ha^{-1} is suitable combination for the tomato production. Further investigation may be needed to observe in different agro-ecological zones before more conformation of the results.

REFERENCES

Adlakha, P.A. and Verma, S.K. (1965). Effect of gibbellic acid on fruiting and yield of tomatoes *Sci. & cult.* **31**: 301-303.

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

Ahmed, K.U. (1995). Phul Phal o Shak Shabji (in Bengali). 2nd edn, Alhaj Kamaluddin Ahmed, Banglow No. 2, Farm Gate, Dhaka, Bangladesh. p. 470.

Akand, M.H., Mazed, H.E.M.K., Pulok, M.A.I., Chowdhury, M.H.N. and Moonmoon, J.F. (2015). Growth and yield of tomato (*Lycopersicon esculentum* Mill.) as influenced by different level of gibberellic acid application. *Int. J. Applied Res*. **1**(3):71-74.

Akash, K., Biswas, T.K., Singh, N. and Lal, E.P. (2014). Effect of gibberellic acid on growth, quality and yield of tomato (*Lycopersicon esculentum* Mill.). *J. Agric. Vet. Sci.* **7**(7):28-30.

Alam, M.S., Iqbal, T.M.T., Ami, M. and Gaffar, M.A. (1989). Kamishitattic Fasaler Utpadan O Unnayan (In Bengali). T. M. Jubair Bin Iqbal, Sirajganj. Pp. 23-239.

Alpaslan, M. and Gunes, A. (2001). Interaction effects of boron and salinity stress on the growth, membrane permeability and mineral composition of tomato and cucumber plants. *Plant and Soil*. **236**(1): 123-128.

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

BBS. (2004). Statistical Year Book. Bangladesh Bureau of Statistics. Statistics Division, Ministry of Planning, Govt. of the People's Republic of Bangladesh, p. 135.

BBS. (2010). Statistical Year Book. Bangladesh Bureau of Statistics. Statistics Division, Ministry of Planning, Govt. of the People's Republic of Bangladesh, p. 149.

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

Blevins, D.G., Reinbott, T.M. and Boyce, P.J. (1993). Foliar fertilization of soybeans with boron and magnesium. *Plant Physiol*. p. 1-6.

Bora, P.C. and Selman, I.W. (1969). Growth and nitrogen accumulation in young tomato plants treated with gibberellic acid. *J.Exp. Bot*. **20**:288-301.

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

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

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

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

Chaudhary, B.R., Sharma, M.D., Shakya, S.M. and Gaut, D.M. (2004). Effect of plant growth regulators on growth, yield and quality of chilli (*Capsicum annuum* L.). *J. Inst. Agric. Anim. Sci.* **27**:65-68.

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

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

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

Chude, V.Q. and Oyinlola, E.Y. (2001). Yield and nutritional qualities of two tomato (*Lycopersicon lycopersicum* Karst) varieties as influenced by boron fertilization in tropical environment. Fourteenth International Plant Nutrition Colloquium, Hannover, Germany. pp. 358-359.

Davis, J.M., Sanders, D.C., Nelson, P.V., Lengnick, L. and Sperry, W.J. (2003). Boron improve growth, yield, and nutrient content of tomato. *J. Americ. Society of Hort. Sci.* **128** (3): 441- 446.

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

Desai, S.S., Chovatia, R.S. and Singh, V. (2012). Effect of different plant growth regulators and micronutrients on fruit characters and yield of tomato cv. GUJARAT TOMATO-3 (GT-3), *Asian J. Hort*. **7**(2):546-549.

Ejaz, M., Rahman, S., Waqas, R., Manan, A., Imran, M. and Bukhari, M.A. (2011). Combined efficacy of macro-nutrients and micro-nutrients as foliar application on growth and yield of tomato. *Int. J. Agro Vet. & Medic. Sci.* **5**(3): 327-335.

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

FAO. (2002). FAO Production Year Book. Food and Agricultural Organization of the United Nations, Rome 00100, Italy.

Farzaneh, N., Ghochin, A. and Majd, K.H. (2011). The effect of nitrogen and boron on growth, yield and concentration of some nutrient elements of tomato. *J. Sci. & Technol. of Greenhouse Cult.***1**(2): 19-29.

Gabal, G.M., Oben, G. and Marcell, R. (1990). Effect of GA_3 on morpho-physiological characters and yield of kidney beans *(Phasetolus valgaris). J. Agron. Crop Sci.* **160** (2): 91·101.

Gelmesa, D., Abebie, B. and Desalegn, L. (2012). Regulation of tomato (*Lycopersicon esculentum* Mill.) fruit setting and earliness by gibberellic acid and 2,4-dichlorophenoxy acetic acid application. *African J. Biotech*. **11**(51):11200-11206.

Gomez, K.A. and Gomez, A.A. (1984). Statistical procedures for agricultural research (2^{nd} Edn.). *Int. Rice Res*. John Willey and Sons, *Int. Sci.* Singapore. **3**:28-92.

Groot, S.P.C., Bruinsma, J. and Karssen, C.M. **(**1987). The role of endogenous gibberellins in seed and fruit development of tomato: Studies with a gibberellin-deficient mutant. *Physiol. Plant*. **71**:184–190.

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

Gupta, U.C. and Cutcliffe, J.A. (1985). Boron nutrition of carrots and table beets grown in a boron deficient soil. *Commun. Soil Sci*. **65**:381-409.

Gurdev, S. and Saxena, O.P. (1991). Seed treatments with bio-regulators in relation to wheat productivity. Proc. Nat. Symp. on Plant Growth. New Delhi, India. p.201-210.

Gurmani, A.R., Andaleep, R. and Khan, S. (2012). Biochemical attributes, plant growth and yield of tomato as affected by boron application rates. *J. Agric. Res.* **48**(2):451-455.

Gustafson, F.G. (1960). Influence of gibberellic acid on setting and development of Fruits in tomato. *Plant Physiol*. **35**:521-23.

Haque, M.E. (2007). Effect of nitrogen and boron on the growth and yield of tomato. MS thesis, Department of Soil Science, Sher-E-Bangla Agricultural University, Dhaka-1207.

Hathout, T.A., Sheteawi, S.A. and Khallal, S.M. (1993). Effect of mode of application of some hormonal contents. *Egypt.J. Physiol, Sci*. **17**(1):45-62.

Hossain, M.A.E. (1974). Studies on the effect of parachlorophenoxy acetic acid and gibberellic acid on the production of tomato. M.Sc. Ag, Thesis, Dep. Hort. Bangladesh Agril. Univ. Mymensingh.

Hossein, M. (2008). Effect of zinc and boron on the growth and yield of tomato. M.S. Thesis, Department of Agricultural Chemistry, BAU, Mymensingh.

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

Jyolsna, V.K. and Mathew, U. (2008). Boron nutrition of tomato grown in the laterite soils of southern Kerala. *J. Tropic. Agric.* **46**(1-2):73–75.

Kallo. (1986). Tomato (*Lycopersicon esculentum*, Mill.). allied publishers Pvt. New Delhi. pp. 203-226.

Kamruzzaman, A.H.M. (2007). Effect of B on the yield of mustard. M.S. Thesis. Department of Crop Botany, BAU, Mymensingh.

Kataoka, K., Uemachi, A. and Yazawa, S. (2003). Fruit growth and pseudoembryo development affected by uniconazole, an inhibitor of gibberellin biosynthesis, in pat-2 and auxin-induced parthenocarpic tomato fruits. *Scientia Horticulturae*. **98**:9-16.

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

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

Khan, M.M.A., Gautam, A.C., Mohammad, F., Siddiqui, M.H., Naeem, M. and Khan, M.N. (2006). Effect of gibberellic acid spray on performance of tomato. *Turk. J. Biol*. **30**: 11-16.

Krishi Projukti Hatboi (Handbook on Agro-technology). (2014). 6th edition, Bangladesh Agricultural Research Institute (BARI), Gazipur 1701, Bangladesh.

Kumar, M. and Sen, N.L. (2005). Effect of zinc, boron and gibberellic acid on yield of okra [*Abelmoschus esculentus* (L.) Moench]. *Indian J. Hort*. **62**(3):308-309.

Leonard, M., Kinet, K.M., Bodson, M. and Bernier, G. (1983). Enhanced Inflorescence development in tomato by growth substance treatments In relation to ^{14}C assimilate distribution. *Physiological plant arun*. **57**(1):85-89.

Lewis, D.H. (1980). Are there inter-relations between the metabolic role of boron, synthesis of phenolic phytoalexins and the germination of pollen? *New Phytol*. **84**:261–270.

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

Luis, M., Blasco, B., Juan, J., Rios and Riuz, M.J. (2012). Parameters symptomatic for boron toxicity in leaves of tomato plants. *Journal of Botany*. **12**(726206):17.

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

Mehta, A.K. and Mathi, P.J. (1975). Effect of growth regulators on summer tomato (*Lycopersicon esculentum* Mill.). *Haryana Hort. Sci.* **4**(34):167-176.

Nada, K., Nakai, H., Yoshida, H., Isozaki, M. and Hiratsuka, S. (2010). The effects of excess boron on growth, photosynthesis and fruit maturity of tomato [*Lycopersicon esculentum*] grown in hydroponic culture. *J. Hort. Res.* **9**(2):203-208.

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

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

Nelson, P.V., Krauskopf, D.M. and Mingis, N.C. (1977). Visual symptoms of nutrient deficiencies in Rieger Elatior begonia. *J. Amer. Soc. Hort. Sci*. **101**:65-68.

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

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

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

Oyinlola, E.Y. and Chude, V.O. (2004). Response of irrigated tomato to boron fertilizer on yield and quality. *Nigerian J. Soil Res*. **5**: 53-61.

Prasad, R.N., Singh, S.K., Yadava, R.B. and Chaurasia, S.N.S. (2013). Effect of GA_3 and NAA on growth and yield of tomato. *Vegetable Science*. **40**(2):195-197.

Rahman, M.M, Begum, R.A., Sheel, N.C. and Naser, H.M. (2013). Essential nutrient deficiency symptoms and their management in tomato plant (in bengali). Soil Science Division, BARI, Joydebpur, Gazipur-1701.

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

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

Rashid, M.M. (1983). Sabjeer Chash, 1st Edn., Begum Shahla Rashid Publishers, Joydebpur , Gazipur, 86-87.

Roy, R. and Nasiruddin, K.M. (2011). Effect of different level of GA_3 on growth and yield of cabbage. *J. Environ. Sci. & Natural Resources.* **4**(2):79-82.

Sakamoto, T. (2012). Role of Boron in plant and soil. *Jouranl of Citable Reviews of Life Sciences*. **12**(20): 23-29.

Salam, M.A., Siddique, M.A. and Rahim, M.A. (2010). Quality of tomato *(Lycopersicon esculentum* mill.) As influenced by boron and zinc under different levels of NPK fertilizers. *Bangladesh J. Agric. Res.* **35**(3):475-488.

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

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

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

Sanyal, D., Kar, P.L. and Longkukar, M. (1995). Effect of growth regulators on the physico-chemical composition of tomato (*Lycopersicon esculentum* Mill.). *Adv. Hort. & Forestry*. **4**:67-71.

Sathya, S. (2006). Effect of Boron on yield of tomato. M.Sc. (Ag.) Thesis. Agricultural College and Research Institute, Madurai, India.

Sawhney, V.K. and Greyson, R.I. (1972). On the initiation of the inflorescence and floral organs in tomato (*Lycopersicon esculentum*). *Can. J. Bot*. **62**:1493–1495.

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

Shah, M. (2006). Effect of N, P, K and B on the growth and quality of tomato. MS Thesis. Department of Horticulture, BAU, Mymensingh.

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

Singh, D. and Gangwar, R. (1991). Management practices for higher productivity in India a review. *Agric. Res.* **12**:15-21.

Sperry, W.J. (1995). Influence of boron and potassium on quality, yield, and nutrition of fresh-market tomato. PhD diss. N.C. State Univ., Raleigh, N.C.

Suganiya, S. and Kumuthini, D.H. (2015). Effect of Boron on flower and fruit set and yield of ratoon Brinjal crop. *Int. J. Scientific Res. Innov. Technol.* **2**:1.

Sumiati, E. (1987). Effect of plant growth regulators on flowering and yield of for tomato cultivars planted at Sukamandi in the low land. Bull. *Penelitian Hortikultura*. **15**(2):180-190.

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

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

Ullah, R., Ayub, G., Ilyas, M., Ahmad, M., Umar, M., Mukhtar, S. and Farooq, S. (2015). Growth and yield of tomato (*Lycopersicon esculentum* L.) as influenced by different levels of Zinc and Boron as foliar application. *American-Eurasian J. Agric. & Environ. Sci*. **15**(12):2495-2498.

Wikipedia. (2016). Gibberellic acid. https://en.wikipedia.org/wiki/Gibberellic_acid.

Wu, C.W., Lin, J.Y., Tarug, S.F. and Cheru, J.L. (1983). Effect of growth regulators on the growth and development of tomato and effect of plant growth regulators on vegetative growth of tomato. *J. Agric. China*. **124**:31-42.

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

Yadav, P.V.S., Abha, T. and Sharma, N.K. (2001). Effect of zinc and boron on growth, flowering and fruiting of tomato *(Lycopersicon esculentum, Mill). Haryana J. Hort. Sci*. **30**(1/2):105-107.

APPENDICES

Appendix I. (A) Records of meteorological information (monthly) during the period from October 2014 to March 2015

Name of months	Air temperature (^0C)		Relative humidity	Rain fall (mm)
	Maximum	Minimum		
October, 2014	32	17	83	40
November, 2014	28	16	80	0
December, 2014	22	13	73	0
January, 2015	21	12	68	0
February, 2015	27	18	65	5
March, 2015	30	20	58	13

Source: Bangladesh meteorological department (climate and weather division), Agargaon, Dhaka

(B) Morphological characteristics of soil of the experimental plot

Morphological features	characteristics
Location	Horticulture Garden, SAU ,Dhaka
AEZ	Modhupur Tract (28)
General Soil Type	Shallow Red Brown Terrace Soli
Land Type	Medium High Land
Soil Series	Tejgaon Fairly Leveled
Topography	Fairly Level
Flood Level	Above Flood Level
Drainage	Well Drained

(C) Sequence of cultural operation done in the experiment

Cultural Operations		**Date**
Seed sowing	:	1_{th} November, 2014
Plot preparation / Final land preparation	:	22_{th} November, 2014
Transplanting of seedlings	:	1_{th} December, 2014
First time fungicide application	:	15_{th} December, 2014
Sticking of plants	:	10_{th} January, 2015
Second time fungicide application	:	28_{th} January, 2015
First time harvesting	:	10_{th} March, 2015
Final harvesting	:	30_{th} March, 2015

Appendix –II Analysis of variance of different characters of tomato

Source of variation	**Degree of freedom**	**Mean square**			
		Plant height			
		20 DAT	**35 DAT**	**50 DAT**	**65 DAT**
Replications	2	4.623*	8.871**	13.138**	93.250*
Factor- A (GA_3)	3	9.145 NS	73.296*	60.653*	164.149*
Factor- B (Boron)	2	4.083*	150.174*	331.081*	636.906*
Interaction-(AxB)	6	3.520*	21.367*	156.0287*	328.110*
Error	22	3.425	12.583	31.546	71.129

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

Appendix –II Continued

Source of variation	Degree of freedom	Mean square			
		Number of leaves			
		20 DAT	35 DAT	50 DAT	65 DAT
Replications	2	0.394*	2.123*	26.567**	2.932**
Factor- A (GA_3)	3	2.352*	19.123*	56.279*	27.435*
Factor- B (Boron)	2	3.377*	27.570*	152.837*	83.227*
Interaction-(AxB)	6	8.133*	9.591*	37.267*	75.447*
Error	22	0.301	0.995	6.506	8.804

**Significant at 1% level
*Significant at 5% level

Appendix –II Continued

Source of variation	Degree of freedom	Mean square		
		Number of branches		
		35 DAT	50 DAT	65 DAT
Replications	2	0.010**	0.002**	0.276*
Factor- A (GA_3)	3	0.151*	1.442*	2.132*
Factor- B (Boron)	2	2.726*	5.493*	1.578*
Interaction-(AxB)	6	0.118*	1.277*	1.287*
Error	22	0.012	0.140	0.169

**Significant at 1% level
*Significant at 5% level

Appendix –II Continued

Source of variation	Degree of freedom	Mean square	
		Number of flower clusters per plant	
		50 DAT	65 DAT
Replications	2	0.039**	2.643*
Factor- A (GA_3)	3	0.603*	3.442*
Factor- B (Boron)	2	1.194*	15.663*
Interaction-(AxB)	6	0.280*	5.029*
Error	22	0.124	0.975

**Significant at 1% level
*Significant at 5% level

Appendix –II Continued

Source of variation	Degree of freedom	Mean square	
		Number of flowers per cluster	
		50 DAT	65 DAT
Replications	2	0.372**	0.214*
Factor- A (GA_3)	3	0.159*	0.626*
Factor- B (Boron)	2	0.570*	0.347*
Interaction-(AxB)	6	0.385*	3.420*
Error	22	0.083	0.106

**Significant at 1% level
*Significant at 5% level

Appendix –II Continued

Source of variation	Degree of freedom	Mean square	
		Number of flowers per plant	
		50 DAT	65 DAT
Replications	2	1.401**	67.085*
Factor- A (GA_3)	3	18.573*	333.484*
Factor- B (Boron)	2	25.021*	1177.197**
Interaction-(AxB)	6	9.411*	691.090**
Error	22	1.411	28.909

**Significant at 1% level
*Significant at 5% level

Appendix –II Continued

Source of variation	Degree of freedom	Mean square	
		Number of fruit clusters per plant	
		65 DAT	80 DAT
Replications	2	0.226 *	0.412*
Factor- A (GA_3)	3	2.100*	1.145*
Factor- B (Boron)	2	4.238*	2.801*
Interaction-(AxB)	6	2.692 *	2.638*
Error	22	0.172	0.294

**Significant at 1% level
*Significant at 5% level

Appendix –II Continued

Source of variation	Degree of freedom	Mean square	
		Number of fruits per cluster	
		65 DAT	80 DAT
Replications	2	0.344**	0.640*
Factor- A (GA_3)	3	0.552*	0.321*
Factor- B (Boron)	2	4.572*	1.001*
Interaction-(AxB)	6	0.728**	0.217*
Error	22	0.343	0.142

**Significant at 1% level
*Significant at 5% level

Appendix –II Continued

Source of variation	Degree of freedom	Mean square		
		Number of fruits per plant		
		50 DAT	65 DAT	80 DAT
Replications	2	0.041**	1.285**	17.294*
Factor- A (GA_3)	3	1.591*	7.165*	79.151*
Factor- B (Boron)	2	19.981*	286. 087*	220.225**
Interaction-(AxB)	6	1.003*	93.294*	52.749*
Error	22	0.037	2.644	9.833

**Significant at 1% level
*Significant at 5% level

Appendix-II Continued

Source of variation	Degree of freedom	Mean square					
		Fruit diameter (cm)	Weight of fruits/plant (gm)	Individual fruit weight of plant	Dry matter content in leaf (%)	Dry matter content in fruit (%)	Fruit yield (t/ha)
Replications	2	1.376*	23867.028**	73.498*	3.145*	0.172**	4.496**
Factor- A (GA_3)	3	4.493*	412363.185*	749.600**	18.251*	9.953*	383.855*
Factor- B (Boron)	2	3.335*	196883.361*	470.135*	14.630*	2.284*	340.696**
Interaction- (AxB)	6	0.951*	386994.324*	150.917*	10.425*	9.673**	377.993**
Error	22	0.296	24733.391	40.297	0.976	0.532	13.960

**Significant at 1% level
*Significant at 5% level

Appendix-III: Production cost (Tk.) of tomato per hectare land

Treatment	Labour cost	Ploughing cost	Seed cost	Insecticide/pesticide	Cow dung	Manure and fertilizers						Sticking	Sub total (A)
						Irrigation	Urea	TSP	MP	Boron	GA_3		
G_0B_0	20000	20000	8000	9000	45000	12000	7200	5500	3900	00	00	10000	140600
G_0B_1	20000	20000	8000	9000	45000	12000	7200	5500	3900	1800	00	10000	142400
G_0B_2	20000	20000	8000	9000	45000	12000	7200	5500	3900	2700	00	10000	143300
G_1B_0	20000	20000	8000	9000	45000	12000	7200	5500	3900	00	3000	10000	143600
G_1B_1	20000	20000	8000	9000	45000	12000	7200	5500	3900	1800	3000	10000	145400
G_1B_2	20000	20000	8000	9000	45000	12000	7200	5500	3900	2700	3000	10000	146300
G_2B_0	20000	20000	8000	9000	45000	12000	7200	5500	3900	00	4000	10000	144600
G_2B_1	20000	20000	8000	9000	45000	12000	7200	5500	3900	1800	4000	10000	146400
G_2B_2	20000	20000	8000	9000	45000	12000	7200	5500	3900	2700	4000	10000	147300
G_3B_0	20000	20000	8000	9000	45000	12000	7200	5500	3900	00	5000	10000	145600
G_3B_1	20000	20000	8000	9000	45000	12000	7200	5500	3900	1800	5000	10000	147400
G_3B_2	20000	20000	8000	9000	45000	12000	7200	5500	3900	2700	5000	10000	148300

Ploughing @=200 Tk./bullock, Cow dung@=4.5 tk/kg, Labour@=200 Tk./Head, Seed cost 24 Tk./gm, Urea=16 Tk./kg, TSP=22 Tk./kg, MP=15 Tk./kg, Boron=180 Tk./kg, GA_3=300Tk./gm, Insecticide: Ridomil gold=150 Tk./100 gm, Dithane M-45=120 Tk./100 gm, Malathion=200 Tk./250 ml, Furadan=400 Tk./kg

Appendix-III: Continued

B. Over head cost

Treatments	Cost of lease of land for 6 month (13% of value of land Tk.8,00,000/year	Miscellaneous cost (Tk .Of the input cost)	interest of running capital for 6 month (Tk.13% of cost/year)	Sub Total (Tk.) (B)	Total Cost of production(Tk./ha) Total cost (A)+ Overhead cost (B)
G_0B_0	52000	7030	12976	72006	212606
G_0B_1	52000	7120	13093	72213	214613
G_0B_2	52000	7165	13160	72325	215625
G_1B_0	52000	7180	13181	72361	215961
G_1B_1	52000	7270	13304	72574	217974
G_1B_2	52000	7315	13365	72680	218980
G_2B_0	52000	7230	13249	72479	217079
G_2B_1	52000	7320	13372	72692	219092
G_2B_2	52000	7365	13434	72799	220099
G_3B_0	52000	7280	13317	72597	218197
G_3B_1	52000	7370	13440	72810	220210
G_3B_2	52000	7415	13502	72917	221217

G_0 = 0 ppm GA_3 B_0 = 0 kg B ha^{-1}
G_1 = 70 ppm GA_3 B_1 = 10 kg B ha^{-1}
G_2 = 90 ppm GA_3 B_2 = 15 kg B ha^{-1}
G_3 = 110 ppm GA_3