RESPONSE OF TOMATO TO DIFFERENT PLANT GROWTH REGULATORS

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JUNE, 2018

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A Thesis

Submitted to the Department of Agricultural Botany
Sher-e-Bangla Agricultural University, Dhaka
In partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE (MS)
IN
AGRICULTURAL BOTANY
SEMESTER: JANUARY- JUNE, 2018

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CERTIFICATE

This is to certify that the thesis entitled "***RESPONSE OF TOMATO TO DIFFERENT PLANT GROWTH REGULATORS***" submitted to the Department of Agricultural Botany, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of ***MASTERS OF SCIENCE (M.S.)*** in ***AGRICULTURAL BOTANY***, embodies the result of a piece of bona-fide research work carried out by ***MD. HABIBUR RAHMAN***, Registration No. ***12-05176*** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Date: June, 2018

Dhaka, Bangladesh

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Dedicated to
My
Beloved Parents

ACKNOWLEDGEMENTS

The author seems it a much privilege to express his enormous sense of gratitude to the almighty Allah for there ever ending blessings for the successful completion of the research work.

The author wishes to express his gratitude and best regards to his respected Supervisor, ***Dr. Mohammad Mahbub Islam****, Professor, Department of Agricultural Botany, Sher-e-Bangla Agricultural University, Dhaka, for his continuous direction, constructive criticism, encouragement and valuable suggestions in carrying out the research work and preparation of this thesis.*

The author wishes to express his earnest respect, sincere appreciation and enormous indebtedness to his reverend Co-supervisor, ***Dr. Ashabul Hoque****, Professor, Department of Agricultural Botany, Sher-e-Bangla Agricultural University, Dhaka, for his scholastic supervision, helpful commentary and unvarying inspiration throughout the research work and preparation of the thesis.*

The author feels to express his heartfelt thanks to the honorable chairman of Agricultural Botany, ***Dr. Kamrun Nahar****, Associate professor, along with all other teachers and staff members of the department of Agricultural Botany, Sher-e-Bangla Agricultural University, Dhaka, for their co-operation during the period of the study.*

The author feels proud to express his deepest and endless gratitude to all of his course mates and friends to cooperate and help him during taking data from the field and preparation of the thesis. The author wishes to extend his special thanks to his class mates and friends for their keen help as well as heartiest co-operation and encouragement.

The author expresses his heartfelt thanks to his beloved parents, Elder Sister and Brother and all other family members for their prayers, encouragement, constant inspiration and moral support for his higher study. May Almighty bless and protect them all.

The Author

RESPONSE OF TOMATO TO DIFFERENT PLANT GROWTH REGULATORS

ABSTRACT

An experiment was carried out at the research farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from November 2017 to March 2018 to study the response of tomato to different plant growth regulators. The experiment consisted of seven (7) treatments *viz*. (1) T_1 = Control, (2) T_2 = 20 ppm Gibberellic Acid (GA_3), (3) T_3 = 100 µM Salicylic Acid (SA), (4) T_4 = 10 µM Methyl Jasmonate (MeJA), (5) T_5 = 20 ppm GA_3 + 100 µM SA, (6) T_6 = 20 ppm GA_3 + 10 µM MeJA and (7) T_7 = 100 µM SA + 10 µM MeJA. The experiment was laid out in Randomized Complete Block Design (RCBD) with five replications. Results revealed that the treatment, T_2 (20 ppm GA_3) showed the highest plant height (81.63 cm) but the highest number of leaves plant^{-1} (53.58) and SPAD value (53.08) were obtained from the treatment, T_6 (20 ppm GA_3 + 10 µM MeJA) at 65 days after transplanting (DAT).The lowest values of this parameter were found with control (T_1) treatment. The highest numbers of flower cluster^{-1} (6.78), number of fruits cluster^{-1} (4.54) were observed from the treatment, T_5 (20 ppm GA_3 + 100 µM SA). Separately, the highest number of flower cluster plant^{-1} (9.77), fruit diameter (15.02 cm), single fruit weight (51.86 g), number of fruits plant^{-1} (36.40), fruit weight plant^{-1} (kg) (1.90 kg), fruit weight plot^{-1} (16.76 kg) and fruit yield ha^{-1} (69.85 t) were found from the treatment, T_6 (20 ppm GA_3 + 10 µM MeJA). The lowest number of flower clusters plant^{-1} (6.75), number of flower cluster^{-1} (5.55), fruit length (7.63 cm) and fruit diameter (11.70 cm), number of fruits plant^{-1} (30.25), fruit weight plant^{-1} (1.56 kg), fruit weight plot^{-1} (13.91 kg) and fruit yield ha^{-1} (57.94 t) were observed from the treatment, T_1 (Control). Therefore, these experimental results concluded that GA_3 along with MeJA gave the highest fruit yield of tomato than sole application of GA_3 or together application of GA_3 along with SA under the edaphic and climatic conditions of Sher-e-Bangla Agricultural University (SAU).

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ABBREVIATIONS AND ACRONYMS

AEZ	=	Agro-Ecological Zone
BBS	=	Bangladesh Bureau of Statistics
BCSRI	=	Bangladesh Council of Scientific Research Institute
cm	=	Centimeter
CV %	=	Percent Coefficient of Variation
DAS	=	Days After Sowing
DMRT	=	Duncan‟s Multiple Range Test
et al.,	=	And others
e.g.	=	exempli gratia (L), for example
etc.	=	Etcetera
FAO	=	Food and Agricultural Organization
g	=	Gram (s)
i.e.	=	id est (L), that is
Kg	=	Kilogram (s)
LSD	=	Least Significant Difference
m^2	=	Meter squares
ml	=	MiliLitre
M.S.	=	Master of Science
No.	=	Number
SAU	=	Sher-e-Bangla Agricultural University
var.	=	Variety
^oC	=	Degree Celceous
%	=	Percentage
NaOH	=	Sodium hydroxide
GM	=	Geometric mean
mg	=	Miligram
P	=	Phosphorus
K	=	Potassium
Ca	=	Calcium
L	=	Litre
µg	=	Microgram
USA	=	United States of America
WHO	=	World Health Organization

CHAPTER I

INTRODUCTION

Tomato (*Lycopersicon esculentum*) is a fruit vegetable which belongs to the family Solanaceae. It is a self-pollinated vegetable and the most popular and widely grown vegetables in the world, ranking second after potato (Prasad *et al*., 2013). Tomato has a significant role in human nutrition. It is a rich source of minerals and vitamins such as ascorbic acid and carotene which are anti-oxidants and promote good health (Wilcox *et al*., 2003). Tomatoes can make people healthier and decrease the risk of conditions such as cancer, osteoporosis and cardiovascular disease. People who eat tomatoes regularly have a reduced risk of contracting cancer diseases such as lung, prostate, stomach, cervical, breast, oral, colorectal, esophageal, pancreatic, and many other types of cancer (Bhowmik *et al*., 2012). The red pigment of tomato is contains lycopene which is the newly discovered bioflavonoids and is responsible as Anti cancer fighting agents (Bhowmik *et al*., 2012). Therefore, it has lots of importance to human health.

Among the vegetables, tomato is one of the most important crop in terms of acreage, production, yield, commercial use and consumption (BBS, 2015). In Bangladesh, November-February is the cultivation period of tomato in *rabi* season crop in when suitable weather remains. The total production of tomato in Bangladesh was 12.22 t/ha and area coverage was 67535 acre of land with 368121 MT yield (BBS, 2016). The world dedicated 5.02 million hectares in 2014 for tomato cultivation and the total production was about 188.2 million tons with world average farm yield was 37.46 t/ha (FAOSTAT,2016). Production status of tomato in Bangladesh is very low compared to world average. So, it is urgently needed to increase tomato production in our country.

The lower yield of tomato in Bangladesh, however, is not an incidence of the low yielding potentiality of this crop but of the fact that the lower yield may be attributed to a number of reasons *viz*. unavailability of quality seeds of improved varieties, fertilizer management, disease infestation and improper moisture management and lack of knowledge about the use of plant growth regulators (PGRs) in tomato to improve fruit yield.

To overcome low yield potentiality of tomato, plant growth regulators may be considered as a yield promoting substances. Plant growth regulators (PGR_s), is a natural or synthetic chemical that is sprayed or otherwise applied to a seed or plant in order to alter its characteristics. Sometimes it is referred to as plant hormones. Plant growth regulators function as chemical messengers for intercellular communication (Pramanik and Mohapatra, 2017). In tomato, growth regulators like GA_3 play a pivotal role in germination, root development, branching, flower initiation, fruiting, lycopene development, synchronization and early maturation, parthenocarpic fruit development, ripening, TSS, acidity, seed production etcetera (Pramanik *et al*., 2017). Plant growth and development are regulated by action and balance of different groups of growth regulators, which promote such processes (Prins *et al*., 2010). It is used extensively in tomato to enhance yield by improving fruit set, size and number (Batlang, 2008; Serrani *et al.*, 2007).

GA_3 is one of the important growths stimulating hormone or PGR which enhance cell division and cell elongation thus help in the growth and development of plants. GA_3 increases the leaves size, stem length and fruit set (Serrani *et al*., 2007). Gemici *et al*. (2006) reported that application of synthetic auxin and gibberellins are effective in increasing both yield and quality of tomato. Fruit set in tomato was successfully improved by application of plant growth regulators (Desai *et al*., 2014). It significantly increases growth characters, yield and also improved quality of tomato (Pundir and Yadav, 2001). However, to my knowledge sufficient studies did not conduct to find the

response of tomato with GA_3 under Sher-e-Bangla Agricultural University (SAU) climatic and edaphic conditions.

Salicylic acid (SA) is an endogenous plant growth regulator of phenolic nature which enhances plant resistance to pathogens and other stresses (Rao *et al*., 2000). In addition to provide resistance to plant diseases; SA also has been found to induce tolerance to than some abiotic stresses such as drought (Hayat *et al*., 2008), heat (Larkindale and Huang, 2004), salinity (Shakirova *et al*., 2003), chilling (Taşgin *et al*., 2003), heavy metal (Metwally *et al*., 2003; Choudhury and Panda, 2004) and UV radiation (Rao and Davis, 1999). Moreover, SA plays role in the regulation of some physiological processes such as seed germination, fruit yield, glycolysis, flowering in the morphogenic plants, nutrient uptake and transport, photosynthetic rate, stomatal conductance and transpiration (Hayat *et al*., 2010). However, to my knowledge little is known about the response of tomato to SA under SAU climatic and edaphic conditions.

Jasmonic acid (JA) is an another plant growth regulators that play an important role in plant development and physiological processes such as seed germination, root growth, flowering, ripening, senescence, photosynthesis, the formation of gum and bulb, defense response against pathogens and insect attack, plant response to wound and abiotic stresses (Maciejewska *et al*., 2004; Choi *et al*., 2005; Kim *et al*., 2009; Warabieda *et al*., 2010). In addition, MeJA induces or increases the biosynthesis of many secondary metabolites that play important roles in plant adaptation to particular adverse environments (Choi *et al*., 2005). Ester of JA is MeJA which has been using in agriculture to get desirable yield of crops. However, to my knowledge no study has conducted to find the contribution of MeJA on changes the morphological character and yield of tomato under SAU climatic and edaphic conditions.

In this circumstance, no experiment was conducted to find out the sole and/or together applications of GA_3, SA and MeJA on the performance of tomato. Therefore, the present study was taken to fulfill the following objectives:

1. To investigate the response of tomato with reference to morpho-physiology and yield to sole application of GA_3, SA, and MeJA
2. To investigate the response of tomato with reference to morpho-physiology and yield to the together application of GA_3 or SA or MeJA or their combination

CHAPTER II

REVIEW OF LITERATURE

The literature pertaining to "the response of tomato to different plant growth regulators" is briefly given below. In this chapter, due to paucity of the adequate experimental evidences on these aspects, the similar work done on the crops has been reviewed to understand the effect of different treatments.

2.1 Effect of plant growth regulators

Tomato (*Lycopersicon esculentum*) is one of the most popular vegetable in Bangladesh. November to February is the congenial period for tomato cultivation in Bangladesh. Plant hormones are used extensively to enhance plant growth, fruit number, fruit set, fruit size and yield of horticultural crops (Batlang, 2008). Plant growth substances are essential for growth and development of tomato plant. It plays an important role in flowering, fruit setting, ripening and physiochemical changes during storage of tomato. Fruit set in tomato was successfully improved by application of plant growth regulators and micronutrients (Desai *et al*., 2012). In fact, the use of growth regulators had improved the production of tomato including other vegetables in respect of better growth and quality (Saha *et al*., 2009). Pramanik *et al*. (2017) observed that plant growth regulators (also called plant hormones) are numerous chemical substances that profoundly influence the growth and differentiation of plant cells, tissues and organs. Plant growth regulators function as chemical messengers for intercellular communication. In tomato, different growth regulators play a pivotal role in germination, root development, branching, flower initiation, fruiting, lycopene development, synchronization and early maturation, parthenocarpic fruit development, ripening, TSS, acidity, seed production etc.

2.1.1 Effect of GA_3

Jakhar *et al*. (2018) carried out an investigation to find out the effects of plant growth regulators on growth and yield of tomato cultivar „Shivaji". Treatments consist of different levels of GA_3 (25, 50 and 75 ppm), NAA (25, 50 and 75 ppm) and Kinetin (25, 50 and 75 ppm) along with control. These different concentrations of GA_3, NAA and Ki were sprayed on the crop at 7, 14 and 21 days after transplanting. All growth, phonological as well as yield parameter was found to be significantly superior at different concentration of GA_3, NAA and Ki as compare to control treatment. Maximum plant height (104.33 cm), number of leaves per plant (64.73) and number of branches per plant (11.20) at 90 days after transplanting, minimum days to 50 % flowering (44.40 days), maximum numbers of flower per plant (61.00), fruit length (6.10 cm), fruit diameter (5.93 cm), number of fruit per plant (30.80), fruit yield per plant (3.66 kg) and fruit yield per ha (1355.56 tonnes) was reported in treatment where plant has been sprayed with 50 ppm GA_3.

Kumar *et al*. (2018) conducted an experiment to study the effect of varying levels of NAA, 2, 4-D and GA_3 on growth, quality and yield of tomato and to ascertain the best concentration of NAA, 2, 4-D and GA_3 for vegetative growth and fruit quality of tomato. The experiment consisted tomato variety *viz*. kashi vishesh (H-86) and different levels of NAA (15, 30, 45 ppm), 2, 4-D (5, 10, 15 ppm) and GA_3 (20, 30, 40 ppm) of different concentrations were used. From the result it was observed that concentration of GA_3 @ 40 ppm concentration showed significant effects on growth, flowering, yield and quality of tomato.

Akand *et al*. (2015) conducted an experiment to find out the effect of GA_3 on the growth and yield of summer tomato. The experiment consisted of four concentration of GA_3 such as control G_0= control (no GA_3), G_1= 75 ppm GA_3, G_2 = 100 ppm GA_3 and G_3= 125 ppm. All parameter varied significantly at different concentration of GA_3. The highest yield (92.99 t/ha) was obtained

from G_3 (125 ppm GA_3) treatment whereas the G_0 gave the lowest yield (60.46 t/ha).

Rahman *et al.* (2015a) carried out an experiment to evaluate influence of different concentrations of GA_3 on biochemical parameters at different growth stages in order to maximize yield of summer tomato var. Binatomato-2. The concentrations of GA_3 were 0, 25, 50, 75 and 100 ppm. The application of 50 ppm GA_3 by root soaking had significantly increased the number of flowers, fruits and fruit yield per plant but similar results were achieved when only 25 ppm GA_3 was applied at the flowering stage. The fruit yield of tomato per plant increased linearly with the increased number of flowers and fruits per plant.

Rahman *et al*. (2015b) conducted an experiment to assess the impact of plant growth regulators on growth and yield of summer tomato. The experiment consisted of two tomato varieties *viz*. BARI Hybrid Tomato-4 and BARI Hybrid Tomato-8 and four types of plant growth regulator (PGR); *viz*., (i) control (without PGR), (ii) 4-CPA (4-chlorophenoxy acetic acid), GA_3 (gibberellic acid) and 4-CPA +GA_3. The maximum plant height (87.90 cm), number of flowers and fruits (49.04 and 21.91, respectively) plant^{-1}, individual fruit weight (61.16 g) and fruit yield (27.28 t ha^{-1}) were observed in BARI Hybrid Tomato-8 when treated with 4-CPA + GA_3 together, and the minimum for all these parameters were found in control plants.

Sattigeri *et al.* (2014) carried out an experiment to find out the influence of organic, inorganic nutrients forms and plant growth regulators on various morphological growth, biochemical traits, and yield components in tomato. The experiment consisted of two organics i.e., FYM and vermicompost at two different concentrations, one P-solubilizer nutrients *viz*., KNO_3 and $FeSO_4$ and plant growth regulators *viz*., salicylic acid and GA_3 with three replications. The morphological traits *viz*., number of branches, in leaf increased significantly due to application of organic, nutrients and plant growth regulators. Among various treatments the application of GA_3 (20 ppm), P-solubilizer (2.5 kg/ha)

and vermicompost (2 T/ha) were effective in increase plant height, leaves, fruit diameter and number of fruits.

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

Jones *et al.* (2014) carried out a field experiment to assess the growth, flowering, fruiting yield and quality traits of Tomato cv. Kashi Vishesh (H-86). The experiment was consisted of 10 treatments namely, Control, GA_3 @ 20 ppm, GA_3 @ 40 ppm, GA_3 @ 60 ppm, NAA @ 10 ppm, NAA @ 20 ppm, NAA @ 30 ppm, 2, 4-D @ 10 ppm, 2, 4-D @ 15 ppm and 2, 4-D @ 20 ppm to find out the effect of the growth, flowering, fruiting, yield and quality of tomato and various horticulture characters namely; plant height (cm), number of branches, number flowers per plant, number of clusters per plant, number of fruits per clusters, number of fruits per plant, average fruit length (cm), average fruit diameter (cm), average fruit weight (g), fruit yield per plant (kg), fruit yield per plot (kg), fruit yield per hectare (q), acidity (%) and total soluble solids TSS (% Brix). However, application of the plant bio regulators had a significant influence on plant growth, flowering, fruiting, yield and quality traits of tomato and GA_3 gave the highest yield than other plant growth regulators. So, GA_3 was superior among all treatments under investigation for response of tomato production.

Kumar *et al.* (2014) conducted a study to determine the effects of gibberellic acid on growth, fruit yield and quality of tomato. The experiment consisted of one tomato variety- Golden and six treatments with five levels of gibberellic

acid (GA_3- 10 ppm, 20 ppm, 30 ppm, 40 ppm and 50 ppm). The highest plant height, number of leaves, number of fruits, fresh fruit weight has been observed and ascorbic acid, total soluble solid (TSS) was estimated for GA_3 at 50 ppm.

Sarkar *et al*. (2014b) conducted an experiment with the signification of realizing the influence of plant hormones on flower and fruit setting of summer tomato. The experiment consisted of two varieties namely BARI hybrid tomato-3 and BARI hybrid tomato-4, and four types of plant hormones @ 40 ppm, *viz*. Control; 2,4-Dichlorophenoxy acetic acid; 4-Chlorophenoxy acetic acid (Tomatotone) and 1-Naphthalene acetic acid. The experiment revealed that, application of 2,4-Dichlorophenoxy acetic acid hastened flowering, fruiting and number of flower and fruit clusters plant^{-1} of the variety BARI hybrid tomato-4. 1-Naphthalene acetic acid and 4-Chlorophenoxy acetic acid also showed significant increase in flower and fruit setting of summer tomato.

Choudhury *et al*. (2013) carried out a field experiment to assess the effect of different plant growth regulators on tomato during summer season. Different plant growth regulators (PGR) *viz*. PGR_0 = Control, PGR_1 = 4-CPA (4-chloro phenoxy acetic acid) @ 20 ppm, PGR_2 = GA_3 (Gibberellic Acid) @ 20 ppm and PGR_3 = 4-CPA + GA_3 @ 20 ppm of each were used in the study. The growth and yield contributing characters significantly differed due to different plant growth regulators. The maximum plant height at 60 DAT (86.01cm), number of flowers cluster per plant (10.60), number of flowers per plant (39.69), number of fruits per plant (36.54), single fruit weight (74.01 g) and yield (28.40 t ha^{-1}) were found in PGR_3 and the minimum for all the parameters were found in control (PGR_0) treatment.

Prasad *et al.* (2013) conducted a field trial on the effect of GA_3 and NAA on tomato. The different concentration of GA_3 (20, 40, 60 and 80 ppm) and NAA (25, 50, 75 and 100 ppm) were sprayed on the crop to study the growth behavior and yield and yield attributes of tomato. It was found that there was a

linear increase in growth parameters like plant height and number of branches per plant with increasing level of GA_3 and NAA. The maximum plant height was recorded as 85.3cm and 82.3 cm with the application of GA_3 @ 80 ppm and NAA @ 100ppm, respectively after 60 days of transplanting. Similarly, the yield and yield attributes were also affected significantly with increasing concentrations of GA_3 and NAA. Maximum yield of 483.6q/ha and 472.2 q/ha were obtained with the use of GA_3 @ 80 ppm and NAA @100ppm, respectively.

Ali *et al*. (2012) the experiment was laid out in Randomized Complete Block Design with three replications. Three plant growth regulators (G_1=NAA, G_2=GA3 and G_3=IAA) and three tomato varieties (V_1=BARI tomato 3, V_2=BARI tomato 7 and V_3=BARI tomato 9) were used in this experiment. Use of plant growth regulators the results of the experiment showed that G_3 produced highest number of branches per plant (12.37), number of flowers per plant (91.51) and yield (126.6 t/ha). In case of tomato variety highest number of branches per plant (11.81), number of flowers per plant (91.66) and yield (99.74 t/ha) produced by V_2. For combined effect V_2G_3 produced highest number of branches per plant (15.23), number of flowers per plant (105.2) and yield (151.5 t/ha). It may be concluded that IAA with BARI Tomato 7 gave best result.

Desai *et al*. (2012) conducted an experiment to find out the effect of different plant growth regulators and micronutrient on fruit characters and yield of tomato cv. Gujarat Tomato-3 (GT-3). The fruit characters and yield parameters in plant significantly differed due to different plant growth regulators. The maximum fruit length (7.57 cm), girth (6.47 cm) and pulp-seed ratio (12.93) was found in gibberellic acid @ 75 ppm, whereas fruit weight (57 g), yield plant^{-1} (2.47 kg) and yield hectare^{-1} (913.258 q/ha) were found in naphthalene acetic acid @ 75 ppm and the minimum for all the parameters were found in control treatment.

Gelmesa *et al.* (2012) conducted an experiment with the objective of determining the effects of different concentrations and combinations of the plant growth regulators (PGRs) 2,4-D and GA_3 spray on fruit setting and earliness of tomato varieties. The experiment consisted three levels of 2,4-D (0, 5 and 10 ppm) and four levels of GA_3 (0, 10, 15 and 20 ppm). The study indicated that application of GA3 extended flowering and maturity time and increased fruit number per cluster, fruit set percentage and marketable fruit.

Ayub and Rezende (2010) carried out a study with the aim of assessing the behavior of tomato fruits subjected to increasing concentrations of gibberellic acid (GA_3) in tomato crops, cultivar Fanny, under the crossing fence system with a single branch per plant. The adopted treatments were as follows: 0, 30, 60, 90, and 120 ppm of GA3, applied whenever the diameter of the first fruits of the second clusters reached roughly 10 mm. At harvest when the fruits had achieved 30 to 50% of reddish color, the fresh mass, length, and longitudinal and transversal diameters were measured.

Rezende and Ayub (2010) carried out a research with the aim of assessing behavior of tomato fruits subjected to increasing concentrations of gibberellic acid (GA_3). The following treatments were 0, 30, 60, 90, and 120 ppm of GA_3, were applied whenever the diameter of the first fruits of the second clusters reached roughly 10 mm. and at harvest when the fruits had achieved 30 to 50% of reddish.

Saha *et al*. (2009) to evaluate the effect of various growth regulators namely NAA (0, 25, 50 and 75 ppm) and GA_3 (0, 15, 40 and 60 ppm) in factorial randomized block design on yield and fruit quality of tomato. Significant response of NAA (25 ppm) with respect to number of fruits/plants, fruit weight/plant, total soluble solid (TSS) and vitamin C and yield was obtained over the control. Similarly, maximum yield and vitamin C was obtained with the application of 40 ppm GA_3. Combined application of NAA (25 ppm) and

GA_3 (40 ppm) was more effective than their individual application in terms of yield, TSS and vitamin C content, respectively.

Uddain *et al.* (2009) conducted an experiment to find out the effect of different plant growth regulators on tomato. Four different plant growth regulators (Denoted as PGR) were used as treatments, *viz*. PGR_0 = Control, PGR_1 = NAA 30 ppm, PGR_2=GA @ 30 ppm and PGR_3 = 2,4-D @ 30 ppm in the study. The growth and yield contributing characters were significantly differed due to different plant growth regulators on tomato. The maximum plant height at 45 DAT (76.36 cm), number of leaves/plant at 45 DAT (72.86), number of branches/plant at 45 DAT (17.85), number of flowers/cluster (5.81), number of flower cluster/plant (8.83), number of flowers/plant (59.62), number of fruits cluster (4.81), number of fruits/plant (42.66), average weight of individual fruit (92.06 g), yield/plant (2.49 kg) and yield/hectare (93.23 t/ha) were found from PGR_2.

Abdel-Rahman (2008) assessed changes in growth, endogenous levels of hormones, and ethylene evolution and cellulite and pectolytic enzyme activities of cherry tomato fruits from anthesis through ripening. After anthesis, growth of cherry tomato fruit follows a three – dimensional and sigmoid growth pattern which consists of cell division, cell enlargement and mature green. Pink and red stages. Cytokinin's and auxins were abundant and reached their peak during early development (cell division). Gibberellin levels were more prominent during the period of cell enlargement and reached a peak before the green mature stage.

Knoche and Peschel (2007) in developing tomato (*Lycopersicon esculentum* L.) fruit were investigated. Growth regulators were applied when fruit development within trusses ranged from the flower to the mature stage. Developmental stage of fruit at the time of application was indexed by fruit diameter. Fruit were harvested at maturity, the CM isolated enzymatically on an individual fruit basis and mass of CM per unit fruit surface area calculated.

In mature fruit, mass of CM per fruit increased with fruit size, but mass of CM per unit surface area was independent of fruit size, position within a truss and position of the truss on the plant.

Bakrim *et al.* (2007) studied the effect of phytohormones: gibberellic acid (GA_3), naphthalene acetic acid (NAA), benzyl amino purine (BAP) application on some morphological and biochemical parameters of tomato. NAA treatment resulted in marked reduction in shoot length. GA_3 treatment promoted maximal shoot elongation. BAP affected negatively shoot length only at late stages. NAA inhibited root elongation all along the test period. GA_3 treatment had no effect on root length, whereas BAP showed strong inhibition on root elongation.

Jellani *et al*. (2006) reported that the tomato cv. Roma parasitized by Orobanche was treated with different concentrations of gibberellic acid (GA_3; at 10-1 M) as foliar spray. The application of growth regulators minimized the detrimental effect of parasite on the host. Foliar spray of GA_3 at 10-4 M improved the productivity and performance of tomato plant in terms of nutrient content, plant height, plant vigour, dry weight and yield (1325.2 g). Root dipping in ABA at 10-5 M and 10-6 M also showed a positive effect on root dry weight, leaf P content of tomato and N content of both tomato and Orobanche.

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

Bokode *et al*. (2006) reported that the growth of plant as assessed by height of plant was significantly influenced by different growth substance. The treatment with GA_3 50ppm concentration gave maximum height of plant in tomato.

Number of primary branches was not influenced by various treatments. Application of GA_3 at 50ppm was found it be more effective in earliness to 50% flowering.

Bhalekar *et al.* (2006) studied the effects of GA_3, NAA, 4-CPA and boron at 25 or 50 ppm on the growth and yield of tomato (cv. Dhanshree). Plant height was greatest with 4-CPA at 50 ppm (72.22 cm). The number of primary branches per plant did not significantly vary among the treatments. GA_3 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 quintal/ha).

Gemici *et al.* (2006) reported that application of synthetic auxin and gibberellins (GAs) are effective in increasing both yield and quality of tomato. Application of certain PGRs likes auxin and Gibberellic acid (GA_3) that bring the possibility of tomato production under adverse environmental conditions. Those PGRs are used extensively in tomato to enhance yield by improving fruit set, size and number (Serrani*et al*., 2007 and Sasaki *et al*., 2005) and could have practical application for tomato growers. Tomato fruit setting was promoted by GA_3 at low concentration (Khan *et al*., 2006 and Poliquit *et al*., 2007).

Sasaki *et al*. (2005) reported that treatment 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 (GA_3). In the field experiment, tomato treated with a mixture of 4-CPA and GA_3 showed increased fruit set and the number of normal fruits (Excluding abnormal types such as puffy fruit) were more than the plants treated with 4-CPA alone during summer.

Bhosle *et al.* (2002) determined the effects of NAA (25, 50 and 75 ppm), gibberellic 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. The number of flowers per cluster, fruit weight and marketable yield increased with increasing rates of the plant growth regulators. Treatment with 30 ppm gibberellic acid resulted in the tallest plants, whereas treatment with 25 ppm 4-CPA and 45 ppm gibberellic acid resulted in the highest number of primary branches of Dhanashree (4.16) and Rajashree (5.38), respectively where 50 ppm 4-CPA resulted the highest yield (23.7 t/ha).

Naeem *et al*. (2001) conducted an experiment with different concentration of Gibberellic Acid and time of plantation. Both time and concentrations had affected significantly the growth parameters of plants. Maximum days to flowering (42.67), fruit per plant (77.69), plant height (77.78 cm), fruit weight (71.15 gm), number of branches (12.33) per plant and total yield (26840 kg/ha) were recorded in the plants sprayed with 60 mg/lit of gibberellic acid 10 days before transplantation, while minimum values were noted in controlled treatment. Maximum fruit drop per plant was found for control treatment and minimum for the plants treated with gibberellic acid at 60 mg/lit.

Singh and Lal (2001) conducted a field experiment to determine the effect of plant bioregulators on the growth and yield of tomato cv. Pant T-3. The bioregulator treatments comprised CIPA (10 and 20 ppm); NAA (20 and 40 ppm); 2,4-D (5 and 10 ppm), Alar [daminozide] (50 and 100 ppm); GA_3 (5 and 10 ppm); ethephon (50 and 100 ppm); PPP (paclobutrazol, 5 and 10 ppm); and the control (water, 0 ppm). All the plant bioregulators decreased plant height compared to the control. The number of branches per plant increased with 10 ppm GA_3. All the bio regulators decreased the number of days to fruit maturity compared to the control. The minimum number of days to fruit maturity were found in 10 ppm 2,4-D. The maximum and minimum number of fruits per plant was recorded in 5 ppm GA_3 and 10 ppm 2,4-D, respectively.

2.1.2 Effect of salicylic acid (SA)

Afsana *et al*. (2017) conducted a study to find out the role of exogenous foliar application of salicylic acid (SA) and calcium (Ca^{2+}) on growth, reproductive behavior and yield of tomato. BARI Tomato-15 was used as planting material. Six different treatments *viz*., A_0=0 mM of SA and 0 mM Ca^{2+}, A_1=0.25 mM SA and 0 mM Ca^{2+}, A_2=0 mM SA and 5 mM Ca^{2+}, A_3 =0.25 SA and 5 Ca^{2+}, A_4 =0 of SA and 10 Ca^{2+} and A_5 = 0.25 SA and 10 mM Ca^{2+} were applied in the morning at 15, 30, and 45 days after transplanting (DAT). The morphological and yield contributing characters as well as yield of tomato were positively influenced with single and combined application of salicylic acid (SA) and calcium (Ca^{2+}). Significant increase of plant height and number of leaves plant^{-1} at 20, 40 and 60 DAT were observed with the application of A_3 treatment. Application of A_3 treatment also showed significant influence on production of cluster plant^{-1} (20.44), flowers plant^{-1} (168.1), and fruits plant^{-1} (99.42) as well as fruit yield (72.57 t ha^{-1}). However, application of A_4 treatment failed to improve the morphological and yield contributing characters as well as yield of tomato over the A_0 treatment (control).

Tomar *et al.* (2016) conducted an experiment aimed to investigate the effect of foliar application with salicylic acid (2 mM/L) alone or combined with chitosan (0.1%) with or without TMV inoculation on improving resistance, growth, productivity and quality of tomato Hybrid Super Jackal F1. The SA (salicylic acid) plus CH (chitosan) foliar application without TMV inoculation gave the highest significant values of vegetative growth in both seasons. Combination treatment of SA plus CH increased significantly N, P, K. Fe and Zn concentration. This treatment was also effective in increasing tomato yield compared with treatment of infection alone.

Javaheri *et al.* (2014) studied the effects of salicylic acid on some quality characters of tomato at different concentration of salicylic acid (10^{-2}, 10^{-4}, 10^{-6}, 10^{-8} molar and control) in seedling stage as foliar replication. This study

showed that salicylic acid significantly affected number of panicles in a bush, yield, fruit number in panicle, fruit number in bush, fruit weight and fruit diameter. Among foliar application, the highest rate of tomato yield with mean of 3059.5 g obtained in SA_3 (SA at 10^{-6} M), highest numbers of panicle in tomato bushes with mean of 31.25 measured in SA_1 (SA at 10^{-2} M). Highest fruit number in panicle and highest fruit number in bush obtained by mean of 3.5 and 66.75 in SA_1 (SA at 10^{-2} M), respectively and minimum amount of all this characters was recorded in control treatment and the highest amount of fruit weight and also fruit diameter was measured in control treatment with mean of 61.50 g and 51.75 mm, respectively.

Kowalska and Smolen (2013) conducted a study to evaluate the effect of foliar application of salicylic acid and $KMnO_4$ (the latter causing oxidative stress) on the yield, fruit quality and nutritional status of tomato plants under increased salt concentration in nutrient solution. The experiment included two sub-blocks with two EC levels (2.5 and 4.5 mS cm^{-1}). Within each sub-block, foliar applications were distinguished as (1) control, without foliar application; (2) salicylic acid (SA) and (3) SA/$KMnO_4$. In the SA/$KMnO_4$ combination, solutions of these compounds were applied alternately every 7 days. SA was applied in the concentration of 0.01%, while the concentration of $KMnO_4$ was 0.1%. Foliar treatments were conducted at 7-day intervals from the 3rd cluster flowering stage until ten days before the first harvesting of fruits. Irrespective of the EC of the nutrient solution, foliar application of SA as well as SA/$KMnO_4$ had no significant effect on the tomato yield, total acidity and dry matter or soluble sugar content in fruits.

Kazemi (2013) conducted an experiment in order to study effect of salicylic acid and calcium foliar application on growth, yield and yield components of strawberry plants. These factors included of salicylic acid in 3 levels (0.25. 0.5 and 0.75 mM) and calcium in 2 levels (2.5 and 5 mM) spray on strawberry. Results showed that salicylic acid (0.25 mM) and calcium chloride (2.5 mM)

spray either alone or in combination (0.25 mM SA+ 2.5 mM Ca) affected on vegetative and reproductive growth, significantly. Mean comparisons indicated yield, and quality of strawberry plants was improved in low salicylic acid and calcium chloride concentration. In Finally, salicylic acid and calcium chloride application can be helpful for yield improvement and prevent of decreasing yield.

Khandaker *et al*. (2011) conducted this study to determine the effect of foliar salicylic acid (SA) applications on growth, yield and bioactive compounds of red amaranth grown under greenhouse conditions. SA was applied at three different concentrations (10^{-3}, 10^{-4} and 10^{-5} M), three times during the vegetation at 7-day intervals one week after sowing. All of three doses of SA application enhanced the plant growth, yield and leaf‟s bioactive compounds compared to the control. The growth parameters and yield of red amaranth was significantly influenced by foliar SA applications. The highest yield, antioxidant activity, amount of beta-cyanins, chlorophyll and total polyphenol occurred in 10^{-5} M SA treatment. According to results, applications SA at rate of 10^{-5} M should be recom-mended in order to improve yield and bioactive compounds in red amaranth.

Salehi *et al*. (2011) conducted a pot experiment to evaluate the effect of SA on tomato growth under salt stress condition. The experiment consisted of 4 levels of irrigation water salinity (0, 4, 8 and 12 dS/m) and 4 levels of SA concentration (0, 10^{-6}, 10^{-4} and 10^{-2} M) which was foliar sprayed. There was highly significant reduction in shoot fresh and dry weights and number of flowers per plant with increasing salinity. There was no significant difference between shoot fresh and dry weighs and number of flowers per plant for SA treated plants and control. However, fresh weight of plants treated with 10-^{6} M SA was significantly higher than the other two concentrations. Within each salinity level, SA application did not have significant effects on the measured characteristics.

2.1.3 Effect of methyl jasmonate (MeJA)

Kazemi (2014) conducted an experiment to study the effect of methyl jasmonate and salicylic acid as pre-harvest treatments on the tomato vegetative growth, yield and fruit quality. These factors included methyl jasmonate in 3 levels (0.25. 0.5 and 0.75 $mmolL^{-1}$) and salicylic acid in 2 levels (0.5 and 0.75 $mmolL^{-1}$) applied on tomato. Results indicated that salicylic acid (0.5 $mmolL^{-1}$) and methyl jasmonate (0.25 $mmolL^{-1}$) either alone or in combination (0.5 $mmolL^{-1}$ SA+ 0.25 $mmolL^{-1}$ MJ) increased vegetative and reproductive growth, yield and chlorophyll content. The application of salicylic acid (0.5 $mmolL^{-1}$) along significantly increased the leaves-NK content and dry weight, but methyl jasmonate application alone or in cccmbmation had no significant effect on Leaves-NK content. Application of salicylic acid with mothyl-asmonate improved the yield contributing factors, that resulted in significant increase in tomato fruit yield.

Rahimi *et al*. (2013) conducted an experiment to study the effect of salicylic acid (SA) and Methyl jasmonate (MeJA) on growth, yield and quality of cumin (*Cuminum cyminum* L.). The plants were sprayed with concentration of 0 (control: distilled water), 0.01, 0.1 and 1 mM of SA and MeJA. Results showed that the lowest concentrations of SA (0.01 and 0.1 mM) resulted in significant promotion of plant height and number of branches and umbels per plant. Fruit yield significantly increased by the application of 0.1 mM SA followed by 0.1 mM MeJA.

Lolaei *et al*. (2013) conducted a study to investigate the impacts of methyl jasmonate on the weight and yield of strawberry with two cultivars (selva and Queen elisa). Three concentration of methyl jasmonate (0, 0/25, 0/50 and 1/00 Mm) and control treatment were used as foliar application during bud formation. Applications of methyl jasmonate concentrations in strawberry fruits were showed fruit firmness. In selva and queen elisa cultures, vegetative growth decreased significantly by the addition of 1 mg MJ. Strawberries

treated with MJ had higher soluble solids content. Number of the fruits and growth rate of the plant decreased as jasmonic acid concentration increased. Anthocyanin in fruit by MJ treated fruit was increased. The effect of MJ was significant on yield and growth of strawberry plants.

Manan *et al*. (2016) conducted a study to investigate the effect of foliar application of methyl jasmonate ($C1_3H_{20}O_3$) (MeJA) on physiological and biochemical processes in tomato under both saline and non-saline conditions with two tomato genotypes; Rio Grande (salt tolerant) and Savera (salt sensitive). The salinity substantially decreased the physiological and biochemical parameters. Different doses of MeJA (0.0, 10, 20, 30, 40, 50, 60 ìM) were applied on both control and salt stressed tomato plants. Methyl Jasmonate MeJA significantly ameliorated the deleterious effects of salinity on tomato plants by inducing the physiological and biochemical resistance. Different parameters responded to MeJA at various extents. The findings illustrate that all the parameters responded to foliar application of MeJA and it is quite helpful creating physiological and biochemical resistance in salinity stressed tomato plants.

Rohwer Erwin (2008) reported that a particular class of growth regulators, collectively called jasmonates are involved in plant responses to such events and elicit unique responses. The effects of jasmonates on plant growth are varied and include storage organ formation, induction of plant defences against biotic (e.g., herbivores and pathogens) and abiotic (e.g., drought and ozone) stresses, and growth inhibition in tissues such as roots and young shoots. In addition, jasmonates can interact with other hormone pathways, especially ethylene, to affect growth and development. Detailed knowledge of jasmonate responses in models such as Arabidopsis is being put to use in a wide variety of horticultural crops.

2.2 Conclusion in brief:

From the above review of literature, it was clear that the plant growth regulators play an important role in respect of growth, yield and yield attributes of tomato. So, use of different hormones may be an alternative considering growth and yield advantages and also facing adverse situation.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at the Sher-e-Bangla Agricultural University farm, Dhaka, Bangladesh during the period from November 2017 to March 2018 to study the response of tomato to different plant growth regulators. The details of the materials and methods have been presented below:

3.1 Experimental location

The present piece of research work was conducted in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207. The location of the site is 90°33´ E longitude and 23°77´ N latitude with an elevation of 8.2 m from sea level. Location of the experimental site presented in Appendix I.

3.2 Soil

The soil of the experimental area belongs to the Modhupur Tract (UNDP, 1988) under AEZ No. 28 and was dark grey terrace soil. The selected plot was medium high land and the soil series was Tejgaon (FAO, 1988). The characteristics of the soil under the experimental plot were analyzed in the Soil Testing Laboratory, SRDI, Khamarbari, Dhaka. The details of morphological and chemical properties of initial soil of the experiment plot were presented in Appendix II.

3.3 Climate

The climate of experimental site was subtropical, characterized by three distinct seasons, the winter from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October (Edris *et al*., 1979).

3.4 Test crop and its characteristics

The tomato variety; BARI tomato-15 was used for the present study. This variety is tolerant to Yellow leaf curl virus. It is a high yielding winter variety. Thick skin and edible flesh having very good self-life. Fruit is oval shape; less seeded and single fruits is with 65-70g in weight. It has attractive red flesh color. Average number of fruits per plant is 40-45 and life time is 100-110 days. Within 60-70 days after transplantation fruit harvest start and harvest up to 25-30 days. Due to thick and rigid skin of tomato, storage time is high.

3.5 Experimental details

3.5.1 Treatments

The experiment comprised of one factor as follows:

1. T_1 = Control by H_2O
2. T_2 = 20 ppm GA_3
3. T_3 = 100 μM SA
4. T_4 = 10 μM MeJA
5. T_5 = 20 ppm GA_3 + 100 μM SA
6. T_6 = 20 ppm GA_3 + 10 μM MeJA
7. T_7 = 100 μM SA + 10 μM MeJA

Legend:

GA_3 = Gibberellic Acid

SA = Salicylic Acid

MeJA = Methyl Jasmonate

3.5.2 Experimental design and layout

The experiment was laid out in Randomized Complete Block Design (RCBD) with five replications. The layout of the experiment was prepared for distributing the concentration of growth regulators including control. The seven (7) treatments of the experiment were assigned at random into 35 plots. The size of each unit plot was 1.6 m × 1.5 m. The distance between blocks and plots were 0.5 m and 0.25 m respectively. The layout of the experiment field is presented in Appendix III.

3.6 Variety used and seed collection

BARI tomato-15, a high yielding variety of tomato (*Solanum lycopersicum* Mill.) developed by Bangladesh Agricultural Research Institute (BARI), Gazipur was used as test crop. Seeds were collected from Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur, Bangladesh.

3.7 Raising of seedlings

The land selected for nursery bed was well drained and were sandy loam type soil. The area was well prepared to obtain fine tilth. All weeds and dead roots were removed and the soil was mixed with well rotten cowdung at the rate of 5 kg/bed. The seed bed size was 3m × 1m raised above the ground level. One seed bed was prepared for raising the seedlings. Five (5) grams of seeds were sown in the seed bed on 3 November 2017. After sowing, the seeds were covered with light soil. Complete germination of the seeds took place with 5 days after seed sowing. Necessary shading was made by bamboo mat (chatai) from scorching sunshine or rain. No chemical fertilizer was used in the seed bed.

3.8 Preparation of the main field

The plot selected for the experiment was opened in the last week of November 2017 with a power tiller, and was exposed to the sun for a few days, after, which the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a good tilth. Weeds and stubble were removed and finally obtained a desirable tilth of soil for transplanting. The land operation was completed on 1st December 2017. The individual plots were made by making ridges (20 cm high) around each plot to restrict lateral runoff of irrigation water.

3.9 Fertilizers and manure application

The N, P and K nutrients were applied through urea, Triple super phosphate (TSP) and Muriate of potash (MoP), respectively. Well rotten cowdung also

used. All the fertilizers and manure were applied according to Krishi Projukti Hat Boi, 2016. Name and doses of nutrients were as follows:

Plant nutrients	Manure and fertilizer	Doses ha^{-1}
--	Cowdung	10 t
N	Urea	550 kg
P	TSP	200 kg
K	MoP	220 kg
S	Gypsum	60 kg
Zn	$ZnSO_4$	5 kg
B	Borax	5 kg

One third (1/3) of whole amount of Urea and half (½) of whole amount of MoP and full amount of cowdung, TSP, Gypsum, $ZnSO_4$ and Borax were applied at the time of final land preparation. The remaining urea and MoP were top dressed in two equal installments- at 25 days after transplanting (DAT) and 50 DAT respectively.

3.10 Transplanting of seedlings

Healthy and uniform sized 30 days old seedlings were taken separately from the seed bed and were transplanted in the experimental field on 2nd December, 2017 maintaining a spacing of 45 cm × 60 cm. The seed bed was watered before uprooting the seedlings so as to minimize the damage of the roots. This operation was carried out during late hours in the evening. The seedlings were watered after transplanting. Shading was provided by piece of banana leaf sheath for three days to protect the seedlings from the direct sun. A strip of the same crop was established around the experimental field as border crop to do gap filling and to check the border effect.

3.11 Application of GA_3, SA and MeJA

Applications of different plant growth regulators (GA_3, SA and MeJA) were applied according to the treatment at 15 days intervals and were done at 20, 35 and 50 days after transplanting as per treatment.

3.12 Intercultural Operation

After establishment of seedlings, various intercultural operations were accomplished for better growth and development of the tomato.

3.12.1 Gap filling and weeding

When the seedlings were established, the soil around the base of each seedling was pulverized. A few gaps filling was done by healthy plants from the border whenever it was required. Weeds of different types were controlled manually as and when necessary.

3.12.2 Irrigation

Irrigation was done as required. The first irrigation was given in the field at 20 days after transplanting (DAT) through irrigation channel. The second irrigation was given at the stage of maximum vegetative growth stage (35 DAT). Further the field was irrigated as required.

3.12.3 Plant protection

The crop was infested with cutworm, leaf hopper and others. The insects were controlled successfully by spraying Malathion 57 EC @ 2ml /L water. The insecticide was sprayed fortnightly from a week after transplanting to a week before first harvesting. During foggy weather precautionary measures against disease infestation especially late blight of tomato was taken by spraying Dithane M-45 fortnightly @ 2 g/L.

3.13 Harvesting

Fruits were harvested at 5 days intervals during maturity to ripening stage. The maturity of the crop was determined on the basis of red colouring of fruits. Harvesting was started from 10 March, 2018 and completed by 4 April, 2018.

3.14 Data Collection and Recording

Nine plants were selected randomly from each unit plot for recording data on crop parameters and yield was taken plot wise. The following parameters were recorded during the study:

1. Plant height (cm)
2. Number of leaves plant^{-1}
3. SPAD value
4. Number of flower clusters plant^{-1}
5. Number of flowers cluster^{-1}
6. Number of fruits cluster^{-1}
7. Fruit length (cm)
8. Fruit diameter (cm)
9. Single fruit weight (g)
10. Fruit weight plant^{-1} (g)
11. Fruit weight plot^{-1} (kg)
12. Fruit yield t/ha

3.15 Procedure of recording data

3.15.1 Plant height (cm)

The height of plant was recorded in centimeter (cm) at different days after sowing of crop duration. Data were recorded as the average of 5 plants selected at random of each plot. The height was measured from the ground level to the tip of the leaves. Data were taken at 25, 45 and 65 days after transplanting (DAT).

3.15.2 Number of leaves plant^{-1}

Number of leaves plant^{-1} was counted at different days after transplanting (DAT) of crop duration. Leaves number plant^{-1} were recorded from pre-

selected 5 plants by counting all leaves from each plot and mean was calculated. Data was taken at 25, 45 and 65 days after transplanting (DAT).

3.15.3 SPAD value

Leaf chlorophyll content was measured using a hand-held chlorophyll content SPAD meter (CCM-200, Opti-Science, USA). At each evaluation the content was measure at 25, 45 and 65 days after transplanting five times from five leaves at different position and the average was used for analysis.

3.15.4 Number of flower cluster plant^{-1}

The number of flower clusters was counted from the randomly selected 5 plants and the average number of clusters produced per plant was calculated.

3.15.5 Number of flowers cluster^{-1}

Total number of flowers per clusters was recorded from the five sample plants, and the average number of flowers cluster^{-1} was calculated.

3.15.6 Number of fruits cluster^{-1}

The number of fruits and clusters was recorded from the five sample plants, and the average number of fruits cluster^{-1} was recorded by the following calculation

$$\text{Number of fruits cluster}^{-1} = \frac{\text{Total number of fruits from 5 plants}}{\text{Total number of clusters from 5 plants}}$$

3.15.7 Fruit length (cm)

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

3.15.8 Fruit diameter (cm)

Diameter or fruit was measured at the middle portion of 20 selected marketable fruits from each plot with a slide calipers and their average was calculated in centimeter (cm).

3.15.9 Single fruit weight (g)

From first harvest to last harvest total fruit number and weight was counted from 5 plants to determine single fruit weight. By using the following formula, single fruit weight was calculated and expressed in gram.

$$\text{Weight of individual fruit (g)} = \frac{\text{Total weight of fruits from 5 selected plants}}{\text{Total number of fruits from 5 selected plants}}$$

3.15.10 Number of fruits plant^{-1}

Total fruit number was counted from 5 selected plants and average value was calculated as number of fruits per plant.

3.15.11 Fruit weight plant^{-1} (g)

Total fruit weight was counted from 5 selected plants and average value was calculated as fruit weight per plant and was expressed in gram (g).

3.15.12 Fruit yield plot^{-1} (kg)

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

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

After collection of per plot yield, it was converted to ton per hectare by the following formula

$$\text{Fruit yield per hectare (ton)} = \frac{\text{Fruit yield per plot (kg)} \times 10000\ m^2}{\text{Plot size } (m^2) \times 1\,000\ kg}$$

3.16 Statistical Analysis

The data obtained for different characters were statistically analyzed to observe the significant difference among the treatment by using the MSTAT-C computer package program. The mean values of all the characters were calculated and analysis of variance was performed. The significance of the difference among the treatments means was estimated by the Least Significant Difference Test (LSD) at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The present experiment was conducted to study the response of tomato to different plant growth regulators and the results obtained from the study have been presented, discussed and compared in this chapter through different tables, figures and appendices. The results have been presented and discussed and possible interpretation has been given under the following headings.

4.1 Growth and physiological parameters

4.1.1 Plant height

Plant height of tomato was significantly varied due to different growth regulators except at 25 DAT (Table 1 and Appendix IV). At 25 DAT, the highest plant height (30.47 cm) was found from the treatment T_2 (20 ppm GA_3) and the lowest plant height (25.58 cm) at 25 DAT was observed from the control treatment (T_1).The tallest plant (66.55 cm) at 45 DAT was achieved from T_2 (20 ppm GA_3) which was significantly different from all other treatments where the smallest plant (44.29 cm) was recorded from T_1 (Control). At 65 DAT, the treatment T_2 (20 ppm GA_3) showed the highest plant height (81.63 cm) where T_1 (Control) gave the lowest plant height (72.29 cm) which was statistically similar with the treatment T_6 (20 ppm GA_3 + 10 μM MeJA). GA_3 exhibited better performance to elongate the length of tomato than sole application of SA or MeJA. The activity of GA_3 is also slightly declined with SA or MeJA to increase the height of tomato plant. Similar results on plant height were also observed by Jakhar *et al*. (2018), Rahman *et al*. (2015b) and Sattigeri *et al.* (2014). All together, these results suggest that GA_3, SA and MeJA increased plant height of tomato.

Table 1. Plant height of tomato as influenced by plant growth regulators

Treatment	Plant height (cm)		
	25 DAT	45 DAT	65 DAT
T_1	25.58	44.29 e	72.29 c
T_2	30.47	66.55 a	81.63 a
T_3	28.55	51.54 b	74.64 b
T_4	29.31	50.89 bc	74.68 b
T_5	28.95	48.43 d	74.63 b
T_6	27.09	49.26 cd	73.25 bc
T_7	29.53	50.67 bc	74.96 b
$LSD_{0.05}$	NS	1.78	2.09
Significant level	NS	*	*
CV (%)	9.07	6.83	8.31

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

Here,

T_1 = Control by H_2O

T_2 = 20 ppm GA_3

T_3 = 100 µM SA

T_4 = 10 µM MeJA

T_5 = 20 ppm GA_3 + 100 µM SA

T_6 = 20 ppm GA_3 + 10 µM MeJA

T_7 = 100 µM SA + 10 µM MeJA

Legend:

GA_3 = Gibberellic Acid

SA = Salicylic Acid

MeJA = Methyl Jasmonate

4.1.2 Number of leaves plant^{-1}

As plant height, number of leaves plant^{-1} at 25 DAT was not significantly influenced by different growth regulators, moreover significant influence was recorded on number of leaves plant^{-1} affected by different growth regulators at both 45 and 65 days after transplanting (DAT) (Table 2 and Appendix V). At 25 DAT, the highest number of leaves plant^{-1} (10.00) was found from the treatment T_6 (20 ppm GA_3 + 10 µM MeJA) where the lowest (9.17) was obtained from T_3 (100 µM SA). At 45 DAT, the highest number of leaves plant^{-1} (18.00) was found from the treatment T_6 (20 ppm GA_3 + 10 µM MeJA) which was significantly different from all other treatments but the lowest number of leaves plant^{-1} (15.58) was found from the treatment T_1 (Control) which was statistically identical with the treatment T_3 (100 µM SA). It was also observed that the highest number of leaves plant^{-1} (53.58) was achieved from the treatment T_6 (20 ppm GA_3 + 10 µM MeJA) followed by T_4 (10 µM MeJA) where the lowest number of leaves plant^{-1} (46.00) at 65 DAT was recorded from T_3 (100 µM SA) followed by T_1 (Control).These results are not consistent with the plant height to the similar treatment (Table 1). The highest number of leaves per plant found from T_6 treatment but the highest plant height found from T_2 treatment. These results suggest that sole application of GA_3 failed to give maximum number of leaves as gave the maximum plant height in this experiment. The results on number of leaves plant^{-1} obtained from the present study was similar with the findings of Jakhar *et al*. (2018), Sattigeri *et al.* (2014) and Kazemi (2014).

Table 2. Number of leaves plant^{-1} of tomato as influenced by plant growth regulators

Treatment	Number of leaves plant^{-1}		
	25 DAT	45 DAT	65 DAT
T_1	9.42	15.58 c	47.42 e
T_2	9.42	17.08 b	51.83 bc
T_3	9.17	15.84 c	46.00 f
T_4	9.83	16.17 bc	52.42 b
T_5	9.67	17.00 b	51.33 cd
T_6	10.00	18.00 a	53.58 a
T_7	9.25	16.17 bc	50.67 d
$LSD_{0.05}$	1.58	0.88	0.90
Significant level	NS	*	*
CV (%)	10.65	10.21	6.60

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

Here,

T_1 = Control by H_2O

T_2 = 20 ppm GA_3

T_3 = 100 µM SA

T_4 = 10 µM MeJA

T_5 = 20 ppm GA_3 + 100 µM SA

T_6 = 20 ppm GA_3 + 10 µM MeJA

T_7 = 100 µM SA + 10 µM MeJA

Legend:

GA_3 = Gibberellic Acid

SA = Salicylic Acid

MeJA = Methyl Jasmonate

4.1.3 SPAD value

In this study, I measured leaf SPAD value of tomato as an indicator of chlorophyll content. SPAD value at 25 DAT was not significantly influenced by different growth regulators but at 45 and 60 DAT, significant influence was recorded on SPAD value affected by different growth regulators (Table 3 and Appendix VI). At 25 DAT, the highest SPAD value (49.74) was found from the treatment T_6 (20 ppm GA_3 + 10 μM MeJA) where the lowest (49.01) was obtained from T_1 (Control). At 45 DAT, the highest SPAD value (54.72) was found from the treatment T_6 (20 ppm GA_3 + 10 μM MeJA) which was statistically identical with the treatment T_7 (100 μM SA + 10 μM MeJA) and statistically similar with the treatment T_2 (20 ppm GA_3) and T_5 (20 ppm GA_3 + 100 μM SA). The lowest SPAD value (44.01) at 45 DAT was found from the treatment T_1 (Control) which was significantly different from all other treatments followed by T_5 (20 ppm GA_3 + 100 μM SA). At 60 DAT, the highest SPAD value (53.08) was also achieved from the treatment T_6 (20 ppm GA_3 + 10 μM MeJA) which was statistically identical with the treatment T_7 (100 μM SA + 10 μM MeJA) where the lowest SPAD value (44.83) was also recorded from T_1 (Control) followed by T_2 (20 ppm GA_3). Therefore, all together these results suggest that SPAD values increase with different plant growth regulators including GA_3, SA and MeJA.

Table 3. SPAD value of tomato as influenced by plant growth regulators

Treatment	SPAD value		
	25 DAT	45 DAT	60 DAT
T_1	49.01	44.01 d	44.83 d
T_2	49.36	53.17 ab	49.38 c
T_3	49.17	52.08 b	51.53 b
T_4	49.41	50.06 c	51.85 b
T_5	49.37	53.11 ab	51.42 b
T_6	49.74	54.72 a	53.08 a
T_7	49.43	54.04 a	53.03 a
$LSD_{0.05}$	1.54	1.67	1.12
Significant level	NS	*	*
CV (%)	6.21	6.50	5.39

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

Here,

T_1 = Control by H_2O

T_2 = 20 ppm GA_3

T_3 = 100 µM SA

T_4 = 10 µM MeJA

T_5 = 20 ppm GA_3 + 100 µM SA

T_6 = 20 ppm GA_3 + 10 µM MeJA

T_7 = 100 µM SA + 10 µM MeJA

Legend:

GA_3 = Gibberellic Acid

SA = Salicylic Acid

MeJA = Methyl Jasmonate

4.2 Yield contributing parameters

4.2.1 Number of flower clusters plant^{-1}

A strong variation was observed among the treatments of growth regulators in producing number of flower clusters plant^{-1} (Table 4 and Appendix VII). Number of flower cluster plant^{-1} was increased with the application of growth regulators compares to control. Results revealed that the treatment T_6 (20 ppm GA_3 + 10 µM MeJA) demonstrated the highest number of flower cluster plant^{-1} (9.77) which was statistically identical with the treatment T_2 (20 ppm GA_3) and T_5 (20 ppm GA_3 + 100 µM SA) whereas the lowest number of flower cluster plant^{-1} (6.75) was observed from control treatment **(**T_1**).** These results are almost consistent with the morphological parameters including plant height and leaf number per plant of tomato (Table 1 and 2). Similar results were also observed by Jones *et al.* (2014), Choudhury *et al*. (2013) and Rezende and Ayub (2010).

Therefore, these results suggest that the application of plant growth regulators increase number of flower clusters per plant by altering morphological characters.

4.2.2 Number of flowers cluster^{-1}

There was a significant variation on number of flowers cluster^{-1} influenced by different growth regulators (Table 4 and Appendix VII). Results indicated that number of flower cluster^{-1} was increased with the application of growth regulators compares to control. The treatment T_5 (20 ppm GA_3 + 100 µM SA) demonstrated the highest number of flower cluster^{-1} (6.78) which was statistically identical with the treatment T_6 (20 ppm GA_3 + 10 µM MeJA) and statistically similar with the treatment T_7 (100 µM SA + 10 µM MeJA). The lowest number of flower cluster^{-1} (5.55) was observed from control treatment **(**T_1**)** followed by T_3 (100 µM SA) and T_4 (10 µM MeJA). These results are also consistent with the formation of number of flower cluster per plant to different treatment of this study (Table 4). Supported results were also found by Jones *et*

al. (2014), Rezende and Ayub (2010), Afsana *et al*. (2017) and Kowalska and Smolen (2013).

Therefore, these results suggest that GA_3 along with SA or MeJA increase the number of flower development of tomato.

4.2.3 Number of fruits cluster^{-1}

As number of flowers cluster per plant has the significant influence was noted on number of fruits cluster^{-1} affected by different growth regulators (Table 4 and Appendix VII). Results indicated that the highest number of fruits cluster^{-1} (4.54) was found from the treatment T_5 (20 ppm GA_3 + 100 µM SA) which was statistically identical with the treatment T_6 (20 ppm GA_3 + 10 µM MeJA) whereas the lowest number of fruits cluster^{-1} (3.31) was observed from T_3 (100 µM SA) followed by T_4 (10 µM MeJA) and T_1 (Control).

Therefore, it suggests that fruits of tomato are increase with plant growth regulators than control condition. Similar results were also observed by Rezende and Ayub (2010) and Afsana *et al*. (2017) which supported the present findings.

4.2.4 Fruit length

Fruit length was significantly varied due to the application of different growth regulators (Table 4 and Appendix VII). Results revealed that the highest fruit length (8.91 cm) was found from the treatment T_2 (20 ppm GA_3) which was significantly different from all other treatments followed by T_6 (20 ppm GA_3 + 10 µM MeJA) whereas the lowest fruit length (7.63 cm) was observed from the treatment T_1 (Control) which was statistically identical with the treatment T_3 (100 µM SA) and statistically similar with the treatment T_5 (20 ppm GA_3 + 100 µM SA). It suggests that fruit length of tomato is increased with plant growth regulators than control condition. Similar results were also observed by Jakhar *et al*. (2018) and Desai *et al*. (2012) which supported the present study.

4.2.5 Fruit diameter

Significant variation was remarked on fruit diameter influenced by the application of different growth regulators (Table 4 and Appendix VII). It was observed that the highest fruit diameter (15.02 cm) was found from the treatment T_6 (20 ppm GA_3 + 10 µM MeJA) which was significantly different from all other treatments followed by T_5 (20 ppm GA_3 + 100 µM SA). The lowest fruit diameter (11.70 cm) was observed from the treatment T_1 (Control) followed by the treatment T_2 (20 ppm GA_3). Jakhar *et al*. (2018) and Sattigeri *et al.* (2014) also found similar results of the present study.

Table 4. Yield contributing parameters of tomato as influenced by plant growth regulators

Treatment	Yield contributing parameters				
	Number of flower clusters plant^{-1}	Number of flower Cluster^{-1}	Number of fruits Cluster^{-1}	Fruit length (cm)	Fruit diameter (cm)
T_1	6.75 e	5.55 d	3.82 c	7.63 d	11.70 e
T_2	9.50 a	6.40 b	4.23 b	8.91 a	13.52 d
T_3	8.83 b	6.06 c	3.31 d	7.69 d	14.22 c
T_4	7.76 d	5.87 c	3.64 c	8.12 c	14.24 c
T_5	9.49 a	6.78 a	4.54 a	7.89 cd	14.68 b
T_6	9.77 a	6.74 a	4.51 a	8.57 b	15.02 a
T_7	8.17 c	6.47 ab	4.16 b	8.03 c	14.53 bc
$LSD_{0.05}$	0.41	0.30	0.23	0.28	0.31
Significant level	*	**	*	*	*
CV (%)	6.33	11.40	7.77	8.16	8.29

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

Here,

T_1 = Control by H_2O
T_2 = 20 ppm GA_3
T_3 = 100 µM SA
T_4 = 10 µM MeJA
T_5 = 20 ppm GA_3 + 100 µM SA
T_6 = 20 ppm GA_3 + 10 µM MeJA
T_7 = 100 µM SA + 10 µM MeJA

Legend:

GA_3 = Gibberellic Acid
SA = Salicylic Acid
MeJA = Methyl jasmonate

4.3 Yield parameters

4.3.1 Single fruit weight (g)

Significant variation was observed on single fruit weight influenced by different growth regulators (Table 5 and Appendix VIII). Results revealed that the highest single fruit weight (51.86 g) was found from the treatment T_6 (20 ppm GA_3 + 10 µM MeJA) which was statistically identical with the treatment T_2 (20 ppm GA_3). The lowest single fruit weight (49.90 g) was observed from the treatment T_1 (Control) which was statistically identical with the treatment T_7 (100 µM SA + 10 µM MeJA). The result on single fruit weight achieved from the present study was similar with findings of Choudhury *et al*. (2013) and Ayub and Rezende (2010). These results are also consistent with the morphological and yield contributing characters of this study.

4.3.2 Fruit weight plant^{-1} (kg)

As fruit plant^{-1}, fruit weight plot^{-1} varied significantly due to different growth regulators (Table 5 and Appendix VIII). Results showed that the highest fruit weight plant^{-1} (1.90 kg) was found from the treatment T_6 (20 ppm GA_3 + 10 µM MeJA) which was statistically identical with the treatment T_2 (20 ppm GA_3). The lowest fruit weight plant^{-1} (1.56 kg) was observed from the treatment T_1 (Control) which was statistically similar with the treatment T_3 (100 µM SA). Similar results were also achieved by Jakhar *et al*. (2018), Kumar *et al*. (2018), Kazemi (2014) and Rahimi *et al*. (2013) which supported the present study. These results also consistent of different parameters of this study such as morphological, single fruit weight (g), number of fruits per plant. Therefore, these results suggest that plant growth regulators increase tomato fruit yield.

4.3.3 Fruit weight plot^{-1}

As fruit plant$^{-1,}$ fruit weight plot^{-1} was found significant with the application of different growth regulators (Table 5 and Appendix VIII). It was observed that the highest fruit weight plot^{-1} (16.76 kg) was found from the treatment T_6 (20

ppm GA_3 + 10 µM MeJA) which was statistically identical with the treatment T_2 (20 ppm GA_3). The lowest fruit weight plot^{-1} (13.91 kg) was observed from the treatment T_1 (Control) followed by the treatment T_3 (100 µM SA). Jakhar *et al.* (2018), Kumar *et al*. (2018), Kazemi (2014) and Rahimi *et al*. (2013) also found similar result which supported the present study. These results also consistent of different parameters of this study such as morphological, single fruit weight (g), number of fruits per plant. Therefore, these results suggest that plant growth regulators increase tomato fruit yield.

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

As fruit plant^{-1}, the recorded data on fruit yield ha^{-1} (t) was significant with the application of different plant growth regulators (Table 5 and Appendix VIII). Results signified that the highest fruit yield ha^{-1} (69.85 t) was found from the treatment T_6 (20 ppm GA_3 + 10 µM MeJA) which was statistically identical with the treatment T_2 (20 ppm GA_3). The lowest fruit yield ha^{-1} (57.94 t) was observed from the treatment T_1 (Control) followed by the treatment T_3 (100 µM SA). It was also observed that the highest fruit yield per hectare from the treatment T_6 (20 ppm GA_3 + 10 µM MeJA) might be due to cause of highest results on single fruit weight, number of fruits plant^{-1}, fruit weight plant^{-1} and fruit weight plot^{-1} from the same treatment. The results achieved on fruit yield ha^{-1} was similar with the findings of Jakhar *et al*. (2018), Kumar *et al*. (2018), Kazemi (2014) and Rahimi *et al*. (2013). These results also consistent of different parameters of this study such as morphological, single fruit weight (g), fruit length(cm), fruit diameter(cm)(Table 4 and 5). Therefore, these results suggest that plant growth regulators increase tomato fruit yield.

Table 5. Yield parameters of tomato as influenced by plant growth regulators

Treatment	Yield parameters			
	Single fruit weight (g)	Fruit weight plant^{-1} (kg)	Fruit weight plot^{-1} (kg)	Fruit yield t/ha
T_1	49.90 c	1.56 d	13.91 d	57.94 d
T_2	51.79 a	1.83 a	16.29 a	67.85 a
T_3	51.51 ab	1.62 cd	14.42 c	60.10 c
T_4	51.00 b	1.72 b	15.19 b	63.28 b
T_5	51.50 ab	1.73 b	15.44 b	64.32 b
T_6	51.86 a	1.90 a	16.76 a	69.85 a
T_7	50.30 c	1.70 bc	15.12 b	63.00 b
$LSD_{0.05}$	0.55	0.08	0.47	2.10
Significant level	*	**	*	*
CV (%)	8.17	7.29	9.64	10.63

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

Here,

T_1 = Control by H_2O

T_2 = 20 ppm GA_3

T_3 = 100 µM SA

T_4 = 10 µM MeJA

T_5 = 20 ppm GA_3 + 100 µM SA

T_6 = 20 ppm GA_3 + 10 µM MeJA

T_7 = 100 µM SA + 10 µM MeJA

Legend:

GA_3 = Gibberellic Acid

SA = Salicylic Acid

MeJA = Methyl Jasmonate

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted in the farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from November 2017 to March 2018 to study the response of tomato to different plant growth regulators. One factor experiment was conducted consisted of seven (7) plant growth regulator treatments including control. Seven plant growth regulators treatments were as (1) T_1 (Control), (2) T_2 (20 ppm GA_3), (3) T_3 (100 µM SA), (4) T_4 (10 µM MeJA), (5) T_5 (20 ppm GA_3 + 100 µM SA), (6) T_6 (20 ppm GA_3 + 10 µM MeJA) and (7) T_7 (100 µM SA + 10 µM MeJA). The experiment was laid out in one factor Randomized Complete Block Design (RCBD) with five replications. Data on different growth parameters and yield with yield contributing characters were recorded. The collected data were statistically analyzed for evaluation of the treatment effect.

Significant variation among the treatments was observed regarding different parameters. Results signified that in terms of growth parameters, the highest plant height (30.47, 66.55 and 81.63 cm at 25, 45 and 65 DAT, respectively) was obtained from the treatment, T_2 (20 ppm GA_3) where the highest number of leaves plant^{-1} (10.00, 18.00 and 53.58 at 25, 45 and 65 DAT, respectively) was obtained from the treatment, T_6 (20 ppm GA_3 + 10 µM MeJA). On the other hand, the lowest plant height (25.58, 44.29 and 72.29 cm at 25, 45 and 65 DAT, respectively) was obtained from the treatment, T_1 (Control) where the lowest number of leaves plant^{-1} (9.17, 15.58 and 46.00 at 25, 45 and 65 DAT, respectively) was obtained from the treatment, T_3 (100 µM SA).

In terms of morphological parameters, the highest SPAD value (49.74, 54.72 and 53.08 at 25, 45 and 65 DAT, respectively) were found from the treatment, T_6 (20 ppm GA_3 + 10 µM MeJA). Similarly, the lowest SPAD value (49.01,

44.01 and 44.83 at 25, 45 and 65 DAT, respectively) was found from the treatment, T_1 (Control).

Regarding yield contributing parameters, the highest number of flower cluster plant^{-1} (9.77) was observed from the treatment, T_6 (20 ppm GA_3 + 10 µM MeJA) where the highest number of flower cluster^{-1} (6.78) and number of fruits cluster^{-1} (4.54) were observed from the treatment, T_5 (20 ppm GA_3 + 100 µM SA) but the highest fruit length (8.91 cm) was observed from T_2 (20 ppm GA_3) and the highest fruit diameter (15.02 cm) was observed from the treatment, T_6 (20 ppm GA_3 + 10 µM MeJA). Again, the lowest number of cluster plant^{-1} (6.75), number of flower cluster^{-1} (5.55), fruit length (7.63 cm) and fruit diameter (11.70 cm) were found from the treatment, T_1 (Control) but the lowest number of fruits cluster^{-1} (3.31) was observed from the treatment, T_3 (100 µM SA).

Considering yield parameters, the highest single fruit weight (51.86 g), number of fruits plant^{-1} (36.40), fruit weight plant^{-1} (kg) (1.90 kg), fruit weight plot^{-1} (16.76 kg) and fruit weight ha^{-1} (69.85 t) were observed from the treatment, T_6 (20 ppm GA_3 + 10 µM MeJA). Similarly, the lowest single fruit weight (49.90 g), number of fruits plant^{-1} (30.25), fruit weight plant^{-1} (1.56 kg), fruit weight plot^{-1} (13.91 kg) and fruit weight ha^{-1} (57.94 t) were observed from the treatment, T_1 (Control).

From the above findings it can be concluded that the treatment, T_6 (20 ppm GA_3 + 10 µM MeJA) gave best results in most of the parameters regarding yield and yield contributing parameters. In terms of yield of tomato, treatment T_6 (20 ppm GA_3 + 10 µM MeJA) and T_5 (20 ppm GA_3 + 100 µM SA) gave statistically same result but T_6 (20 ppm GA_3 + 10 µM MeJA) showed highest yield of tomato. So, this treatment (T_6 (20 ppm GA_3 + 10 µM MeJA)) can be considered as the best among the studied treatments during the crop duration.

Recommendations

1. Further experiment can be conducted in respect of many other plant growth regulators including the present studied parameters at different locations of Bangladesh for final recommendation.

2. From the findings of the present study, the treatment, T_6 (20 ppm GA_3 + 10 μM MeJA) can be used as potential treatment for tomato cultivation to achieve higher tomato yield.

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APPENDICES

Appendix I. Agro-Ecological Zone of Bangladesh showing the experimental location

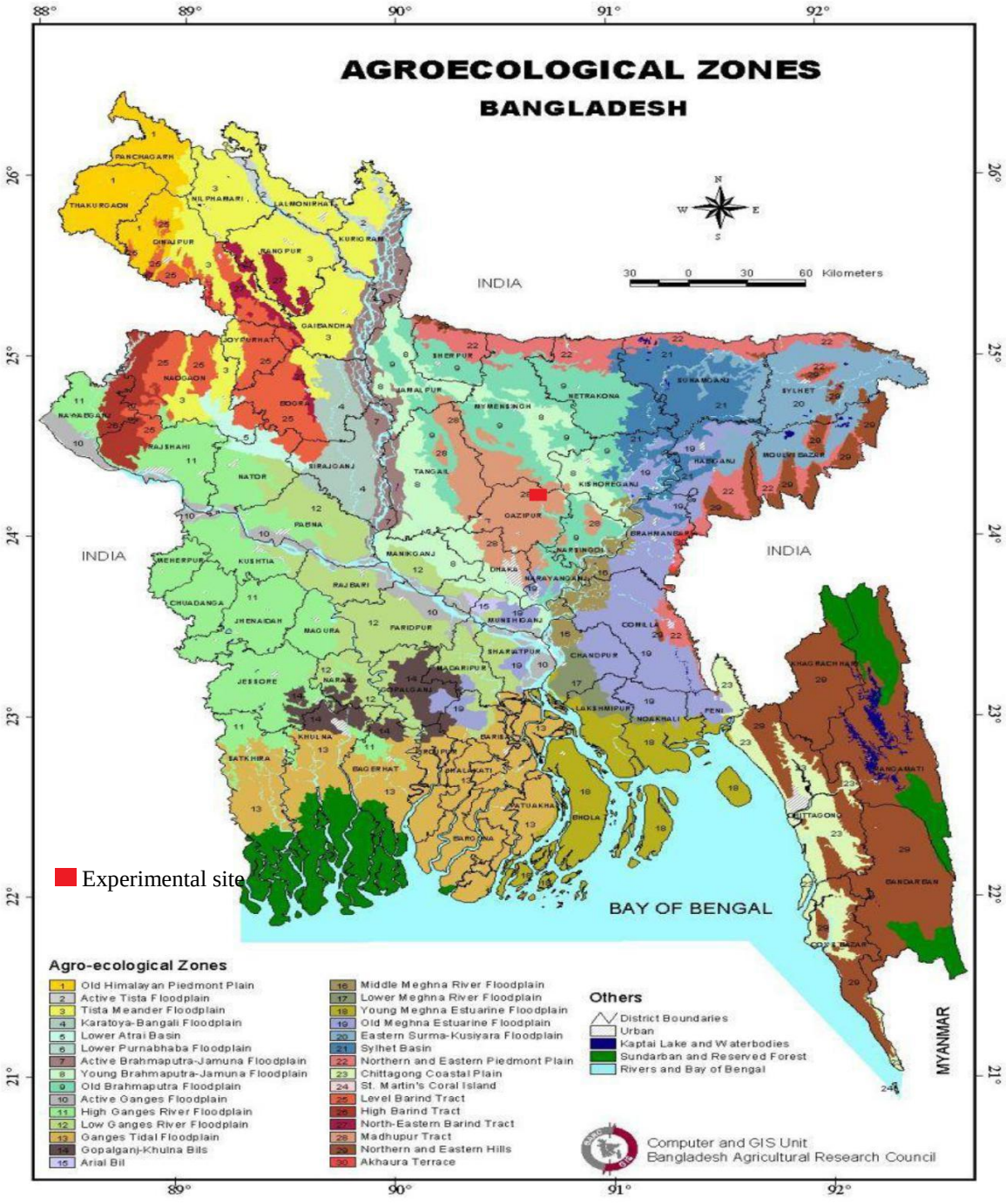

Fig. 1. Experimental site

Appendix II. Characteristics of experimental soil analyzed at Soil Resources Development Institute (SRDI), Farmgate, Dhaka.

A. Morphological characteristics of the experimental field

Morphological features	**Characteristics**
Location	Agronomy Farm, SAU, 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	Not Applicable

Source: Soil Resource Development Institute (SRDI)

B. Physical and chemical properties of the initial soil

Characteristics	**Value**
Partical size analysis % Sand	27
%Silt	43
% Clay	30
Textural class	Silty Clay Loam (ISSS)
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20
Exchangeable K (me/100 g soil)	0.1
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI)

Appendix III. Layout of the experiment field

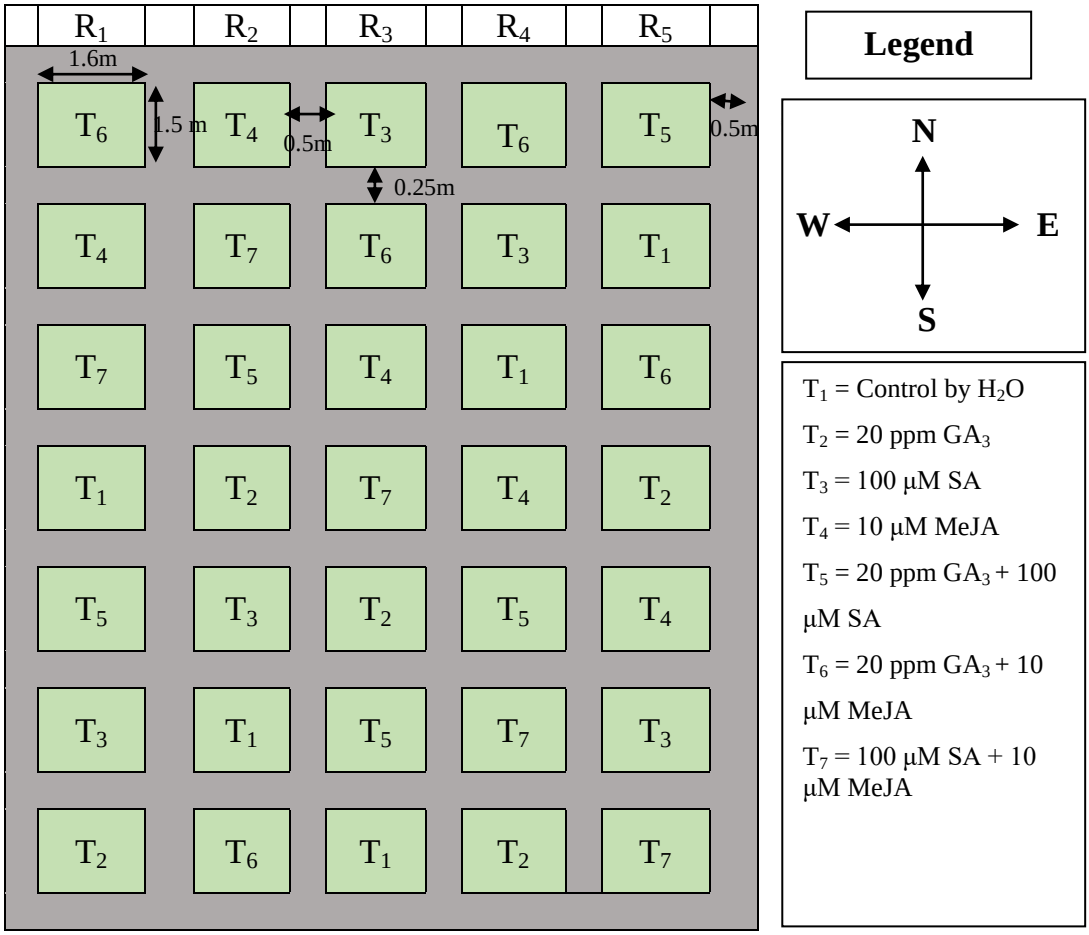

Fig. 2. Layout of the experimental field

Appendix IV. Plant height of tomato as influenced by plant growth regulators

Sources of variation	Degrees of freedom	Mean square of plant height (cm)		
		25 DAT	45 DAT	65 DAT
Replication	4	2.953	3.043	5.854
Factor A	6	10.899^{NS}	19.842*	36.343*
Error	24	4.679	6.437	8.979

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

Appendix V. Number of leaves plant^{-1} of tomato as influenced by plant growth regulators

Sources of variation	Degrees of freedom	Mean square of number of leaves plant^{-1}		
		25 DAT	45 DAT	65 DAT
Replication	4	2.491	3.137	3.754
Factor A	6	5.378^{NS}	12.889*	30.302*
Error	24	1.03	2.85	4.17

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

Appendix VI. SPAD value of tomato as influenced by plant growth regulators

Sources of variation	Degrees of freedom	Mean square of SPAD value		
		25 DAT	45 DAT	60 DAT
Replication	4	3.810	5.475	7.884
Factor A	6	20.73^{NS}	53.720**	33.191*
Error	24	4.076	6.261	8.471

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

Appendix VII. Yield contributing parameters of tomato as influenced by plant growth regulators

Sources of variation	Degrees of freedom	Mean square of yield contributing parameters				
		Number of cluster plant^{-1}	Number of flower cluster^{-1}	Number of fruits cluster^{-1}	Fruit length (cm)	Fruit Diameter (cm)
Replication	4	2.756	0.406	0.543	0.094	1.418
Factor A	6	6.900*	4.832*	2.840**	5.877**	14.932*
Error	24	3.976	0.510	0.613	2.173	6.544

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

Appendix VIII. Yield parameters of tomato as influenced by plant growth regulators

Sources of variation	Degrees of freedom	Mean square of yield parameters			
		Single fruit weight (g)	Fruit weight plant^{-1} (g)	Fruit weight Plot^{-1}(kg)	Fruit weight ha^{-1} (t)
Replication	4	3.422	0.054	5.214	3.652
Factor A	6	32.315**	1.052**	23.932*	68.135*
Error	24	7.429	0.060	5.016	6.996

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