ROLE OF GIBBERELLIC ACID AND BORON ON GROWTH AND YIELD OF TOMATO(*Solanum lycopersicum* L.)

BY

ISMAT ARA LABONY

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Approved by:

Dr. Shahnaz Sarkar **Professor** **Supervisor**	**Dr. Mohammad Mahbub Islam** **Associate Professor** **Co-Supervisor**

Dr. Mohammad Mahbub Islam
Associate Professor
Chairman
Examination Committee

Dr. Shahnaz Sarkar
Professor
Department of Agricultural Botany
Sher-e-Bangla Agricultural University
Dhaka, Bangladesh

Ref: Date:

CERTIFICATE

This is to certify that thesis entitled, **"ROLE OF GIBBERELLIC ACID AND BORON ON GROWTH AND YIELD OF TOMATO (*Solanum lycopersicum* L.)"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE** in **AGRICULTURAL BOTANY,** embodies the result of a piece of bona fide research work carried out by **ISMAT ARA LABONY, Registration No. 06-1897** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: December, 2012
Dhaka, Bangladesh

Prof. Dr. Shahnaz Sarkar
Department of Agricultural Botany
Sher-e-Bangla Agricultural University
Supervisor

DEDICATED TO
MY
BELOVED PARENTS

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ABSTRACT

The field experiment was conducted at the Sher-e-Bangla Agricultural University Farm, Dhaka, Bangladesh from October 2011 to March, 2012 to evaluate the role of gibberellic acid and boron on growth and yield of tomato. Four dose of gibberilic acid, viz., No Gibberellic Acid (GA_3), 10 ppm (GA_3), 20 ppm (GA_3) and 30 ppm (GA_3) and three levels of boron, viz., no Boric Acid, 1.5625 Kg Boric Acid/ha and 3.125 Kg Boric Acid/ha were used to conduct this experiment. The experiment was laid out in Randomized complete Block Design (RCBD) having two factors and replicated three times. The main effect of gibberllic acid indicated that, the plant height was influenced significantly by the gibberllic acid. The tallest plant, maximum number of leaves per plant, number of branches per plant, maximum number of flowers cluster per plant, number of flowers per cluster, number of flowers per plant were produced by 30 ppm gibberellic acid. The earliest of days of first flowering, earliest in 50% flowering, maximum number of fruits per cluster, number of fruit per plant, minimum percent of fruit dropping, earliest of days of first harvesting), the longest fruit length, largest fruit breath, largest individual fruit weight was observed in 20ppm gibberellic acid. The different gibberellic acid had significant effect on the yield of fruits per hectare. The maximum yield of fruits per hectare (68.00 tones) was obtained 20ppm gibberellic acid. The maximum growth and yield contributing character of tomato was observed in 3.125 Kg Boric Acid/ha. The highest yield of fruit (67.14 t/ha) was obtained from 3.125 Kg Boric Acid/ha. The interaction between different gibberellic acid and boron was significantly influenced on the all growth and yield characters. The maximum growth and yield contributing character of tomato was observed in 20.00 ppm of gibberellic acid with 3.125 Kg boric acid per ha. The highest yield of fruits per hectare (78.56 tones) was obtained from 20 ppm GA_3 with 3.125 Kg Boric Acid/ha.

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LIST OF ABBREVIATION AND ACRONYMS

AEZ	=	Agro-Ecological Zone
BARI	=	Bangladesh Agricultural Research Institute
BBS	=	Bangladesh Bureau of Statistics
FAO	=	Food and Agricultural Organization
N	=	Nitrogen
B	=	Boron
GA_3	=	Gibberellic acid
et al.	=	And others
TSP	=	Triple Super Phosphate
MOP	=	Muirate of Potash
RCBD	=	Randomized Complete Block Design
DAT	=	Days after Transplanting
ha^{-1}	=	Per hectare
g	=	gram (s)
kg	=	Kilogram
SAU	=	Sher-e-Bangla Agricultural University
SRDI	=	Soil Resources and Development Institute
wt	=	Weight
LSD	=	Least Significant Difference
^0C	=	Degree Celsius
NS	=	Not significant
Max	=	Maximum
Min	=	Minimum
%	=	Percent
NPK	=	Nitrogen, Phosphorus and Potassium
CV%	=	Percentage of Coefficient of Variance

Chapter 1
Introduction

CHAPTER I

INTRODUCTION

Tomato (*Solanum lycopersicum*) belongs to Solanaceae and is one of the important popular nutritious fruit vegetables crop grown in all over the world including Bangladesh. Usually, it grows well during winter season and cultivated in all parts of the country (Haque *et al.*, 1999) but now it also cultivated in summer season. The origin of tomato is South America (Salunkhe *et al.,* 1987) particularly the Peru-Ecuador-Bolivia areas of Andes and is adapted to a wide variety of climates. At present, tomato ranks third, next to potato and sweet potato, in terms of world vegetable production (FAO, 2002). The leading tomato producing countries of the world are China, India, Egypt, Turkey, Iran, Italy, Mexico, Brazil and Indonesia (FAO, 1999).

The food value of tomato fruit is very rich because of higher contents of carotene, vitamin A, B and C along with minerals- calcium and potassium (Bose and Som, 1990). Vitamin A and calcium act as an antioxidant and secondary messenger, respectively which have anti aging properties. It is much popular as salad and is also used to prepare soups, juice, ketchup, pickles, sauces, paste, powder and other products (Ahmad *et al.*, 1986; Thompson and Kelly, 1983 and Bose and Som, 1990).

Previous report showed that Bangladesh produced 190 thousand tons of tomato with 23.88 thousand hectares of land during the year 2009-2010 and the average yield being 7.95 t ha^{-1} (BBS, 2011), which is very low in comparison with that of tomato producing other countries, namely India (15.67 t/ha), Japan (52.82 t/ha) and USA (63.66 t/ha) and suggesting that the yield of tomato in our country is not enough to fulfill our present demand. The low yield of tomato in Bangladesh, however, is not an indication of low yielding ability of this crop, but of the fact that the tomatoes grown here are not always of high yielding cultivars and that the cultural practices commonly used by the growers are not improved. Since the soil and climatic conditions of Bangladesh during the winter season are congenial to proper growth of tomato, it is expected that improved management practices would augment the yield considerably. Tomato has a great demand throughout the year, but its production is concentrated during the months from January to march in our country. Although production of summer tomatoes has just started in this country, there is still a long away to go for successful commercial production.

In Bangladesh, tomato is cultivated only in winter season. There is considerable interest in extending the cultivation of tomato over a longer period. However, high temperature before and after the short winter season inhibit the flower and fruit development. Induction of artificial parthenocarpy through application of plant growth regulators (PGRs) enables fertilization-independent fruit development that can reduce yield fluctuation in crops like tomato, pepper (Heuvelink and Korner, 2001). This could be possible by application of certain PGRs like auxin and GA_3 that bring the possibility of tomato production under adverse environmental conditions. Gemici *et al.* (2006) reported that application of synthetic auxin and gibberellins (GAs) are effective in increasing both yield and quality of tomato. Those PGRs are used extensively in tomato to enhance yield by improving fruit set, size and number (Batlang, 2008; Serrani *et al.*, 2007a) and could have practical application for tomato growers. Tomato fruit setting was promoted by gibberellic acid (GA_3) at low concentration (Sasaki et al., 2005; Khan et al., 2006). Furthermore, Bensen and Zeevaart (1990) reported that GA_3 is more effective on promotion of vegetative growth at concentration of 10 ppm or below, interestingly the fruit weight increased at concentration both 20 ppm and 30 ppm but not at 10 ppm. Johnson and Liverman, (1957) reported that GA_3, promote fruit development and yield even under high temperature environment. In addition, Singh and choudhury, (1966). stated that fruit set of tomato can be increased by applying PGRs to compensate the deficiency of natural growth substances required for its normal development Therefore, these results suggest that external use of GA_3 have positive influence on the growth and development and fruit yield of tomato. However, little is known about the concentration of GA_3 on tomato production.

It has been reported that macronutrients are consumed in larger quantities and are present in plant tissue in quantities from 0.2% to 4.0% (on a dry matter weight basis) whereas micro nutrients are present in plant tissue in quantities measured in parts per million (ppm), ranging from 5 to 200 ppm, or less than 0.02% dry weight. These micro elements are sometimes called minor elements or trace elements, but use of the term micronutrient is encouraged by the American Society of Agronomy and the Soil Science Society of America. Among these micronutrient on of the important micronutrient is boron (B). Bose and Tripathi, (1996) reported that the increase in vegetative growth of tomato could be attributed to physiological role of B 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. 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. Besides this on of the main effect of boron is, it helps in well growth of reproductive part of the plant. Boron deficiency induces the inhibition of root growth and disrupts cell membranes, which has a direct effect on plant's ion uptake. Fruit becomes unmarketable because of their cracked or corky lesions under deficiency of B. Separately, excess boron can block the transportation of calcium that is sensitive to drought or salinity stress. However, to my knowledge, information is limited about the doses of B on regulation of growth and fruit yield of tomato.

Many author showed that GA_3 can increase plant height, fruit weight (Sasaki *et al*., 2005; Khan *et al.,* 2006). In addition, B also has effects on many functions of the plant such as hormone movement, active ions absorption, flowering and fruiting process, pollen germination, carbohydrates, nitrogen metabolism and water relations in the plants. However, the combined use of GA_3 and B is not clearly shown by the earlier scientist. Considering the above situation, the present experiment was designed with the following objectives:

I. To examine the effects of GA_3 and B on growth and yield performance of tomato.

II. To study the interaction effect of GA_3 and B on growth and yield of tomato.

III. To find out the best combination of GA_3 and B for better growth and yield of tomato.

Chapter 2
Review of literature

CHAPTER II

REVIEW OF LITERATURE

Tomato is an important vegetable crop and received much attention of the researchers throughout the world to develop its suitable production technique. Establishment and growth of tomato plants depend on gibberellic acid and boron. Number of researchers has studied the effect of gibberellic acid and boron on the growth and yield of tomato in different countries of the world, but their findings have little relevance to the agro-ecological situation of Bangladesh. However, literature available in this respect at home and abroad has been reviewed here, which will contribute useful information to the present study.

2.1 Effect of gibberellic acid on the growth and yield of tomato

Gelmesa *et al.* (2010) conducted to determine the effects of different concentrations and combinations of 2,4-dichlorophenoxyacetic acid (2,4-D) and gibberellic acid (GA_3) spray on fruit yield and quality of tomato. The experiment consisted of two tomato varieties-one processing (Roma VF) and one fresh market (Fetan), three levels of 2,4-dichlorophenoxyacetic acid (2,4- D) (0, 5 and 10 mg l-1) and four levels of gibberellic acid (GA_3) (0, 10, 15 and 20 mg l-1) arranged in 2 × 3 × 4 factorial combinations, in randomized completed block design with three replications. The result showed increase in fruit length from 5.44 to 6.72 cm at 10 mg l-1 2,4-D combined with 10 mg l-1 GA_3 above the control, increased fruit weight by 13% due to 2,4-D and reduced fruit weight in single or combined application of GA3 with 2,4-D. Fruit pericarp thickness was increased by about 50% due to 2,4-D and GA3 application above the control. Titratable acidity, total soluble solids and lycopene content were also increased due to combined application of 2,4-D and GA_3 spray. Lower fruit pH is another quality attributes of tomato affected by 2,4-D application while that of GA_3 has no effect. Final fruit yield were significantly improved above the control even though both varieties responded differently. For Roma VF, GA_3 at concentration of 10 and 15 mg l-1 resulted in maximum fruit yield of 69.50 and 67.92 ton ha-1, respectively in the absence of 2,4-D. For Fetan, maximum marketable fruit yield of 74.39 and 74.20 ton ha-1 was obtained from treatment combinations of 10 + 15 and 5 + 0 2,4-D and GA_3, respectively. Hence, yield increment of about 35% for Roma VF and 18% for Fetan were produced at 10 mg l-1 GA_3 and 10 + 15 mg l-1 2,4-D and GA_3, respectively over the control. Significant increase in fruit size and weight due to 2,4-D and increased fruit number due to GA_3 spray contributed to increased fruit yield. The results indicated that both PGRs are important in tomato production to boost yield and improve fruit quality under unfavorable climatic conditions of high temperature. Therefore, it is important to further investigate application methods and concentrations of the PGRs under concern in different growing conditions on different tomato cultivars.

Irfan and Ismail (2009) reported that juglone (5-hydroxy-1,4-naphthoquinone) is an allelochemical responsible for walnut allelopathy. The effects of gibberellic acid (GA_3) and kinetin (KIN) on overcoming the effects of juglone stress on seed germination and seedling growth were investigated in barley, wheat, cucumber, alfalfa, and tomato. Seeds pre-treated with plant growth regulators were used to test their effects on the alleviation of juglone stress. It was observed that seed germination in tomato and wheat was inhibited by juglone and that the plant growth regulators alleviated it significantly. Elongation and dry weight of the seedlings of all the species used in the study were reduced significantly by juglone, and the plant growth regulators alleviated them. The most effective treatment was the GA_3+KIN combination, which was best on seedling growth in tomato and wheat.

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

Vegetable growth regulators are capable of controlling the reproductive development, from flower differentiation until the last stages in fruit development. In particular, fruit set and development stage depends on the endogenous content of this substance, being possible to manipulate the beginning of fruit development by external application of hormones. We have previously evaluated the fruit set and development process in tomato cultivation in the greenhouse in response to the application of beta -NOA and GA< sub>3</ sub> in fixed doses. Differential sensitivity was observed depending on the genotype and regulator type. Studies were conducted to establish the optimum dose and moment for the application of beta -NOA and GA< sub>3</ sub> as ways to improve the fruit set and development of parthenocarpic fruits. Regulator types beta -NOA and GA< sub>3</ sub> in variable doses and application dates were considered as factors. Using unpollinated ovaries as an experimental system, it was possible to conclude that the application of 40 ppm of beta -NOA at 7 days post-anthesis would offer the best advantages from a performance point of view and a lower physiologic impact, not altering the period of fruit development (Aguero *et al.*, 2007) .

The effect of gibberellic acid (GA at 100 and 250 ppm), ethrel [ethephon] at 100 and 250 ppm, paclobutrazol at 100 and 150 ppm, calcium chloride at 0.5 and 1.0% and kinetin at 10 and 25 ppm on the yield and quality of tomato cultivars Co-3 and PKM-1 was evaluated in Tamil Nadu, India. Spraying was at 15, 25, 35 and 45 days after transplanting. Paclobutrazol sprayed on leaves at 150 ppm showed the highest fruit number, with maximum fruit set percentage (64%). Whole plant sprays with GA, paclobutrazol and kinetin resulted in the increase in fruit yield. Calcium chloride at 1% showed maximum fruit skin thickness and storage life (Anuja and Shakila, 2006).

Sasaki *et al.* (2005) studied the effect of plant growth regulators on fruits of tomato (*Lycopersicon esculentum* cv. Momotaro) under high temperature and in a field

(Japan) under rain shelter. Tomato plants exposed to high temperature (34/20° C) had reduced fruit set. Treatments of plant growth regulators reduced the fruit set inhibition by high temperature to some extent, especially treatment with mixtures of 4-chlorophenoxy acetic acid (4-CPA) and gibberellins (GAs). They also reported threat tomatoes treated with a mixture of 4-CPA and GAs showed increased fruit set and the numbers of normal fruits were more than the plants treated with 4-CPA alone during summer.

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

Bhosle *et al.* (2002) reported the effects of NAA (25, 50 and 75 ppm), gebberellic acid (15, 30 and 45 ppm) and 4-CPA (25, 50 and 75 ppm) on the growth and yield of tomato cultivars Dhanashree and Rajashree during the summer of 1997. They reported that the number of flowers per cluster, fruit weight and marketable yield increased with increased with increasing rates of the plant growth regulators.

Treatment with 30 ppm gibberellic acid resulted in the tallest plants, where as treatment with 25 ppm 4-CPA and 45ppm gibberellic acid resulted in the highest number of primary branches of Dhanashree 94.16) and Rajashree (5.38), respectively. The highest marketable yield of Dhanashree and Rajshree was also found from treatment with 75 ppm 4-CPA.

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

Matins *et al.* (1999) studied the growth regulators and leaf anatomy in tomato (*Lycopersicon esculentum* Mill.) cv. Angela Gigante. The plant growth regulators Gas (50 mg/L), NAA (100 mg/L), Chlormequat (1500 mg/L) and SADH [daminozide] (3000 mg/L) were applied to greenhouse tomato cv. Angela Giante plants at the 4-true-leaves stage. Twenty days after treatment the growth promoters (GA3 and NAA) increased the number of stomata per square mm on the adaxial epidermis compared with untreated controls and decreased the number of epidermal cells on both sides of the leaves. The growth retardants (Chlormequat and SADH) increased the thickness of the lacunary parenchyma more than the growth promoters. El-Habbasha *et al.* (1999) studied the response of tomato plants to foliar spray with some growth regulators under late summer conditions. Field experiments were carried out with tomato (cv. Castelrock) over two growing seasons (1993-94) at Shalakan, Egypt. The effects of GA_3, IAA, TPA (tolyphathalamic acid) and 4-CPA (each at 2 different concentrations on fruit yield and quality were investigated. Many of the treatments significantly increase fruit set percentage and total fruit yield, but also the percentage of puffy and parthenocarpic fruits, compared with controls.

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

Bima *et al.* (1995) worked with gibberellic acid and found that GA_3 (5-10 ppm) enhanced germination of seeds and induced flowering. NAA and 2,4-D (5-10 ppm) induced early flowering and promote fruit set.

El- Abd *et al.* (1995) studied the effect of plant growth regulators for improving fruit set of tomato. Two tomato cv. Alicante crops were produced in pots in the greenhouse. When the third flower of the second cluster reached anthesis, the second cluster was sprayed with IAA, GA_3, or ABA at 10-4, 10-6, or 10-8 M each and ACC at 10-9, 10-10 or 10-11 M. all concentrations of IAA, GA_3, ACC and ABA induced early fruit set compared with controls sprayed with distilled water. For the first of the 2 crops, the highest ABA concentration (10-5 M) accelerated fruit set, but the 2 concentrations delayed it. For the second crop, however, all ABA treatments accelerated fruit set. ABA applications also retarded red fruit colour formation, more so at increasing concentrations, IAA at 10-6 M resulted in the formation of double flowers of the total fruits set from treated flowers, 40% were double. GA_3 led to the formation of leafy clusters, with the number of leaves formed increasing with GA_3 concentration.

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

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

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

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

Onofeghara (1981) conducted an experiment on tomato sprayed with GA at 20-1000 ppm and NAA at 25-50 ppm. He observed that GA promoted flower primodia production and the number of primordial and NAA promoted flowering and fruiting. Saleh and Abdul (1980) conducted an experiment with GA_3 (25 or 50 ppm) which was applied 3 times in June or early July. They reported that GA_3 stimulated plant growth. It reduced the total number of flowers per plant, but increased the total yield compared to the control. GA_3 also improved fruit quality.

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 2, 4-D at 5 ppm followed by NAA at 0.2 ppm. He also reported that GA treatments at 10 or 25 ppm improved the yield of tomato cv. Pusa Ruby irrespective of planting date. GA gave earlier setting and maturity.

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

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

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.

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

Adlakha and Verma (1965) observed that when the first four clusters of tomato plants were sprayed three times at unspecified intervals with GA 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 GA in concentration of 50 and 100 ppm on flower cluster at anthesis and noted that the application of GA at 100 ppm could appreciably increase fruit size, weitht, protein, sugar and ascorbic acid contents.
Gustafson (1960) worked with different concentration of GA and observed that when 35 and 70 ppm GA 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 weitht. 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.

Rappaport (1960) noted that GA had no significant effect on fruit weight or size either at cool (11°C) or warm (23°C) night temperatures; but it strikingly reduced fruit size at an optimal temperature (17°C).

2.2 Effect of boron on growth and yield of tomato

Naz *et al.* (2012) Experiment was conducted to study the effect of Boron (B) on the growth and yield of Rio Grand and Rio Figure cultivar of tomato. Different doses of B (0, 0.5, 1.0, 2.0, 3.0 and 5.0kg ha^{-1}) with constant doses of nitrogen, phosphorus and potash was incorporated at the rate of 150, 100, 60 kg ha^{-1} . However, 2 kg B ha^{-1} resulted in maximum number of flower clusters per plant, fruit set percentage, total yield, fruit weight loss and total soluble solid. Rio Grand cultivar of tomato showed significant effect on all parameters. Maximum number of flower clusters per plant, fruit set percentage and total yield were recorded with Rio Grand cultivar of tomato. Generally it can be concluded that 2 kg B ha^{-1} significantly affected flowering and fruiting of Rio Grand cultivar.

Salam *et al.* (2010) was conducted at the 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 (N= 253, P= 90, and K= 125 kg/ha).

An experiment was conducted by Meena (2010) with the treatment comprised on boron (1, 4.5 and 2. Kg/ha) and two foliar spray at 40 DAT and 60 DAT. Sinificnatly more plant height and plant spread at 60 DAT and at harvest, leaf area per plant at harvest, number of flowers per plant, fruit set percentage, number of fruits per plant, average fruit weight and fruit yield and lower fruit drop percentage were recorded with application of boron as foliar spray at 2. Kg/ha. Application of boron at 2.0 kg/ha gave significantly higher total soluble solids, ascorbic acid contents and TSS/acid ratio as coprared to boron at 1.0 and 1.5 kg/ha. Quality parameters such as fruit cracking percentage significantly reduced due to foliar application of boron at 2.0 Kg/ha.

Aydn and Sevinc (2006) carried out a pot experiment with tomato plant grown on zinc (Zn) deficient soil to study the effect of increasing boron (B) and (Zn) application on nutritional status and shoot growth under green house conditions. Three levels of B (0, 10 and 20 mg/kg) and two levels of Zn (0 and 10 mg/kg) applied to tomato plant. At the end of experiment, shoot dry matter yield of tomato plant decreased with B application, while increased with Zn application. Nitrogen, P and k concentrations of plant increased with B and Zn applications. Same way, Cu, Zn and Mn concentrations of tomato also increased same treatments, but Fe concentration of tomato was adverse affected with Zn application while positive affect B application.

The effect of micronutrient boron application on dry matter yield, uptake and distribution in the plant parts of two tomato varieties (Roma VF and Dandio) were studied by (Oyinlola (2005) in a rain fed trial. Results showed variations in boron distribution among plant parts. The concentration of boron (B) ranged from 6.0-10.90, 5.8-18.6 mg/kg., in leaves, stem and roots, respectively. The effect of born 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 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 Roma VF. Application of B increased fruit yield of tomato fruit by 233 and 192% relative to the control for 'Roma VF' and 'Dandino' varieties, respectively.

Naresh Babu (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 fruits per plant (0.961 and 0.969) as well as average fruit weight (0.985 g and 0.980 g) 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.

An experiment was conducted to find out the influences of B and salinity on tomato (*Lycopersicon esculentum* Mill. Cv.5656) in lysimeters by Ben (2002). B levels were 0.028, 0.185, 0.37, 0.74 1.11 and 1.48 mol/m. Excess boron was found to decrease yield and transpiration of tomatoes. This effect was inhibited when plants were exposed to simultaneous B and salinity stresses. Both irrigation water salinity and boron concentration influenced water use of the plants in the same manner as they influenced yield. While yield was found to decrease with increased boron concentration in leaf tissue, increased salinity led to decreased boron accumulation. Yield response was found to correlate better to B concentration in irrigation water and soil solution than to plant tissue B content.

A greenhouse study was conducted by Alpaslan and Gunes (2001) to determine interactive effects of NaCl salinity and B on the growth, Sodium (Na), chloride (Cl), Boron (B), potassium (K) concentrations 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 5 mg/kg B treatments in both plants. Salinity caused an increase 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 nonsaline conditions, but the decrease in dry weights due to B toxicity was more pronounced in saline conditions especially in cucumber.

A green house experiment involving four levels of boron (0, 5, 10 and 20 mg B/kg) and the level of Zinc was conducted by Aydin *et al.* (2000) in tomato plants (*Lycopersicon esculentum* L., cv. Lale). Boron toxicity symptoms occurred at 10 to 20 mg/kg B levels. These symptoms were somewhat lower in the plants grown with applied Zn. Fresh and Dry weights of the plants clearly decreased with applied B. However Zn treatments partially depressed the inhibitory effect of B on the growth.

Increased levels of B increased the concentrations of B in plant tissues and to a greater extent in the absence of applied Zn. Both Zn and B treatments caused an increase in Zn concentration in the plants.

The effect of supplementary phosphorus on growth and yield of tomato (*Lycopersicon esculentum* cv. Target F_1) plants grown at high boron was investigated by Cengiz *et al.* (2009). The results showed that high B reduced dry matter, fruit yield and chlorophyll content. High B plus 0.5 or 1 mM P increased plant dry matter, fruit yield and chlorophyll concentrations as compared to high B treatments only.

Bose and Tripathi (1996) carried out and experiment to find the physiological role of boron and its involvement in the metabolism of protein 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 protein, synthesis of pectin, maintaining the correct water relation with the plant, resynthesis of pectin, maintaining the correct water relation within the plant, resynthesis of adenosine triphopate (ATP) and traslocation of sugar at development of the flowering and fruiting stages.

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 slat absorption, flowering and fruiting process, pollen germination, carbohydrates and 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 shot apex. Cracking of surface of tomato fruit results in large losses.

2.3 Combined use of gibberellic acid and boron on growth and yield of tomato

The effects of GA< sub>3</ sub> [gibberellic acid], NAA, 4-CPA and boron at 25 or 50 ppm on the growth and yield of tomato (cv. Dhanshree) were studied in Rahuri, Maharashtra, India, during the summer season of 2003. Plant height was greatest with GA< sub>3</ sub> at 25 and 50 ppm (74.21 and 75.33 cm, respectively), and 4-CPA at 50 ppm (72.22 cm). The number of primary branches per plant did not significantly vary among the treatments. GA< sub>3</ sub> at 50 ppm resulted in the lowest number of primary branches per plant (69.55). The number of fruits per plant (38.86) was highest 50 ppm boron. The highest yields were recorded for boron at 25 and 50 ppm (254.2 and 264.4 quintal/ha) (Nibhavanti, *et al.*,2006.).

Chapter 3

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

This chapter deals with the materials and methods that were used in carrying out the experiment. It includes a short description of location of the experimental plot, characteristics of soil, climate and materials used for the experiment. The details of the experiment are described below.

3.1 Location of the experiment field

The field experiment was conducted at the Sher-e-Bangla Agricultural University Farm, Dhaka, Bangladesh from October 2011 to March, 2012 to evaluate the role of gibberellic acid and boron on growth and yield of tomato which is shown in Appendix I.

3.2 Climate of the experimental area

The area is characterized by hot and humid climate. The average rainfall of the locality of the experimental area is 209.06 mm, the minimum and maximum temperature is 11.10 °C and 34.80 °C respectively. The average relative humidity was 75.8 % during October 2011 to March, 2012.

3.3. Soil of the experimental field

Initial soil samples from 0-15 cm depth were collected from experimental field. The collected samples were analyzed at Soil Resources Development Institute (SRDI), Dhaka, Bangladesh. The physio-chemical properties of the soil are presented in Appendix II. The soil of the experimental plots belonged to the agro-ecological zone of Madhupur Tract (AEZ-28), which is shown in Appendix II.

3.4 Plant materials used

In this research work, the seeds of one tomato varieties were used as planting materials. The tomato varieties used in the experiments were BARI Tomato 2. Variety is semi-indeterminate type. BARI Tomato-2 was collected from the Horticulture Research Centre, Bangladesh Agricultural Research Institute (BARI) at Joydebpur, Gazipur.

3.5. Raising of seedlings

Tomato seedlings were raised in seedbed of 2 m x 1m size. A distance of 50 cm was maintained between the beds. The soil was well prepared and converted into loose friable and dried mass by spading. All weeds and stubbles were removed. Four gram of seeds was sown on each seedbed. 50gm furadan was applied around each seedbed as precautionary measure against fungus, ants, worm and other harmful insects. The emergence of the seedlings took place with 6 to 8 days after sowing. Diathane M-45 was sprayed in the seedbeds @ 2 g/l, to protect the seedlings from damping off and other diseases. Weeding, Mulching and Irrigation were done as and when required.

3.6 Treatments and layout of the experiment

The experiment consisted of two factors; (A) different dose of gibberilic acid and (B) different levels of boron. The levels of the two factors were as follows:

Factor A: different doses of gibberilic acid

a) G_0= No GibberellicAcid(GA_3)

b) G_1=10 ppm

c) G_2=20 ppm

d) G_3=30 ppm

Factor B: different levels of boron

a) B_0= no Boric Acid

b) B_1=1.5625 Kg Boric Acid/ha

c) B_2=3.125 Kg Boric Acid/ha

3.7 Design and layout of the experiment

The experiment was laid out in Randomized complete Block Design (RCBD) having two factors and replicated three times. An area was divided into three equal blocks. Each block was consists of 12 plots where all treatments were allotted randomly. These there were 36 unit plots altogether in the experiment. The size of each plot was 2.4m × 2.0 m (4.8m^2). The distance between two blocks and two plots were kept 1m and 0.80 m respectively which is shown in Appendix III.

3.8 Cultivation procedure

3.8.1. Land preparation

The land for growing the crop was first opened with a tractor. Later on the land was ploughed three times followed by laddering to obtain desirable tilth. The corners of the land were spaded and larger clods were broken into smaller pieces. After ploughing and laddering, all the stubbles and uprooted weeds were removed and then the land was ready. Finally, the unit plots were prepared as 15 cm raised beds. Ten pits were made in each plot in two rows maintaining a recommended spacing of row to row distance was 60 cm and plant to plant distance was 50 cm (BARI, 2000).The field layout and design or the experiment was followed immediately after land preparation.

3.8.2. Manure and fertilizers and its methods of application

In addition to the fertilizer under treatment, 10 tones of cow dung manure, 550 kg of urea, 450 kg of triple super phosphate (TSP), 250 kg of MoP per hectare and boron as per treatment applied in the experimental plot. Half of the cow dung, the entire quantity of TSP, ½ of MP was applied during final land preparation. The remaining cow dung was applied during pit preparation. The entire urea and the rest of MP were applied in three equal installments at 15, 30 and 50 days after transplanting in the field.

3.8.3 Transplanting of seedlings

Healthy and uniform 30 days old seedlings were uprooted separately from the seed bed and were transplanted in the experimental plots in the afternoon. The seedbed was watered before uprooting the seedlings from the seedbed so as to minimize damage to the roots. The seedlings were watered after transplanting. Seedlings were also planted around the border area of the experimental plots for gap filling.

3.8.4 Intercultural operations

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

a) Gap filling

When the seedlings were well established, the soil around the base of each seedling was pulverized. A few gaps filling was done by healthy seedlings of the same stock where initial planted seedling failed to survive.

b) Weeding and Mulching

Weeding and Mulching were accomplished as and whenever necessary to keep the crop free from weeds, for better soil aeration and to break the crust. It also helped in soil moisture conservation.

c) Staking and Pruning

When the plants were well established, staking was given to each plant by Daincha (*Sesbania* sp.) and bamboo sticks to keep them erect. Within a few days of staking, as the plants grew up, the plants were given a uniform moderate pruning.

d) Irrigation

Light irrigation was provided immediately after transplanting the seedlings and it was continued till the seedlings established in the field. Thereafter irrigation was provided.

e) Plant protection

Insect pests: Malathion 57 EC was applied & 2 ml l^{-1} against the insect pests like cut worm, leaf hopper, fruit borer and others. The insecticide application was made fortnightly for a week after transplanting to a week before first harvesting. Furadan 10 G was also applied during final land preparation as soil insecticide.

Diseases: During foggy weather precautionary measured against disease infection of Winter tomato was taken by spraying Diathane M-45 fortnightly & 2 g l^{-1}, at the early vegetative stage. Ridomil gold was also applied @ 2 g l^{-1} against early blight disease of tomato.

f) Gibberellic acid

Gibberellic acid was sprayed in different times. GA_3 (as per treatment) was sprayed before flowering initiation in three times at 15 days interval.

3.9 Harvesting

Fruits were harvested at 5-day intervals during early ripe stage when they attained slightly red color. Harvesting was started from 20 January, 2012 and was continued up to 13 March 2012.

3.10 Data collection

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

3.10.1 Plant height (cm)

Plant height at 20, 30, 40, 50 days after transplanting (DAT) was measured from sample plants in centimeter from the ground level to the tip of the longest stem and mean value was calculated.

3.10.2 Number of leaves per plant

Number of leaves per plant at 20, 30, 40, 50 days after transplanting (DAT) was recorded by the following formula :

$$\text{Number of leaves per plant} = \frac{\text{Total number of leaves from ten sample plants}}{10}$$

3.10.3 Number of primary branches per plant

Number of primary branches per plant at 20, 30, 40, 50 days after transplanting (DAT) was measured by the following formula:

$$\text{Number of branches per plant} = \frac{\text{Total number of primary branches from ten sample plant}}{10}$$

3.10.4 Days to first flowering

Dates of first flowering were recorded treatment wise and the period of time for first flowering in days was calculated from the date of transplanting.

3.10.5 Days to 50% flowering

The date of 50% flowering on the sample plants was recorded, and the period required in days from the date of transplanting was calculated. The date of opening of the first flower of fifty percent was considered as the date of 50% flowering.

3.10.6 Number of flowers cluster per plant

Total number of flower clusters was counted from selected flowers cluster of sample plant and was calculated by the following formula:

$$\text{Number of cluster per plant} = \frac{\text{Total number of cluster from ten sample plants}}{\text{Total number of flowers clusters from ten sample plants}}$$

3.10.7 Number of flowers per cluster

Total number of flowers was counted from selected flowers cluster of sample plant and was calculated by the following formula:

$$\text{Number of flowers per cluster} = \frac{\text{Total number of flowers from ten sample cluster}}{\text{Ten sample clusters}}$$

3.10.8 Number of flowers per plant

Total number of flowers was counted from selected flowers of sample plant and was calculated by the following formula:

$$\text{Number of flowers per plant} = \frac{\text{Total number of flowers from ten sample plants}}{\text{Ten sample plants}}$$

3.10.9 Number of fruits per cluster

Total number of fruits was counted from selected cluster of sample plant and was calculated by the following formula:

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

3.10.10 Number of fruits per plant

It was recorded by the following formula

$$\text{Number of fruits per plant} = \frac{\text{Total number of fruits from ten sample plants}}{10}$$

3.10.11 Days to last harvesting

Dates of last harvesting were recorded treatment wise and the period of time for last harvesting in days was calculated from the date of transplanting.

3.10.12 Fruit length (cm)

The length of fruit was measured with a slide calipers from the neck of the fruit to the bottom of 10 randomly selected fruits from each plot and their average was taken in centimeter (cm) as the length fruit.

3.10.13 Fruit diameter (cm)

Diameter of fruit was measured at the middle portion of 10 randomly selected fruits from each plot with a slide calipers and their average was taken in centimeter (cm) as the diameter of fruit.

3.10.14Rate of flower dropping (%)

It was recorded by the following formula

$$\text{Rate of flower dropping} = \frac{\text{Number of dropping flowers per plant from ten sample plants}}{\text{Total number of flowers per plant from ten sample plants}} \times 100$$

3.10.15 Weight of individual fruit (g)

Among the total number of fruits harvests during the period from first to final harvest, the fruits, except the first and last harvests, were considered for determining the individual fruit weight in gram (g).

3.10.16 Weight of fruits per plant (kg)

A per scale balance was used to take the weight of fruits per plant. It was measured by total fruit of plant separately during the period from fruit to final harvest and was recorded in kilogram (kg).

3.10.17 Yield of fruits per hectare (t/ha)

It was measured by the following formula

$$\text{Fruit yield per hectare (t/ha)} = \frac{\text{Fruit yield per plot (kg)} \times 10000}{\text{Area of plot in square meter} \times 1000}$$

3.11 Statistical analysis

The recorded data on various parameters were statistically analyzed by using MSTAT statistical package programmed. The mean for all the treatments was calculated and analysis of variance for all the characters was performed by F-test. Difference between treatment means were determined by Duncan`s new Multiple Range Test (DMRT) according to Gomez and Gomes, (1984).

Chapter 4
Results and Discussion

CHAPTER IV

RESULTS AND DISCUSSION

This chapter comprises the presentation and discussion of the results from the experiment. The experiment was conducted to determine the effects of gibberellic acid and boron on growth and yield tomato. Some of the data have been presented and expressed in table (s) and others in figures for ease of discussion, comparison and understanding. A summary of all the parameters have been shown in possible interpretation wherever necessary have given under the following headings.

4.1 Plant height (cm)

The effect of gibberellic acid was significant on plant height at 20, 30, 40 and 50 days after transplanting (DAT). The tallest plant (22.53, 28.18, 37.81 and 60.16 cm at 20, 30, 40 and 50 DAT, respectively) was produced by G_3 (30 ppm gibberellic acid) and the shortest plant (13.51, 18.28, 28.71 and 53.47 cm at 20, 30, 40 and 50 DAT, respectively) was produced by G_0 (control) treatment (Fig. 1 and Appendix IV). The plant height was increased with increasing in gibberellic acid. Similar result was reported by Bhosle *et al.* (2002) who observed that 30ppm GA_3 had better effect on the elongation plant. All together it was suggested that GA_3 increase plant height of tomato.

Plant height is one of the important parameter, which is positively correlated with the yield of tomato (Taleb, 1994). Plant height at 20, 30, 40 and 50 DAT due to the influence of different level of boron fertilizer was significant. The highest plant height (19.41, 25.32, 34.97 and 58.18 cm at 20, 30, 40 and 50 DAT, respectively) was produced from B_2 (3.125 Kg Boric Acid/ha) treatment. However, the lowest plant height (17.44, 23.23, 32.98, 56.07 cm at 20, 30, 40 and 50 DAT, respectively) was obtained from B_0 (control) treatment (Fig. 2 and Appendix IV). It was found that plant height increase with increasing boron significantly up to a certain level. Similar findings also reported by Meena (2010), Naresh Babu (2002) and Cengiz *et al.* (2009).

The combined effects of gebberellic acid and boron fertilizer indicated a significant variation in plant height (Table 3 and appendix IV). The plant height was increased with higher doses of G and B. The tallest plant (24.77, 31.03, 40.93, 62.53 cm at 20, 30, 40 and 50 DAT, respectively) was found in G_3B_2 (30 ppm gibberellic acid with 3.125 Kg Boric Acid/ha) and the smallest plant (10.40, 15.5, 24.60 and 53.00 cm at 20, 30, 40 and 50 DAT, respectively) was found in G_0B_0 (control) treatment. Therse is significant differences were observed among the all treatments. (Nibhavanti, *et al.*,2006.) Reported that plant height was greatest with GA_3 at 25 and 50 ppm (74.21 and 75.33 cm, respectively) . Therefore, the present results of this study indicate that plant height increased with combined use of GA_3 and B.

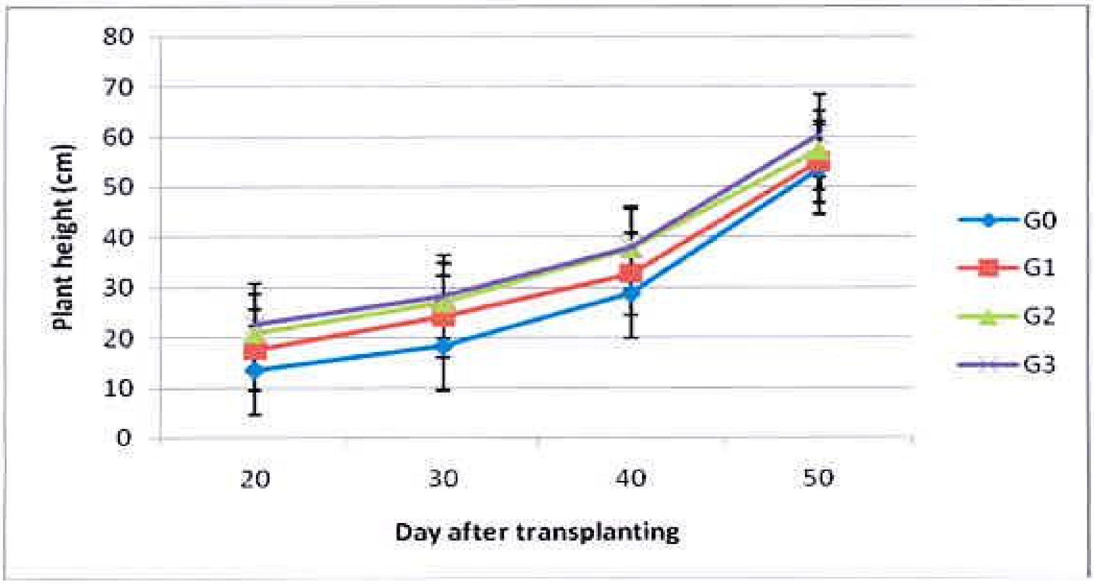

Fig. 1. Effect of gibberellic acid at different DAT on the plant height of tomato (DAT = Days after transplanting, G_0=No GibberellicAcid (GA_3), G_1=10 ppm GA_3, G_2=20 ppm GA_3, G_3=30 ppm GA_3 Error bar shows standard deviation)

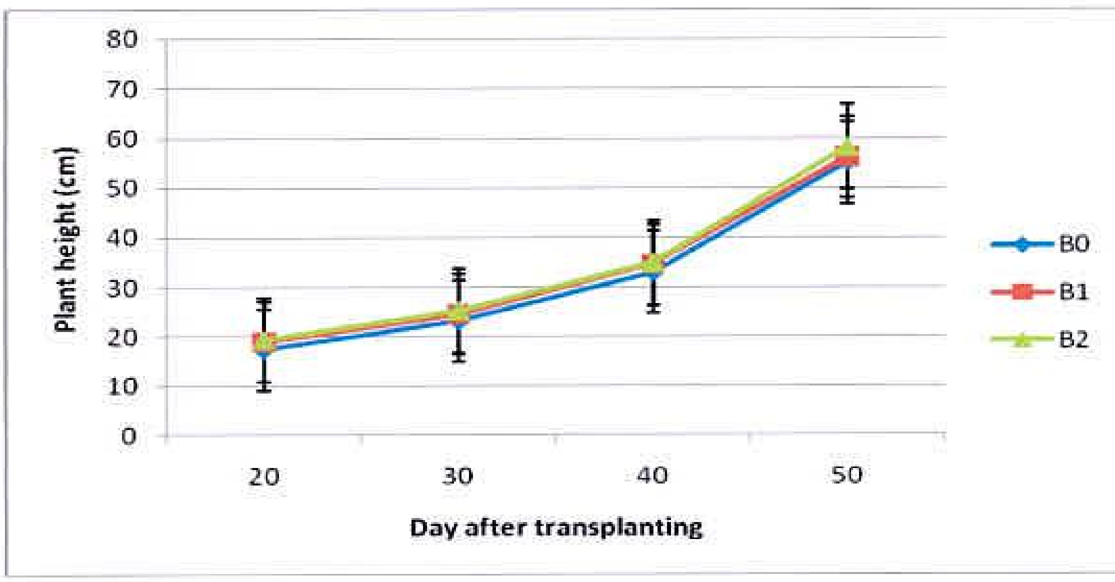

Fig. 2. Effect of boron at different DAT on the plant height of tomato (DAT = Days after transplanting, B_0= No Boric Acid, B_1=1.5625 Kg Boric Acid/ha, B_2=3.125 Kg Boric Acid/ha, Error bar shows standard deviation)

Table 1. Combined effect of gibberellic acid and boron on the plant height of tomato at different day after transplanting (DAT)

Treatment	Plant height (cm)							
	20 DAT		30 DAT		40 DAT		50 DAT	
G_0 B_0	10.4	f	15.5	e	24.6	c	48.53	d
G0 B1	15.3	e	20.67	cde	32.07	b	58.13	abc
G0 B2	14.83	e	18.67	de	29.47	bc	53.6	abcd
G1 B0	15.97	de	23.03	bcd	31.87	b	52.13	cd
G1 B1	20.3	abcd	27.03	abc	35	ab	53.27	abcd
G1 B2	16.3	cde	22.53	bcd	31.07	b	55	abcd
G2 B0	22.6	ab	29	ab	39.97	a	61.4	abc
G2 B1	18	bcde	22.43	bcd	31.73	b	53	bcd
G2 B2	21.73	ab	29.03	ab	38.4	a	61.6	ab
G3 B0	20.8	abc	25.4	abcd	35.5	ab	57.73	abcd
G3 B1	22.03	ab	28.1	ab	39.53	a	60.2	abc
G3 B2	24.77	a	31.03	a	40.93	a	62.53	a
$LSD_{(0.05)}$	4.235		6.162		5.335		8.149	
CV (%)	13.46		14.93		9.22		8.93	

In column, means containing same letter indicate significantly similar under DMRT at 5% level of significance. Values are the means of three replications

G_0=No GibberellicAcid (GA_3)
G_1=10 ppm
G_2=20 ppm
G_3=30 ppm

B_0= No Boric Acid
B_1=1.5625 Kg Boric Acid/ha
B_2=3.125 Kg Boric Acid/ha

4.2 Number of leaves per plant

A good number of leaves indicated better growth and development of crop. It is also possibly related to the yield of tomato. The greater number of leaf, the greater the photosynthetic area which may result higher fruit yield. The gibberellic acid showed significant variation in the number of leaves per plant at 20, 30, 40 and 50 DAT. The maximum number of leaves per plant (12.71, 41.47, 57.67 and 68.18 at 20, 30, 40 and 50 DAT, respectively) was produced by G_3 treatment and G_0 treatment produced the minimum number of leaves per plant (10.22, 32.87, 51.15 and 59.01 at 20, 30, 40 and 50 DAT, respectively) (Fig 3 and Appendix V). Number of leaves per plant increased with increasing gibberellic acid. Similar findings of number of leaves were obtained by Bhosle *et al.* (2002).

Number of leaves per plant due to the influence of boron was no significant at 20, 30, 40 and 50 DAT. The B_2 treatment had the highest number of leaves per plant (11.81, 38.10, 55.85 and 65.01 at 20, 30, 40 and 50 DAT, respectively). However, the lowest number of leaves per plant (10.75, 35.60, 55.39 and 62.84 at 20, 30, 40 and 50 DAT, respectively) was obtained from the B_0 treatment (Fig. 4 and Appendix V).

A significant variation in the number of leaves per plant was found between the gibberillic acid and boron (Table 2, appendix V). The maximum number of leaves per plant (15.07, 45.20, 60.12 and 69.06 84 at 20, 30, 40 and 50 DAT, respectively) was found in G_3B_2 treatment, whereas the lowest number of leaves per plant (10.02, 32.5, 50.25, 58.92 84 at 20, 30, 40 and 50 DAT, respectively) was found in G_0B_0.

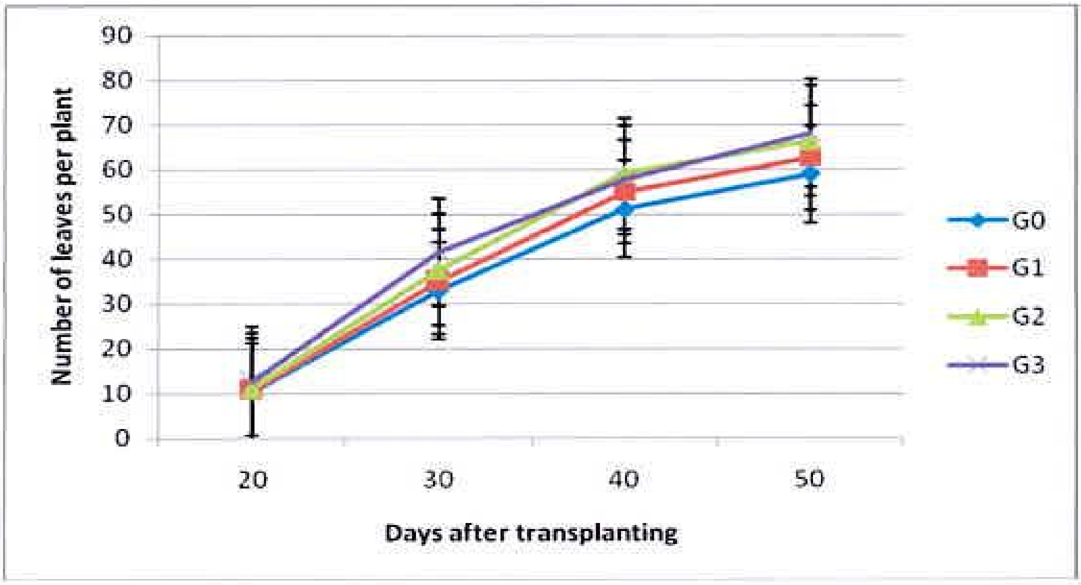

Fig. 3. Effect of gibberellic acid at different DAT on the number of leaves per plant

of tomato (DAT = Days after transplanting, G_0=No GibberellicAcid (GA_3), G_1=10 ppm GA_3, G_2=20 ppm GA_3, G_3=30 ppm GA_3 Error bar shows standard deviation)

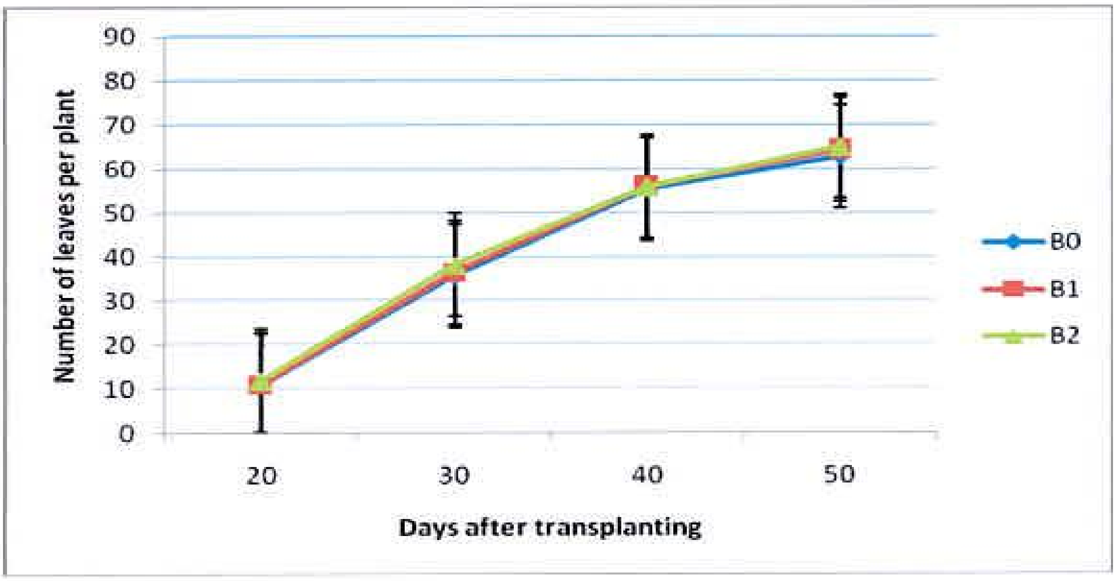

Fig 4. Effect of Boron at different DAT on the number of leaves per plant of tomato (DAT = Days after transplanting, B_0= No Boric Acid, B_1=1.5625 Kg Boric Acid/ha, B_2=3.125 Kg Boric Acid/ha, Error bar shows standard deviation)

Table 2. Combined effect of gibberellic acid and boron on the Number of leaves per plant of tomato at different day after transplanting (DAT)

Treatment	Number of leaves / plant			
	20 DAT	30 DAT	40 DAT	50 DAT
$G_0 B_0$	10.02 f	32.5 g	50.25 d	58.92 e
$G_0 B_1$	10.53 cdef	33.1 fg	52.02 cd	59.09 e
$G_0 B_2$	10.11 ef	33 fg	51.17 cd	59.01 e
$G_1 B_0$	10.22 def	33.6 efg	52.03 cd	59.98 de
$G_1 B_1$	10.91 bcdef	34.9 defg	55.2 bc	63.25 cd
$G_1 B_2$	11.01 bcde	36.2 cdef	57.8 ab	64.67 bc
$G_2 B_0$	10.98 bcde	36.5 cde	58.01 ab	64.79 bc
$G_2 B_1$	11.25 bc	38.25 bcd	55.2 bc	67.09 abc
$G_2 B_2$	11.05 bcd	38 bcd	59.25 ab	67.29 ab
$G_3 B_0$	11.26 bc	39.2 bc	59.51 ab	67.5 ab
$G_3 B_1$	11.8 b	40 b	58.29 ab	67.98 ab
$G_3 B_2$	15.07 a	45.2 a	60.12 a	69.06 a
$LSD_{(0.05)}$	0.8174	3.036	4.202	3.648
CV (%)	9.93	4.88	5.45	5.36

In column, means containing same letter indicate significantly similar under DMRT at 5% level of significance. Values are the means of three replications

G_0=No GibberellicAcid(GA_3)
G_1=10 ppm
G_2=20 ppm
G_3=30 ppm

B_0= Boric Acid
B_1=1.5625 Kg Boric Acid/ha
B_2=3.125 Kg Boric Acid/ha

4.3 Number of branches per plant

The gibberelic acid showed significant variation in the number of branches per plant at 20, 30, 40 and 50 DAT. The maximum number of branches per plant (8.01, 12.03, 16.62, 18.68 at 20, 30, 40 and 50 DAT, respectively) was produced by G_3 treatment. G_0 treatment produced the minimum number of branches per plant (3.63, 7.12, 11.86, 13.71) (Fig 5 and Appendix VI). These results indicate that gibberelic acid increases the growth of tomato, which ensured the maximum number of branch than control.

The effect of boron was no significantly influenced on number of branch per plant. The B_2 had the highest number of branches per plant (6.12, 10.38, 14.77, 16.36 at 20, 30, 40 and 50 DAT, respectively) and the lowest number of branches per plant (5.10, 8.89, 13.03, 15.08 at 20, 30, 40 and 50 DAT, respectively) was obtained from the B_0 treatment (fig 6, appendix VI). It was observed that with the increase of boron number of branch per plant also increase a certain level. Similar findings also reported by Meena (2010), Naresh Babu (2002) and Cengiz *et al.* (2009).

The interaction between different gibberellic acid and boron was found significant on the number of branches per plant (Table 3, appendix VI). The maximum number of branches per plant (8.08, 12.97, 17.98 and 19.25 at 20, 30, 40 and 50 DAT, respectively) was found in G_3B_2 treatment, whereas the lowest number of branches per plant (3.50, 6.98, 11.62, 13.41 at 20, 30, 40 and 50 DAT, respectively) was found in G_0B_0 (control) treatment.

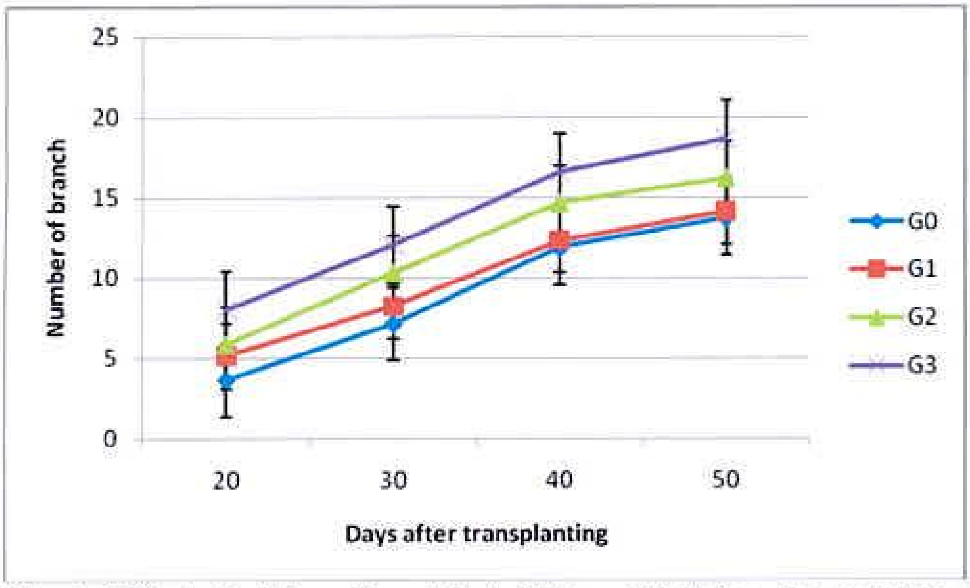

Fig. 5. Effect of gibberellic acid at different DAT on the number of branch per plant of tomato (DAT = Days after transplanting, G_0=No GibberellicAcid (GA_3), G_1=10 ppm GA_3, G_2=20 ppm GA_3, G_3=30 ppm GA_3 Error bar shows standard deviation)

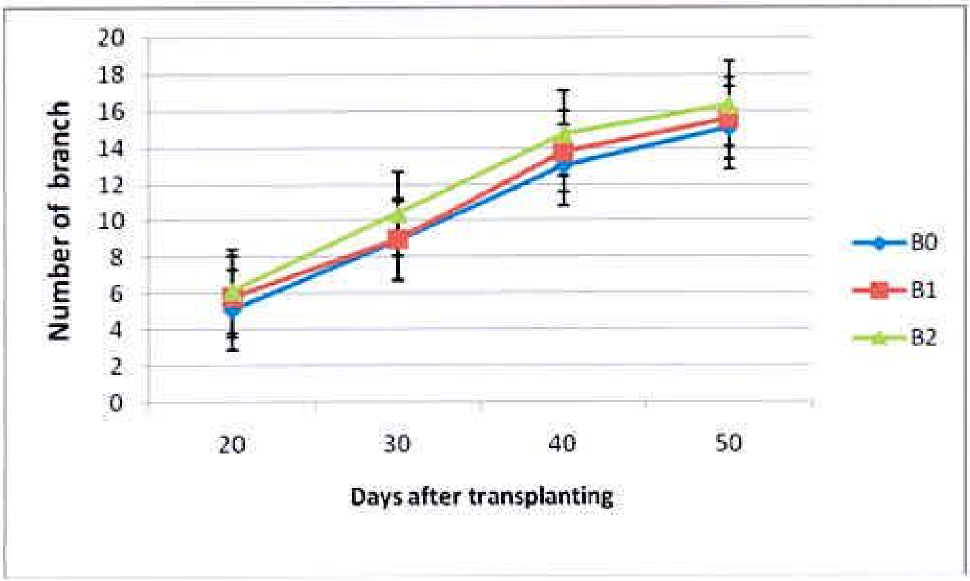

Fig. 6. Effect of boron at different DAT on the number of branch per plant of tomato (DAT = Days after transplanting, B_0= No Boric Acid, B_1=1.5625 Kg Boric Acid/ha, B_2=3.125 Kg Boric Acid/ha, Error bar shows standard deviation)

Table 3. Combined effect of gibberellic acid and boron on the number of branch per plant of tomato at different day after transplanting (DAT)

Treatment	Number of branch / plant			
	20 DAT	30 DAT	40 DAT	50 DAT
$G_0 B_0$	3.5 d	6.98 d	11.62 d	13.41 d
$G_0 B_1$	3.59 d	7.01 d	11.97 d	13.92 bcd
$G_0 B_2$	3.81 d	7.37 d	12 d	13.81 cd
$G_1 B_0$	4.01 d	7.91 cd	12.25 d	14.01 bcd
$G_1 B_1$	6.52 b	8.03 cd	12.57 cd	14.33 bcd
$G_1 B_2$	4.89 c	8.67 c	12.17 d	14.02 bcd
$G_2 B_0$	4.97 c	8.96 c	13.07 cd	14.95 bc
$G_2 B_1$	5.06 c	9 c	13.94 bc	15.26 b
$G_2 B_2$	7.69 a	12.5 ab	16.93 a	18.37 a
$G_3 B_0$	7.93 a	11.69 b	15.19 b	17.94 a
$G_3 B_1$	8.01 a	11.91 b	16.69 a	18.86 a
$G_3 B_2$	8.08 a	12.97 a	17.98 a	19.25 a
$LSD_{(0.05)}$	0.7362	0.9917	1.324	1.229
CV(%)	7.68	6.22	5.64	5.63

In column, means containing same letter indicate significantly similar under DMRT at 5% level of significance. Values are the means of three replications

G_0=No GibberellicAcid(GA_3)
G_1=10 ppm
G_2=20 ppm
G_3=30 ppm

B_0= Boric Acid
B_1=1.5625 Kg Boric Acid/ha
B_2=3.125 Kg Boric Acid/ha

4.4 Days to first flowering

A significant variation was observed in days to first flowering due to gibberellic acid (Table 4, Appendix VII). The G_2 treatment required the earliest of days of first flowering (36.44 days). G_0 treatment was the longest time of first flowering (41.67 days).

A significant difference was observed among the boron in the days to first flowering (Table 5, Appendix VII). Delayed first flowering (40.50 days) was found in B_0 treatment and first flowering was earliest (36.08 days) in B_2, which was statistically similar to B_1 treatment.

The combined effect of gibberellic acid and boron on days of first flowering was found to be significant (Appendix VII). Data in table 6 Shows that, the days of first flowering was minimum (33.33 days) in G_2B_2 (20 ppm gibberellic acid with 3.125 Kg Boric Acid/ha), while it was maximum (109 days) in G_0B_0 treatment.

4.5 Days to 50% flowering

The different gibberellic acid shows significant variation in the days to 50% flowering (Appendix VII). The G_0 treatment required the maximum time of days of 50% flowering (48.78 days). G_2 treatment was the earliest in 50% flowering (43.44 days) (Table 4).

There was a marked difference among the boron in the days to 50% flowering (Appendix VII). Delayed flowering (47.83 days) was found in B_0 treatment and flowering was earliest (43.33 days) in B_0 treatment (Table 5).

Table 4. Effect of gibberellic acid on the yield contributing character of tomato

Treatments	Days of first flowering		Day of 50% flowering DAT		Number of flower cluster/ plant		Number of flowers / cluster		Number of flowers / plant		number of fruits /cluster		Number of fruits / plant	
G_0	41.67	a	48.78	a	6.672	c	4.774	b	32	c	3.786	b	29.65	c
G_1	38.22	b	46.22	ab	7.941	b	5.367	a	42.8	b	4.443	ab	34.13	b
G_2	36.44	b	43.44	c	8.656	a	5.5	a	48.1	a	5.03	a	42.02	a
G_3	36.56	b	44	bc	8.844	a	5.613	a	49.9	a	4.92	a	40.53	a
LSD (0.05)	2.044		2.71		0.6574		0.59		4.6		1.052		4.394	
CV (%)	5.49		5.06		5.14		4.26		4.08		8.91		4.62	

Table 5. Effect of boron on the yield contributing character of tomato

Treatments	Days of first flowering		Day of 50% flowering		Number of flower cluster/		Number of flowers / cluster		Number of flowers / plant		Number of fruits / cluster		Number of fruits / plant	
B_0	40.5	a	47.83	a	6.96	b	4.97	a	34.78	c	4.14	a	30.2	b
B_1	38.08	b	45.67	ab	8.20	a	5.38	a	44.27	b	4.544	a	38.26	a
B_2	36.08	b	43.33	b	8.92	a	5.59	a	50.54	a	4.95	a	41.29	a
LSD $_{(0.05)}$	2.044		2.71		0.888		0.793		6.193		1.423		5.94	
CV (%)	5.49		5.06		5.14		NS		4.08		8.91		4.62	

Table 6. Effect of boron on the yield contributing character of tomato

Treatments	Days of first flowering	Day of 50% flowering	Number of flower cluster/	Number of flowers / cluster	Number of flowers / plant	Number of fruits / cluster	Number of fruits / plant
$G_0 B_0$	43.67 a	51.33 a	5.90 f	4.42 e	26.08 i	3.52 d	22.01 g
$G_0 B_1$	42.33 b	49.00 b	7.07 e	5.33 cd	37.63 efg	3.93 cd	34.12 cde
$G_0 B_2$	39.00 de	46.00 de	7.05 e	4.57 e	32.22 h	3.91 cd	32.81 def
$G_1 B_0$	40.67 c	48.00 bc	7.01 e	5.23 d	36.66 fg	3.98 cd	30.41 f
$G_1 B_1$	37.67 ef	46.00 de	7.55 d	5.19 d	39.18 ef	4.42 bc	35.67 cd
$G_1 B_2$	36.33 g	44.67 ef	9.27 b	5.67 bc	52.65 c	4.93 b	36.32 c
$G_2 B_0$	39.67 cd	46.67 cd	7.11 e	5.05 d	35.9 g	4.51 bc	31.26 ef
$G_2 B_1$	36.33 fg	44.33 ef	8.80 c	5.34 cd	46.98 d	4.81 b	41.79 b
$G_2 B_2$	33.33 h	41.00 h	10.06 a	6.12 a	61.41 a	5.77 a	53.01 a
$G_3 B_0$	38.00 e	45.33 de	7.83 d	5.17 d	40.48 e	4.55 bc	37.12 c
$G_3 B_1$	36.00 g	43.33 fg	9.40 b	5.66 bc	53.3 bc	5.02 b	41.47 b
$G_3 B_2$	35.67 g	41.67 gh	9.30 b	6.01 ab	55.89 b	5.19 ab	43 b
LSD $_{(0.05)}$	1.33	1.76	0.43	0.38	2.99	0.69	2.86
CV(%)	5.49	5.06	5.14	4.26	4.08	8.91	4.62

In column, means containing same letter indicate significantly similar under DMRT at 5% level of significance. Values are the means of three replications

G_0=No GibberellicAcid(GA_3)
G_1=10 ppm
G_2=20 ppm
G_3=30 ppm

B_0= Boric Acid
B_1=1.5625 Kg Boric Acid/ha
B_2=3.125 Kg Boric Acid/ha

The combined effect of different gibberellic acid and boron on days to 50% flowering was found to be significant (Table 6, Appendix VII). The minimum days to 50% flowering (41.00 days) was found in G_2B_2 treatment. The maximum days to 50% flowering (51.33 days) was found in G_0B_0 treatment.

4.6 Number of flowers cluster per plant

The gibberellic acid showed significant variation in the number of flowers cluster per plant (Table 4, Appendix VII). The maximum number of flowers cluster per plant (8.84) was produced by G_3 treatment and G_0 treatment produced the minimum number of flowers cluster per plant (6.67).

There was a significant difference among the boron fertilizer in the number of flowers cluster per plant (Appendix VII). As evident from Table 5, the maximum number of flowers cluster per plant (8.92) was produced in B_2, which was statistically similar to B_1 (1.5625 Kg Boric Acid/ha) treatment. The minimum number of flowers cluster per plant (6.96) was produced in B_0 (control) treatment.

The analysis of variance (Table 6, Appendix VII) indicated a significant variation among the treatment combinations in number of flowers cluster per plant. The maximum number of flowers cluster per plant (10.06) was found in G_2B_2 (20 ppm GA_3 with 3.125 Kg Boric Acid/ha). Whereas the minimum number of flowers cluster per plant (5.90) was found in G_0B_0 treatment.

4.7 Number of flowers per cluster

The gibberellic acid showed significant variation in the number of flowers per cluster (Table 4, Appendix VII). The maximum number of flowers per cluster (5.61) was produced by G_3 treatment, which was statistically similar with G_2 and G_1 treatment and G_0 produced the minimum number of flowers per cluster (4.77).

There was a no significant difference among the boron fertilizer in the number of flowers per cluster (table 5, Appendix VII). The maximum number of flowers per cluster (5.59) was produced in B_2 treatment. The minimum number of flowers per cluster (4.97) was produced in B_0 treatment.

The analysis of variance (Table 6, Appendix VII) indicated a significant variation among the treatment combinations of gibberellic acid and boron fertilizer in number of flowers per cluster. The maximum number of flowers per cluster (6.12) was found in G_2B_2, whereas the minimum number of flowers per cluster (4.42) was found in G_0B_0 treatment.

4.8 Number of flowers per plant

The gibberellic acid showed significant variation in the number of flowers per plant (Table 4, Appendix VII). The maximum number of flowers per plant (49.9) was produced by G_3 treatment, which was statistically similar with G_2 treatment and G_0 produced the minimum number of flowers per plant (32.00).

There was a significant difference among the boron fertilizer in the number of flowers per plant (Table 5, Appendix VII). The maximum number of flowers per plant (50.54) was produced in B_2 treatment. The minimum number of flowers per cluster

(34.79) was produced in B_0 treatment. Boron has effect on many functions of the plant such as hormone movement, active salt absorption, flowering and fruiting process, pollen germination that leads to maximum flowering with optimum doses (Bose and Tripathi, 1996).

The analysis of variance (Table 6, Appendix VII) indicated a significant variation among the treatment combinations of gibberellic acid and boron in number of flowers per plant. The maximum number of flowers per plant (61.41) was found in G_2B_2, whereas the minimum number of flowers per plant (26.08) was found in G_0B_0 treatment.

4.9 Number of fruits per cluster

The gibberellic acid showed significant variation in the number of fruits per cluster (Table 4, Appendix VII). The maximum number of fruits per cluster (5.03) was produced by G_2, which was statistically similar with G_3 treatment and G_0 produced the minimum number of fruits per cluster (3.79).

Number of fruits per cluster due to the influence of different boron was no significant (Table 5, Appendix VII). The B_2 treatment had the highest number of fruits per cluster (4.95). However, the lowest number of fruits per cluster (4.14) was obtained from the B_0 treatment.

The variation among the treatment combinations of gibberellic acid and boron was found statistically significant (Table 6, Appendix VII). The maximum number of fruits per cluster (5.77) was found in G_2B_2, whereas the minimum number of fruits per cluster (3.52) was found in G_0B_0 treatment.

4.10 Number of fruits per plant

The gibberellic acid showed significant variation in the number of fruit per plant (Table 4, Appendix VII). The maximum number of fruit per plant (42.02) was produced by G_2 treatment, which was statistically similar with G_3 and G0 produced the minimum number of fruit per plant (26.65).

Number of fruit per plant due to the influence of boron was significant (Table 5, Appendix VII). The B_2 treatment had the highest number of fruit per plant (41.29), which was statistically similar with B_1 treatment and the lowest number of fruit per plant (30.20) was obtained from the B_0 treatment. Boron affects on the vascular cambium of fruits which are capable for meristematic activities (Singh and Gangwar, 1991).

The interaction between gibberellic acid and boron was found significant on the number of fruits per plant (Table 6, Appendix VII). The maximum number of fruits per plant (53.01) was found in G_2B_2, whereas the lowest number of fruits per plant (22.01) was found in G_0B_0.

4.11Percent flower dropping:

The gobberellic acid showed significant variation in the percent of fruit dropping (Table 7, Appendix VIII). The maximum percent of fruit dropping (12.00) was produced by G_0 treatment and the minimum percent of fruit dropping (9.69) was found in G_2 treatment.

Percent of fruit dropping due to the influence of boron was significant (Table 8, Appendix VIII). The B_0 had the highest percent of fruit dropping (14.29). However, the lowest percent of fruit dropping (8.62) was obtained from B_2 treatment.

The variation among the treatment combinations of gibberellic acid and boron was found statistically significant (Table 9, Appendix VIII). The maximum percent of fruit dropping (17.61) was found in G_0B_0 treatment, whereas the minimum percent of fruit dropping (7.40) was found in G_2B_2.

4.12 Days to first harvesting

A significant variation was observed in days to first harvesting due to gibberellic acid (Table 7, Appendix VIII). The G2 required the earliest of days of first harvesting (96.11 days). G_0 treatment was the longest time of first harvesting (99.56 days).

There was a marked difference among the boron in the days to first harvesting (Table 8, Appendix VIII). Delayed first harvesting (100.30 days) was found in B_0 treatment and first harvesting was earliest (96.25 days) in B_2 treatment.

The combined effect of different gebberellic acid and boron on days of first harvesting was found to be significant (Appendix VIII). Data in table 9 Shows that, the days of first harvesting was minimum (94 days) in G_2B_2 treatment, while it was maximum (102.00 days) in G_0B_0 treatment.

Table 7. Effect of gibberellic acid on the yield and yield contributing character of tomato

Treatments	**Percent of flower dropping**	**Day of first harvest**	**Length of fruit**	**Breath of fruit**	**Weight of individual fruit (g)**	**Weight of fruit / plant (Kg)**	**Yield (t/ha)**
G_0	12.00 a	99.56 a	4.59 a	4.29 a	76.51 c	2.00 b	50.08 c
G_1	11.70 ab	98.78 a	5.02 a	4.34 a	80.04 bc	2.36 a	59.09 b
G_2	9.69 b	96.11 b	5.37 a	4.54 a	85.82 ab	2.66 a	67.27 a
G_3	11.14 ab	98.44 ab	5.27 a	4.59 a	89.27 a	2.47 a	67.92 a
LSD $_{(0.05)}$	2.043	2.379	1.25	0.419	6.011	0.3	4.838
CV(%)	11.50	5.93	NS	NS	6.79	12.89	5.05

Table 8. Effect of boron on the yield and yield contributing character of tomato

Treatments	Percent of flower dropping	Day of first harvest	Length of fruit	Breath of fruit	Weight of individual fruit (g)	Weight of fruit / plant (Kg)	Yield (t/ha)
B_0	14.29 a	100.3 a	4.91 a	4.372 a	80.55 c	2.17 b	57.31 b
B_1	10.48 b	98.08 ab	5.092 a	4.485 a	82.40 b	2.35 ab	58.81 b
B_2	8.619 b	96.25 b	5.188 a	4.463 a	85.78 a	2.61 a	67.14 a
LSD (0.05)	2.762	3.142	1.685	0.567	0.82	0.42	6.54
CV(%)	11.50	5.93	NS	NS	6.79	12.89	5.05

Table 9. Combined Effect of gibberellic acid and boron on the yield and yield contributing character of tomato

Treatments	percent of flower dropping	Day of first harvest	Length of fruit	Breath of fruit	Weight of individual fruit (g)	Weight of fruit / plant (Kg)	Yield (t/ha)
$G_0 B_0$	17.61 a	102.00 a	4.52 b	4.15 d	76 e	1.67 c	41.75 i
$G_0 B_1$	9.33 f	98.00 cde	4.6 b	4.42 a-d	76.52 e	2.11 bc	52.75 h
$G_0 B_2$	9.05 f	96.33 def	4.65 b	4.30 cd	77.01 de	2.23 b	55.75 gh
$G_1 B_0$	15.05 b	100.00 abc	4.65 b	4.30 cd	78.91 cde	2.29 b	57.25 fg
$G_1 B_1$	11.10 de	98.67 bcd	5.22 ab	4.32 bcd	80.21 cde	2.36 b	59 efg
$G_1 B_2$	8.96 f	96.67 de	5.2 ab	4.40 a-d	81.01 cd	2.44 b	61.01 de
$G_2 B_0$	11.59 d	98.33 cde	5.25 ab	4.42 a-d	81.21 cd	2.42 b	60.51 def
$G_2 B_1$	10.07 ef	96.00 ef	5.25 ab	4.50 abc	82.37 bc	2.51 b	62.75 d
$G_2 B_2$	7.40 g	94.00 f	5.61 a	4.70 a	93.87 a	3.06 a	78.56 a
$G_3 B_0$	12.92 c	101.00 ab	5.22 ab	4.62 ab	86.07 b	2.31 b	69.75 c
$G_3 B_1$	11.43 de	99.67 abc	5.3 ab	4.70 a	90.52 a	2.42 b	60.75 de
$G_3 B_2$	9.06 f	98.00 cde	5.29 ab	4.45 a-d	91.21 a	2.69 ab	73.25 b
$LSD_{(0.05)}$	1.331	2.30	0.812	0.273	3.917	0.519	3.153
CV(%)	11.50	5.93	9.47	5.62	6.79	12.89	5.05

In column, means containing same letter indicate significantly similar under DMRT at 5% level of significance. Values are the means of three replications

G_0=No GibberellicAcid(GA_3)
G_1=10 ppm
G_2=20 ppm
G_3=30 ppm

B_0= Boric Acid
B_1=1.5625 Kg Boric Acid/ha
B_2=3.125 Kg Boric Acid/ha

4.13 Length of fruit (cm)

The gibberellic acid was exhibited no significant variation in the length of fruit (Table 7, Appendix VIII). However, the longest fruit length (5.37 cm) was produced by G_2 and G_0 produced the shortest fruit length (4.59 cm). It was found that fruit length increase with increasing gibberellic acid up to a certain level. Similar findings also reported by Gelmesa *et al.* (2010).

An insignificant variation in the length of fruit was found among the boron (Table 8, Appendix VIII). The longest fruit length (5.19 cm) was obtained from B_2 and the shortest fruit length (4.91 cm) was obtained from B_0.

The variation in fruit length due to combined effect of gibberellic acid and boron was found statistically significant (Table 9, Appendix VIII). The longest fruit length (5.61 cm) was found in G_2B_2, whereas the shortest fruit length (4.52cm) was found from G_0B_0.

4.14 Breath of fruit (cm)

The variation in the breath of fruit gibberellic acid was exhibited insignificant (Table 7, Appendix VIII). The largest fruit breath (4.59 cm) was produced by G_2 and G_0 produced the shortest fruit breath (4.29 cm). Similar findings also reported by Gelmesa *et al.* (2010).

An insignificant variation in the breath of fruit was found among the boron (Table 8, Appendix VIII). The largest fruit breath (4.49 cm) was obtained from B_2 and the shortest fruit breath (4.37 cm) was obtained from B_0.

The variation in fruit breath due to combined effect of gibberellic acid and boron r was found statistically significant (Table 9, Appendix VIII). The largest fruit breath (4.7 cm) was found in G_2B_2. The shortest fruit breath (4.15 cm) was found in G_0B_0 treatment.

4.15 Individual fruit weight (g)

Gibberellic acid did influence significantly on the average weight of individual fruit weight (Table 7, Appendix VIII). The largest individual fruit weight (89.27 g) was produced by G_2 and G_0 produced the lowest individual fruit weight (76.51 g). Similar result also reported by Gelmesa *et al.* (2010).

The weight of individual fruit weight was significantly influenced by boron (Table 8, Appendix VIII). The largest individual fruit weight (85.78 g) was obtained from B_2treatment. The lowest fruit weight (80.55 g) was obtained from B_0 (Table 8). These results indicate that boron increases the growth of tomato, which ensured the maximum weight of fruits/plant than control.

Individual fruit weight was significantly affected by both gibberellic acid and boron (Table 9, Appendix VIII). The highest individual fruit weight (93.87 g) was found in G_2B_2 which was statistically similar with G_3B_1 and G_3B_2. Whereas the lowest individual fruit weight (776.00 g) was found in G_0B_0 treatment.

4.16 Yield of fruits (kg) per plant

The gibberelic acid had significant effect on the yield of fruits per plant (Table 7 and Appendix VIII). The maximum yield of fruits per plant (2.66 kg) was produced by G_2 treatment and the minimum yield of fruits per plant (21.00 kg) was produced from G_0. Similar result was found by Anuja and Shakila (2006)

The effect of boron on tomato significantly influenced the yield of fruits per plant (Table 8 and Appendix VIII). The maximum yield of fruits per plant (2.61 kg) was obtained from B_2 treatment and the minimum yield of fruits per plant (2.17 kg) was obtained from B_0. Similar findings was also reported by Meena (2010), Naresh Babu (2002) and Cengiz *et al.* (2009).

The combined effect of gibberellic acid and boron was significant on yield of fruit per plant (Table 9 and Appendix VIII). The highest yield of fruits per plant (3.06 kg) was obtained from G_2B_2.The lowest yield of fruits per plant (15.34 kg) was obtained from G_0B_0.

4.17 Total fruit yield per hectare (t/ha)

The yield of tomato per plot was converted into per hectare, and has been expressed in metric tons. The different doses of gibberellic acid had significant effect on the yield of fruits per hectare.(Table 7, Appendix VIII). The maximum yield of fruits per hectare (68.00 tones) was obtained from G_2 treatment and the minimum yield of fruits per hectare (50.00 tones) was obtained from G_0 treatment. At 20 ppm gibberelic acid ha^{-1}, the yield of fruits was maximum due to the combination of number of fruits per plant, weight of individual fruit and low flower dropping. Fruit yield was gradually decreased due to decreasing number of fruits per plant. Similar result was found by Anuja and Shakila (2006).

The total yield of tomato varied significantly due to the application of different levels of boron fertilizer (Table 8 and Appendix VIII). The highest yield of fruit (67.14 t/ha) was obtained from B_2, while (B_0) gave the lowest (57.31 t/ha) yield. This result showed that the yield of tomato increased gradually with the increased doses of boron fertilizer. This result showed that the yield of tomato increased gradually with the increased doses of boron fertilizer. Similarly Meena (2010) reported that 6 kg B/ha gave the highest fruit yield while the lowest was obtained from control. The result is in conformity of the present study of profound influence of boron levels to increase yield of tomato has been reported by many authors Salam *et al.* (2010).

The combined effects of gibberellic acid and boron fertilizer was significant on yield of fruits per hectare (Table 9 and Appendix VIII). The highest yield of fruits per hectare (78.56 tones) was obtained from G_2B_2 treatment and the lowest yield of fruits per hectare (41.75 tones) was obtained from G_0B_0 treatment (Table 9). The significant differences were observed among the all treatments. (Nibhavanti, *et al.*,2006.) reported that yield was greatest with GA_3 at 25 and 50 ppm (254.2 and 264.4 quintal/ha, respectively) . Therefore, the present results of this study indicate that yield increased with combined use of GA_3 and B.

Chapter 5
Summary and Conclusion

CHAPTER V

SUMMARY AND CONCLUSION

The growth, yield contributing characters and yield of tomato largely depend on soil and climatic conditions and also on variety. Among these, proper gibberellic acid and boron play a vital role.

The field experiment was conducted at the Sher-e-Bangla Agricultural University Farm, Dhaka, Bangladesh from October 2011 to March, 2012 to evaluate the role of gibberellic acid and boron on growth and yield of tomato. Four dose of gibberilic acid, viz., No Gibberellic Acid (GA_3), 10 ppm (GA_3), 20 ppm (GA_3) and 30 ppm (GA_3) and three levels of boron, viz., no Boric Acid, 1.5625 Kg Boric Acid/ha and 3.125 Kg Boric Acid/ha were used to conduct this experiment. The experiment was laid out in Randomized complete Block Design (RCBD) having two factors and replicated three times. Data were taken on growth, yield contributing characters, yield and the collected data were statistically analyzed for evaluation of the treatment effects. The summary of the results has been described in this chapter.

The effect of gibberellic acid was significant on plant height at 20, 30, 40 and 50 day after transplanting (DAT). The tallest plant (22.53, 28.18, 37.81 and 60.16 cm at 20, 30, 40 and 50 DAT, respectively) was produced by G_3 (30 ppm gibberellic acid). The maximum number of leaves per plant (12.71, 41.47, 57.67 and 68.18 at 20, 30, 40 and 50 DAT, respectively) was produced by G_3 (30 ppm gibberellic acid) treatment. The maximum number of branches per plant (8.01, 12.03, 16.62, 18.68 at 20, 30, 40 and 50 DAT, respectively) was produced by G_3 treatment. The gibberellic acid of G_3 (30ppm gibberellic acid) had observed maximum number of flowers cluster per plant (8.84), number of flowers per cluster (5.61), number of flowers per plant (49.9). The earliest of days of first flowering (36.44 days), earliest in 50% flowering (43.44 days), maximum number of fruits per cluster (5.03), number of fruit per plant (42.02), minimum percent of fruit dropping (9.69), earliest of days of first harvesting (96.11 days), the longest fruit length (5.37 cm), largest fruit breath (4.59 cm), largest individual fruit weight (89.27 g) was observed in G_2 (20ppm gibberellic acid) treatment. The different gibberellic acid had significant effect on the yield of fruits per hectare. The maximum yield of fruits per hectare (68.00 tones) was obtained G_2 treatment and the minimum yield of fruits per hectare (50.00 tones) was obtained from G_0 treatment.

Plant height at 20, 30, 40 and 50 DAT due to the influence of different level of boron fertilizer was significant. The highest plant height (19.41, 25.32, 34.97 and 58.18 cm at 20, 30, 40 and 50 DAT, respectively) was produced from B_2 (3.125 Kg Boric Acid/ha) treatment. The B_2 treatment had the highest number of leaves per plant (11.81, 38.10, 55.85 and 65.01 at 20, 30, 40 and 50 DAT, respectively). The B_2 had the highest number of branches per plant (6.12, 10.38, 14.77, 16.36 at 20, 30, 40 and 50 DAT, respectively). The boron of B_2 (3.125 Kg Boric Acid/ha) treatment had earliest of days of first flowering (36.08 days), earliest in 50% flowering (43.33 days), observed maximum number of flowers cluster per plant (8.92), number of flowers per cluster (5.59), number of flowers per plant (50.54), maximum number of fruits per cluster (5.03), number of fruit per plant (42.02), minimum percent of fruit dropping (8.62), earliest of days of first harvesting (96.25 days), the longest fruit length (5.19 cm), largest fruit breath (4.49 cm), largest individual fruit weight (85.78 g). The boron of tomato significantly influenced on the yield of fruits per plant. The maximum yield of fruits per plant (2.61 kg) was obtained from B_2 treatment. The total yield of tomato varied significantly due to the application of different levels of boron fertilizer. The highest yield of fruit (67.14 t/ha) was obtained from B_2, while (B_0) gave the lowest (57.31 t/ha) yield.

The interaction between different gibberellic acid and boron was significantly influenced on the all growth and yield characters. The tallest plant height (24.77, 31.03, 40.93, 62.53 cm at 20, 30, 40 and 50 DAT, respectively) was found in G_3B_2 (30 ppm gibberellic acid with 3.125 Kg Boric Acid/ha), the maximum number of leaves per plant (15.07, 45.20, 60.12 and 69.06 84 at 20, 30, 40 and 50 DAT, respectively) was found in G_3B_2 treatment. The maximum number of branches per plant (8.08, 12.97, 17.98 and 19.25 at 20, 30, 40 and 50 DAT, respectively) was found in G_3B_2 treatment. the days of first flowering was minimum (33.33 days) in G_2B_2 (20 ppm gibberellic acid with 3.125 Kg Boric Acid/ha). The minimum days to 50% flowering (41.00 days) was found in G_2B_2 treatment. The maximum number of flowers cluster per plant (10.06), number of flowers per cluster (6.12), number of flowers per plant (61.41), number of fruits per cluster (5.77), number of fruits per plant (53.01), minimum percent of fruit dropping (7.40), minimum days of first harvesting (94 days), longest fruit length (5.61 cm), The largest fruit breath (4.7 cm) and individual fruit weight (93.87 g) was found in G_2B_2 (20 ppm GA_3 with 3.125 Kg Boric Acid/ha). The highest yield of fruits per plant (3.06 kg) was obtained from

G_2B_2. The combined effect of gibberelic acid and boron fertilizer was significant on yield of fruits per hectare. The highest yield of fruits per hectare (78.56 tones) was obtained from G_2B_2 (20 ppm GA_3 with 3.125 Kg Boric Acid/ha) treatment. The lowest yield of fruits per hectare (41.75 tones) was obtained from G_0B_0 treatment

Considering the stated findings, it may be concluded that growth and yield contributing parameters are positively correlated with gibberellic acid and boron. However, cultivation of BARI Tomato-2 and use of gibberellic acid 20 ppm with 3.125 Kg boric acid per hectare would be beneficial for the farmers.

Considering the situation of the present experiment, further studies in the following areas may be suggested:

1. Such study is needed in different agro-ecological zones (AEZ) of Bangladesh for regional adaptability and other performance.
2. Another level of gibberellic acid and boron may be included for drawing conclusion.

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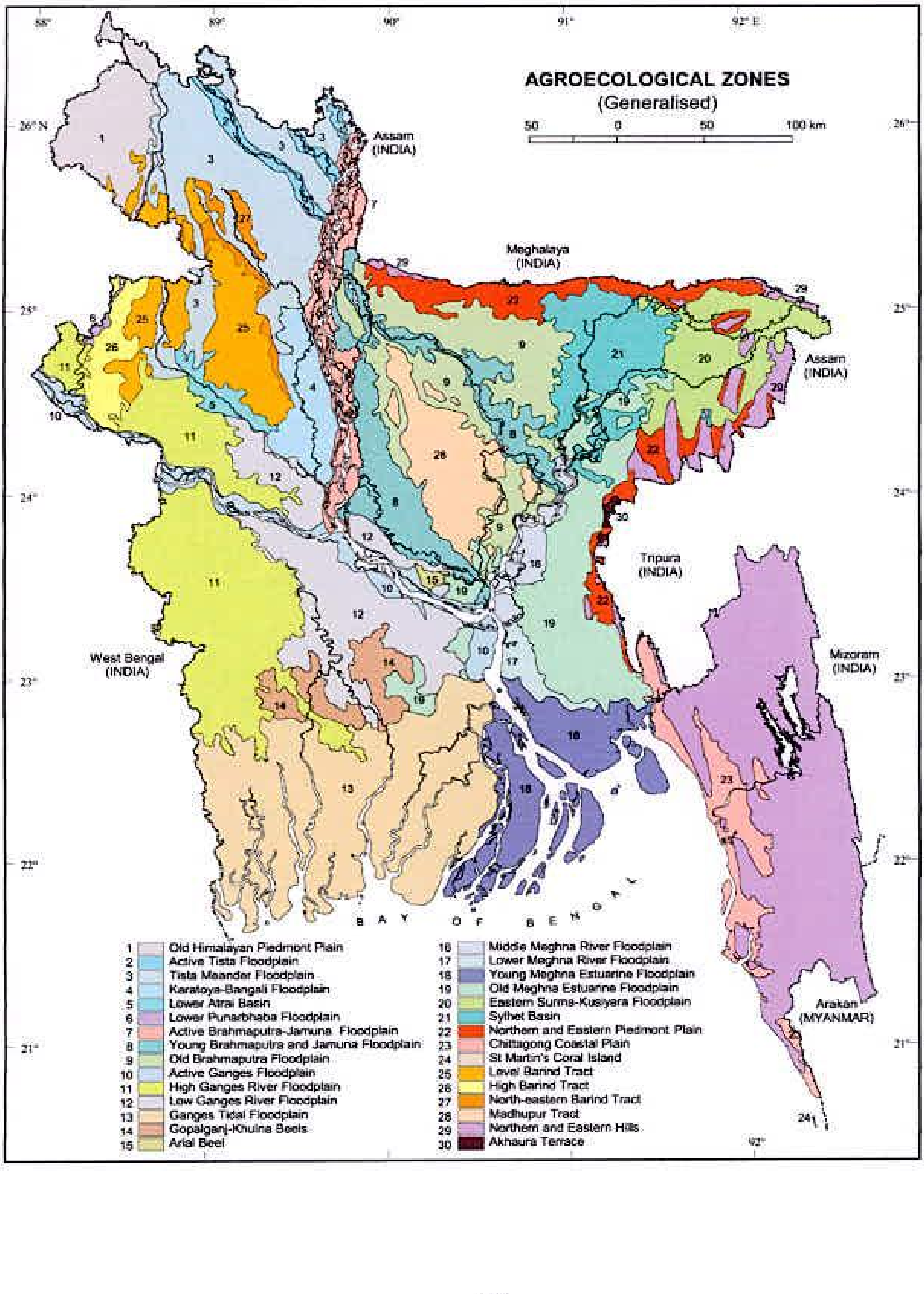
Appendices

APPENDICES

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



Appendix II: Soil characteristics of Sher-e-Bangla Agricultural University Farm, Dhaka are analyzed by Soil Resources Development Institute (SRDI), Farmgate, Dhaka.

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	SAU farm, Dhaka
AEZ	Modhupur tract (28)
General soil type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping pattern	**N/A**

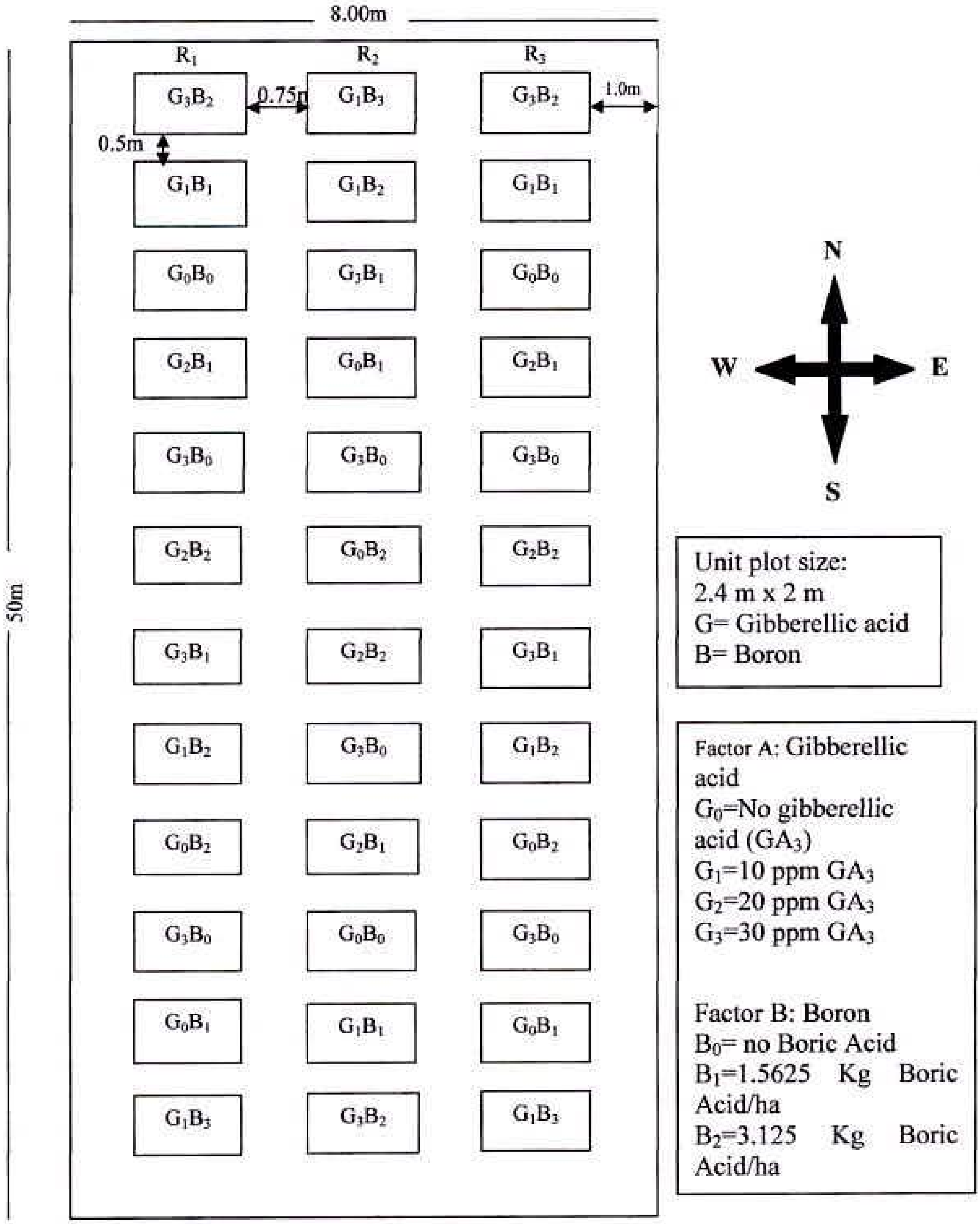
Source: Soil Resources Development Institute(SRDI)

B. Physical and Chemical properties of the Initial soil

Characteristics	Value
Practical size analysis	
Sand (%)	16
Silt (%)	56
Clay (%)	28
Silt + Clay (%)	84
Textural class	Silty clay loam
Ph	5.56
Organic matter (%)	0.25
Total N (%)	0.02
Available P (μgm/gm soil)	53.64
Available K (me/100g soil)	0.13
Available S (μgm/gm soil)	9.40
Available B (μgm/gm soil)	0.13
Available Zn (μgm/gm soil)	0.94
Available Cu (μgm/gm soil)	1.93
Available Fe (μgm/gm soil)	240.9
Available Mn (μgm/gm soil)	50.6

Source: Soil Resources Development Institute (SRDI)

Appendix III. Layout and design of the experimental plot



Appendix IV: Analysis of variance of the data on plant height of tomato as influenced of different gibberellic acid and boron

Sources of Variation	Degrees of freedom	Mean Square			
		Plant height (cm)			
		20 DAT	30 DAT	40 DAT	50 DAT
Replication	2	3.817	17.312	6.034	27.674
Factor A (gibberellic acid)	3	141.814*	172.97*	170.313*	76.582*
Factor B (boron)	2	12.538 NS	13.342 NS	13.281 NS	30.941 NS
AB	6	19.045*	30.808*	44.148*	61.464*
Error	22	6.255	13.242	9.927	23.157

*significant at 5% level of probability,
NS- Non signficant

Appendix V: Analysis of variance of the data on Number of leaves per plant of tomato as influenced of different gibberellic acid and boron

Sources of Variation	Degrees of freedom	Mean Square			
		Number of leaves per plant			
		20 DAT	30 DAT	40 DAT	50 DAT
Replication	2	0.21	3.966	10.507	8.699
Factor A (gibberellic acid)	3	10.47 NS	124.307*	110.47*	149.924*
Factor B (boron)	2	3.703 NS	19.516 NS	1.106 NS	14.691 NS
AB	6	3.295*	6.797*	14.825*	3.463*
Error	22	1.233	3.214	6.159	4.642

*significant at 5% level of probability,
NS- Non signficant

Appendix VI: Analysis of variance of the data on Number of branch per plant of tomato as influenced of different gibberellic acid and boron

Sources of Variation	Degrees of freedom	Mean Square			
		Number of branch per plant			
		20 DAT	**30 DAT**	**40 DAT**	**50 DAT**
Replication	2	0.031	2.168	3.348	1.665
Factor A (gibberellic acid)	3	29.835*	43.174*	43.682*	46.755*
Factor B (boron)	2	3.228 NS	8.34 NS	9.113 NS	5.019 NS
AB	6	2.964*	2.917*	3.1*	2.462*
Error	22	0.189	0.343	0.611	0.527

*significant at 5% level of probability,
NS- Non signficant

Appendix VII: Analysis of variance of the data on yield contributing of tomato as influenced of different gibberellic acid and boron

Sources of Variation	Degrees of freedom	Mean Square						
		Days of first flowering	**Day of 50% flowering**	**Number of flower cluster/ plant**	**Number of flowers / cluster**	**Number of flowers / plant**	**Number of fruits / cluster**	**Number of fruits / plant**
Replication	2	0.194	0.361	0.047	0.012	14.215	0.099	5.797
Factor A (gibberellic acid)	3	53.407*	53.074*	8.718*	1.254*	584.533*	2.889*	297.714*
Factor B (boron)	2	58.694*	60.778*	11.754*	1.219 NS	755.765*	1.968 NS	394.08*
AB	6	2.769*	1.185*	0.877*	0.389*	87.095*	0.166*	50.933*
Error	22	0.619	1.088	0.064	0.051	3.108	0.164	2.859

*significant at 5% level of probability
NS- Non signficant

Appendix VIII: Analysis of variance of the data on yield of tomato as influenced of different gibberellic acid and boron

Sources of Variation	Degrees of freedom	Mean Square						
		percent of flower dropping	**Day of first harvest**	**Length of fruit**	**Breath of fruit**	**Weight of individual fruit (g)**	**Weight of fruit / plant (Kg)**	**Yield (t/ha)**
Replication	2	0.533	0.528	0.21	0.185	11.771	0.196	6.925
Factor A (gibberellic acid)	3	9.486*	19.778*	1.087 NS	0.195 NS	294.144*	0.693*	629.991*
Factor B (boron)	2	100.345*	50.194*	0.239 NS	0.043 NS	84.297*	0.567*	336.422*
AB	6	8.024*	1.528*	0.074*	0.044*	30.048*	0.062*	84.112*
Error	22	1.638	0.831	0.23	0.026	5.352	0.094	3.467

*significant at 5% level of probability,
NS- Non signficant