EFFECT OF PLANTING DATE AND EXOGENOUS NAA AND GA3 ON REPRODUCTION AND FRUIT YIELD OF BARI TOMATO-10

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CERTIFICATE

This is to certify that the thesis entitled, **"EFFECT OF PLANTING DATE AND EXOGENOUS NAA AND GA3 ON REPRODUCTION AND FRUIT QUALITY OF BARI TOMATO-10"**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**ANUPAMA KANCHI SURANJANA SAROJ, Registration No.12-05008**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: June, 2018
Dhaka, Bangladesh

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DEDICATED TO

MY BELOVED PARENTS

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EFFECT OF PLANTING DATE AND EXOGENOUS NAA AND GA_3 ON REPRODUCTION AND FRUIT QUALITY OF BARI TOMATO-10

BY

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ABSTRACT

This pot culture experiment was conducted with the intention of investigating the impact of different sowing dates and concentrations and combinations of NAA and GA_3 on growth and yield contributing attributes of summer tomato. The experiment was laid out in completely randomized design (CRD) with three replications. Different concentrations of NAA and GA_3 viz. T_0= Control, T_1 = foliar application of 20 ppm NAA at vegetative stage, T_2 = 20 ppm GA_3 at vegetative stage T_3 = 20 ppm NAA + 20 ppm GA_3 at vegetative stage, T_4 = 20 ppm NAA at flower cluster initiation stage, T_5 =20 ppm GA_3 at flower cluster initiation stage, T_6 = 20 ppm NAA +20 ppm GA_3 at flower cluster initiation stage, D_1 = Sowing seeds on 1st June and D_2 = Sowing seeds on 1st July, were used in the study. The growth and yield contributing characters were significantly influenced by the application of NAA and GA_3 and sowing dates. At harvest, the tallest plants (88.588 cm and 87.468 cm) were found in T_1 and T_2 respectively. Maximum number of flower plant^{-1}(39.00), and fruit yield plant^{-1}(659.37 g) were found in T_6, whereas the minimum for these characters were recorded in T_1 and T_2. In case of combined effect of sowing date and plant growth regulator, the tallest plant (89.367cm) was found in D_2T_2 and the number of flower plant^{-1} (39.00), fruits plant^{-1} (35.66) and fruit yield plant^{-1} (663.33g) were found in D_2T_6, whereas the minimum for all these characters were found in D_1T_1 and D_2T_2. Sowing seeds in 1st July and application of 20 ppm NAA along with 20 ppm GA_3 can be effective in enhancing growth and yield of BARI Tomato-10.

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LIST OF ABBREVIATION AND ACRONYMS USED IN THIS THESIS

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 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 I
INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill) is one of the most popular vegetables in the world which is cultivated in almost all parts of Bangladesh under both field and garden conditions. It belongs to the family Solanaceae. It is the "No. 1 processing vegetable" because of its demand not only in processing sector but also as a vegetable and protective food. It has been originated in tropical America that includes Peru, Ecuador, Bolivia and areas of Andes (Kaloo, 1986). This fruits are consumed as raw, cooked and in other dishes like soup, juice, jam, jelly, ketchup, pickle, sauce, conserve, puree, paste, powder and other products. Tomato juice is a popular appetizer and beverage. Food value of tomato is very rich because of its higher content of vitamins A, B and C including calcium and carotene (Bose and Som, 1990). Tomato adds flavor to the foods and it is also rich in medicinal value (Uddain *et al*., 2009; Rashid, 1983; Davies and Hobes, 1981). Lycopene pigment is a vital antioxidant that helps fight against cancerous cell formation as well as other kind of health complications and diseases.

Due to the outstanding nutritional and health benefits of tomato, the demand of tomato remains higher throughout the year, but production is far below in relation to demand, especially in the summer season. Therefore, to meet up the growing demand for tomato, priority must be given on the production of summer tomato. Bangladesh Agricultural Research Institute (BARI) and Bangladesh Institute of Nuclear Agriculture (BINA) have developed some varieties of summer tomato, which are high yielding. BARI Hybrid Tomato 4, BARI Hybrid Tomato 8, BARI Tomato-10, Binatomato-2 and Binatomato-3 are popular among the summer tomato varieties.

Tomato requires day temperature of 21–28°C and moderately cool night temperature of 15–20°C for proper fruit setting. High temperature (in both day and night), humidity, rainfall and light intensity are the limiting factors of tomato production (Abdulla and Verkerk, 1968). High day and night temperature above 32°C and 21°C, respectively, were reported as limiting factor to fruit set due to an impaired complex for physiological process in the pistil, which results in floral or fruit abscission (Picken, 1984). High temperatures reduces fruit set, fruit production and yield in tomato (Peet*et al*, 1997).Excessive rainfall and hailstorms also cause damages in summer tomato production. To overcome these problems several plant growth regulators were used to determine the effectiveness in fruit setting. Fruit setting in tomato can be increased by applying plant growth regulators to compensate the deficiency of natural growth substances required for its development.

Application of synthetic auxin and gibberellins are effective in enhancing both yield and quality of tomato (Gemici *et al*., 2006). GA_3 is known to promote fruit development in pollinated ovaries that undergo dormancy due to high temperature (Gelmesa *et al*., 2012). Similarly, sprays of NAA at the time of flowering result in reduced pre-harvest fruit drop and increased number of fruits per plant (Alam and Khan, 2002). Combined application of 20 ppm NAA and 20 ppm GA_3 increases flower per cluster, number of fruits and yield as compared to the plants treated with NAA and GA_3 alone (Hossain *et al.,* 2018). NAA 20 ppm as a whole plant spray at flowering stage gives significantly increased fruit number in tomato. Significantly higher yield in tomato by foliar application of 10 and 20ppm NAA at the time of first flowering is also noted (Sagar *et al.,* 1978). Two sprays of 10ppm NAA at the time of flowering stage gives significantly increased flower and fruit set in tomato (Younis and Tigani, 1978).

BARI Tomato-10 is a newly released summer variety. Application of growth regulators is not done yet on it. Many trials show that application of growth regulators during the flowering stage gives best results. Sometimes vegetative growth hampered because of high temperature and high humidity. As a result, plants are not able to give satisfactory yield after growth regulators treatment. To promote vegetative growth, application of growth regulators during vegetative stage is important. Application of high concentration of NAA at the two leaf stage markedly reduces fruit number (Kaushik *et al.,* 1978). If we divide large doses into equal 5 or 4 small doses and applied those doses in several growth stages, then this problem can be overcome.

Keeping the above circumstances in view, the present experiment was designed to achieve the following objectives:

i. To evaluate the performance of NAA and GA_3 on growth, yield and yield attributing characters of summer tomato var. BARI Tomato-10;
ii. To determine the optimum stage of plant growth to apply NAA and GA_3; and
iii. To determine the optimum concentrations of NAA and GA_3 in order to maximize the yield of BARI Tomato-10.

CHAPTER II

REVIEW OF LITERATURE

Tomato (*Lycopersicon esculentum* Mill) is one of the most popular vegetables in Bangladesh. In our country, tomato is available during winter season. In summer, flower and fruit setting of tomato are interrupted enormously due to high temperature and high humidity which result in poor pollination and fertilization. Using plant growth regulators like NAA and GA_3 on heat tolerant variety might have better performance over hot and humid condition. Plant hormones can improve flower, fruit setting and yield during summer season and may have commercial appreciation. Many researchers were conducted their research to find out the effect of plant growth regulators on fruit setting of tomato. However, in this chapter, literature available in this aspect in the country and abroad has been reviewed.

Role of NAA on flowering and fruiting of tomato

Synthesized auxin are often used for promotion of fruit set in some fruit and vegetable production including tomatoes (Gemici *et al.,* 2006; Khan *et al.,* 2006; Serrani *et al.,* 2007; Batlang, 2008). Patel *et al.*(2012) revealed that application NAA increases the fruit diameter in tomato. Verma *et al* (2014) obtained that fruit set in tomato was successfully improved by application of NAA.

Leopold (1964) observed that with the increase in concentration of auxin there was a comparable increase in percentage of flower cluster. Singh and Upadhayaya (1967) studied the effect of NAA on tomato and reported that NAA induce parthenocarpic fruit. Mehta and Mathai (1976) observed that spraying of tomato plant with NAA 0.2 ppm and 0.1 ppm gave significantly increased fruit set, and number of days taken to fruit setting was significantly lesser to that of control. Kaushik *et al.* (1978) showed that NAA at 1, 10, or 100 mg/l increased fruit set per plant at lowest concentration, the highest concentration markedly reduced fruit number when sprayed on tomato plants at the 2-leaf stage. Sagar *et al.* (1978) noted that NAA 20 ppm as a whole plant spray at flowering stage gave significantly increased fruit number in tomato. It was also noted that significantly higher yield in tomato was obtained by foliar application of NAA 10 and 20 ppm at time of first flowering. Younis and Tigani (1978) reported that two sprays of NAA 10 ppm at time of flowering stage gave significantly increased flower and fruit set in tomato. Gupta *et al.* (2001) recorded minimum day for fruit setting in plant was 42 DAT which was observed with the treatment of 25 ppm NAA. Rodrigues *et.al.* (2001) studied that tomato spraying with 10 ppm NAA followed by pollination on initial trusses resulted in the highest number of fruits (45.63) and seed yield (0.58 g plant^{-1}). Mukherji and Roy (1966) and Howlett (1941) reported that fruit set in tomato was successfully improved by application of NAA. Alam and Khan (2002) reported that foliar spray of NAA at the time of flowering resulted in reduced pre-harvest fruit drop and increased the number of fruits per plant.

Role of NAA on growth of tomato

Patel *et al.* (2012) reported that application NAA increases the plant height and number of branches in tomato. Singh *et al.* (2005) saw that NAA positively affected plant growth and number of branches of tomato. Singh and Upadhyay (1967) observed that NAA 10ppm increased the height and higher doses significantly reduced the height. Mehrotra *et al.* (1971) reported that NAA 25 ppm had little effects on plant height but there was no effect on number of branches when tomato seedling where treated for 30 minutes before transplanting. It was also reported that quality of fruit was improved with the application of NAA at 25 ppm. Patil and Mahajan (1971) noted that higher concentration of 0.4 ppm NAA induced more height in tomato seedling when seedling roots dipped for 24 hours prior to transplanting, while the average diameter of branches number and leaves were not affected. Singh *et al.* (1981) reported that height of the main stem of the plant varied due to NAA, resulted in production of taller plants, maximum number of branches and yield/ha in tomato. Kishan *et al.* (2001) recorded maximum number of primary branches in the treatment NAA 25 ppm. Number of primary branches was not influenced by the growth regulatory substances. Singh *et al.* (2011) revealed application NAA had positive effect on vegetative growth of tomato. Chhonkar and Ghufran (1968) reported that plant height decreased with the increased concentration of NAA.

Role of NAA on yield of tomato

Patel *et al.*(2012) revealed that application NAA increased the diameter of fruit and yield in tomato. Rodrigues *et al.*(2001), Kishan *et al.* (2001), Rai *et al.* (2002), Nibhavanti *et al.* (2004), Singh and Sant (2005) and Bokade (2006) reported that application of NAA increased the yield of tomato due to enhanced plant growth and faster rate of plant development in cell elongation and thereby increased cell enlargement, cell division and differentiation which in turn resulted into increase in number of flowers, fruit set, size and fruit weight. Chhonkar and Singh (1959) recorded increasing yield of tomato by seedling treatment with growth substances. Singh and Upadhayaya (1967) studied the effect of NAA on tomato and reported that the regulator increased the fruit set, size and yield of fruit. NAA could be applied on seeds, roots whole plants or flowers, but foliar application was very effective for increasing the size of fruit and the yield. Singh *et al.* (2005) saw that yield of tomato positively affected by NAA. Alam and Khan (2002) revealed that reduced pre-harvest fruit drop with increased number of fruits per plant and yield were observed due to Naphthalene Acetic Acid (NAA) spray. Singh and Upadhyay (1967) observed that NAA at 10 ppm as soil and foliar application gave increased yield in tomato but NAA at 20 ppm significantly reduced the yield. Perenz *et al.* (1980) found that tomato treated with NAA at 25 and 35 ppm had large fruit size. Singh *et al.* (1981) reported that NAA resulted highest yield/ha in tomato. Alam and Khan (2002) reported that spray of NAA at variable concentration significantly increased the fruits yield of tomato as compared to control. Gupta *et al.* (2003) reported that the application of 75 ppm NAA resulted in largest fruit size at maturity stage of tomato and gave maximum yield. Arvind (2012) reported that combination of variety “NBH NO-1” and 15 ppm NAA was found best in respect increasing productivity of tomato.

Role of NAA on quality of tomato

Patel *et al.* (2012) revealed that application of NAA increased the acidity and TSS in tomato. Pudir and Yadav (2001) said that NAA application in tomato increased total soluble solid percentage significantly. Mehrotra *et al.* (1971) reported that quality of fruit was improved with the application of NAA at 25 ppm. Petronk and Loban (1975) obtained quality of tomato seed by treating the seed with NAA at 50 mg/kg before sowing. Pandita *et al.* (1978) found higher fruit acidity in tomato plant treated with NAA at 100 ppm as foliar spray at appearances of first flowering. The highest vitamin C content was in fruit from the plant treated with NAA at 50 ppm. The beneficial effect of NAA at 100 ppm on fruit TSS was also observed. Alam and Khan (2002) reported that spray of NAA at variable concentration significantly increased the nutrient contents of fruits.

Role of GA_3 on growth, yield and quality of tomato

GA_3 application in tomato plant helped in synthesis of protein including various enzymes, increased the rate of shoot elongation and photosynthetic capacity leading to total leaf area and leaf dry weight (Ballantyine, 1995; Mostafa and Saleh, 2006). Bokode *et al*. (2006) reported that tomato plants treated with 50 ppm GA_3 gave maximum height of plant. Application of GA_3 at 50 ppm was found it to be more effective in earliness to 50% flowering. Bora and Selman (1969) demonstrated that four foliar sprays of GA_3 increased the leaf area, weight and height of tomato plants. Chaudhary *et al. (*2006) Shittu and Adeleke (1999) and Sanyal *et al.* (1995) found that gibberellin induced cell division, cell elongation and cell enlargement. Gabal *et al.* (1999) revealed that number of leaves per plant increased with the application of plant growth regulators in tomato especially GA at 15, 30 and 45 DAT, as plant growth

regulators enhanced cell division with considerable stem elongation. Gelmesa *et al.* (2012) said that GA_3 applications seemed to promote vegetative growth. Gemici *et al.* (2000) indicated that 10 ppm GA_3 treated tomato plants showed a 17% increase in stem length when compared to the control and it was quite effective in increasing fruit size. Hasanuzzaman *et al.* (2015) revealed that application of GA_3 @ 125 ppm showed an increased plant height, number of leaves, branches per plant, dry matter content of stem and root in tomato. Kumar *et al.* (2014) observed the highest plant height and number of leaves treated with GA_3 at 50 ppm. Leonard *et al.* (1983) reported that inflorescence development in tomato plants grown under low light regimes was promoted by GA_3 application directly on the inflorescence. Adlakha and Verma (1965) and Mehta *et al.* (1975) founed that gibberelic acid played role on controlling fruit setting, pre-harvest fruit drop and increasing fruit yield. Shittu and Adelek (1999)and Sanyal *et al.* (1995) reported that gibberellin induced cell division, cell elongation, cell enlargement and ultimately lead to significantly increase the fruit length, girth and pulp-seed ratio. Gelmesa *et al.* (2012) GA_3 applications helped in improvement in number of fruits per cluster, fruit set, and marketable fruit number per plant and extended maturity time and harvest. Hasanuzzaman *et al.* (2015) revealed that application of GA_3@ 125 ppm showed an increased fruit, number of flowers, fruit clusters, and fruits per plant, length and diameter of fruit, yield per plant, yield per plot and yield per hectare. Habbasha *et al.* (1999) found that application of GA_3 increased fruit set percentage and total fruit yield as well as percentage of puffy and parthanocarpic fruit. Naeem *et al.* (2001) revealed that GA_3spray on tomato plant reduced fruit drop and contributes better number of fruits per plant. Hossain (1974) and Adlakha and Verma (1995) found that the application of 50 ppm GA_3 had increased fruit setting. Sanyal *et al.* (1995) observed that foliar application was more

effective than root soaking of seedlings. Adalkha and Verma (1965) reported that when the four clusters of tomato plants were sprayed three times at unspecified intervals with GA_3 at 50 and 100 ppm, the fruit setting was increased by 5% with higher concentration. Uddain *et al.* (2009) observed that growth and yield contributing characters were significantly differed due to the effect of different plant growth regulators on tomato. Rahman *et al.* (2015) reported that the GA_3 applied at different stages had significant influence on the yield and yield attributes of summer tomato. The highest plant height was recorded when 50 ppm of GA_3 was applied at the vegetative stage. They also found that the longest time to first fruit setting was required when the roots of the seedlings were soaked in 100 ppm GA_3 solution. The application of 50 ppm GA_3 by root soaking had significantly increased the number of flowers, fruits and fruit yield per plant but similar results were achieved when only 25 ppm GA_3 was applied at the flowering stage. The fruit yield of tomato per plant increased linearly with the increased number of flowers and fruits per plant. Kaushik *et al.* (1974) applied GA_3 at vegetative stage and obtained increased fruit weight per plant. Saleh and Abdul (1980) observed that GA_3 at 25 or 50 ppm had increased the total yield of tomato compared to the control. Sanyal *et al.* (1995) also found that 50 ppm of GA_3 had profound effect on the yield of tomato. Adlakha and Verma (1965) and Mehta *et al.* (1975) reported that gibberelic acid (GA) played important role in increasing fruit yield and extending shelf-life. Afaf *et al.* (2007) indicated that GA_3 application increased phosphorous accumulation in leaves and stems of tomato plants that was also responsible for required lycopene content in the fruit. Chaudhary *et al.* (2006) and Ouzounidou *et al.* (2010) said that application of GA_3 at 50 ppm increased ascorbic acid and Gelmesa et al (2012) revealed that GA_3 application increased TSS in tomato. Graham and Ballesteros (2006) reported that GA_3 increased proteins,

soluble carbohydrates, ascorbic acid, starch and β-carotene in the tomato. Kumar *et al.* (2014) observed the highest ascorbic acid and total soluble solid (TSS) in tomato plant treated with GA_3 @ 50 ppm. Masroor *et al.* (2006) also reported that foliar application of gibberelic acid significantly increased lycopene content of tomato fruits.

Role of NAA+GA3 on growth and yield of tomato

Hossain *et al.* (2018) was conducted an experiment with the intention of investigating the impact of different concentrations and combination of the plant growth regulators on growth and yield contributing attributes of summer tomato. Different plant growth regulators viz. T_0= Control, T_1 = 20 ppm NAA, T_2 = 20 ppm GA_3 and T_3 = 20 ppm NAA + 20 ppm GA_3 were used in the study. He found the maximum number of cluster plant^{-1}(10.12), bud cluster^{-1}(8.26) flower cluster1(5.99) and fruits plant^{-1}(17.65) and fruit yield plant^{-1} (328.99 g) were found with the application of 20 ppm NAA+20 ppm GA_3, whereas the minimum for these characters were recorded from the control plants. He also obtained that 20 ppm NAA along with 20ppm GA_3 was effective in enhancing growth and yield of summer tomato. Arvind (2012) reported that foliar application of 15 ppm GA_3 followed 25 ppm NAA increased growth and yield of tomato. He also reported that higher concentration of GA_3 and NAA beyond 15 and 25 ppm were not found advantageous for tomato crop. Saha (2009) observed significant response of NAA (25 ppm) with respect to total soluble solid (TSS) and vitamin C was obtained over the control. Similarly maximum 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 TSS and vitamin C content, respectively.

CHAPTER III

MATERIALS AND METHODS

This pot-culture experiment was conducted at the research field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the summer (July to November) of 2018 under transparent polythene shade conditions. Materials used and methods followed during the course of study have been mentioned in this chapter under the following heads and sub-heads.

3.1 Experimental sites

3.1.1 Location

The experiment was carried out at the experimental farm of Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh.

3.1.2 Geographic location

Geographically, the location of the experimental site was 23°74N latitude and 90°35E longitude and at an elevation of 8.5 m from sea level.

3.2 Growing environment

3.2.1 Soil

The soil was collected from Savar river site during the month of May. The soil texture was sandy loam and pH was 6.0-6.4.

3.2.2 Climate

The climate of experimental site was under the subtropical climate. It was characterized by high temperature with high relative humidity and medium rainfall with occasional gusty winds in June to November, 2018 (*Kharif* season).

3.3 Planting material

In this research work, the seeds of BARI tomato-10, also known as Anupama was used as planting material. The seeds were collected from the Horticulture Research Centre, Bangladesh Agricultural Research Institute (BARI) at Joydebpur.

3.3.1 BARI TOMATO-10 (ANUPAMA):

Developed by	Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh
Method of development/origin	Hybridization
Year of release	1998
Yield	40-55 t/ha
Main characteristics	Prolific bearer in summer and rainy season production providing raised bed under poly tunnel without application of hormone. High yielding hybrid variety. Fruit oval shape, skin of tomato thick and rigid, life time 90-100 days. This variety is cultivated all over Bangladesh.
Planting season and time	Cultivation in summer season. In summer season hormone application not necessary but yield increase due to hormone application.

Harvesting time	Within 60 days after transplantation fruit harvest start and harvest up to more than one month.
Resistance/tolerance	High temperature tolerant, Bacteria wilt tolerant and Moderately tolerant to TYLCV
Quality of the product	Due to thick skin and rigid of tomato storage time high and supply is possible for long distance.

Source: BARI

3.4 Experimental Design and Treatments

The experiment was carried out in pots. The two factor pot culture experiment was laid out in the Completely Randomized design (CRD) with three replications.

Factor 1: Different concentrations of two plant growth regulators at vegetative and reproductive stages, namely ─

T_0 = Control (no growth regulators applied)

T_1 = 20 ppm NAA applied in vegetative stage

T_2 = 20 ppm GA_3 applied in vegetative stage

T_3 = 20 ppm NAA+ 20 ppm GA_3 applied vegetative stage

T_4 = 20 ppm NAA applied in the flower cluster initiation stage

T_5 = 20 ppm GA_3 applied in the flower cluster initiation stage

T_6 = 20 ppm NAA+ 20 ppm GA_3applied in the flower cluster initiation stage

Factor 2: Two planting date

D_1 = 1st June (seed sowing)

D_2 = 1st July (seed sowing)

3.4.3 Pot preparation

Plastic pots were used. At first the pots were sun dried. Sandy loam soil and cowdung were mixed and pots were filled with this soil 7 days before transplanting. Weeds and stubbles were removed from the soil. The pH of the soil was 6.0 to 6.4.

3.4.4 Manure and fertilizer application

Manure and fertilizers were applied as per recommendation of Bangladesh Agricultural Research Institute (BARI) for poor soil. Cowdung @ 15 t/ha, TSP @ 250 kg/ha and MP @ 260 kg/ha were applied during pot preparation (BARI, 2014). Furadan 10G (an insecticide) @ 0.25 g/pot was also applied during final pot preparation to control soil insects.

3.4.5 Raising of seedlings

The seeds were sown in the seedbeds on1st June, 2018 and 1st July, 2018. Half gram of seeds of each variety was sown on seedbed by means of two lines for each variety. After sowing, edges were covered with light soil. Within 4 to 7 days emergence of the seedlings took place.

3.4.6 Transplanting of seedlings

Healthy and uniform seedlings of 30 days old were uprooted separately from the seedbed and two seedlings were transplanted in each experimental pot at the afternoon of 1st July, 2018 and 1st August, 2018 respectively. In order to minimize damage of

the root system, the seedbed was watered before uprooting the seedlings. The seedlings were watered just after transplanting.one healthy seedling out of two was allowed to grow and the other one was discarded from the pot 10 days after transplanting.

3.4.7 Intercultural operations

3.4.7.1 Shading

A transparent polythene shade was provided to protect the plants from excess rainfall and sunlight. It was made with the help of polythene sheet and bamboo sticks. The shade was maintained up to final harvest.

3.4.7.2 Weeding

Weeding was accomplished by hand and when necessary with the help of khurpi (a type of patula) to keep the crop free from weeds, for better soil aeration and to break the crust. Weeding helped in soil moisture conservation.

3.4.7.3 Irrigation

Irrigation was provided immediately after transplanting and it was continued until the seedlings were established in the pot. High frequency of irrigation were demanded because it was a pot experiment. Usual irrigation schedule for field grown tomato was not followed. Irrigation was provided each alternate day in general but sometimes the plants demanded everyday irrigation. During the month of July and August irrigation was provided 3 to 4 days interval due to prevailing of high relative humidity (RH).

3.4.7.4 Stalking

After the well establishment of the plants, staking was done to each plant by means of bamboo sticks to keep them upright because tomato is a herbaceous plant with higher fruit weight

3.4.7.5 Plant protection

Furadan 10G (an insecticide) @ 0.5 g/pot was applied during the filling of pots to control cut worm and other soil insects. Aphid (a leaf sucking insect) infested the crop at vegetative and early reproductive stages, which was controlled by Emitaf 20 SL @ 0.25 ml L^{-1} of water at 7 days interval for three weeks. During the summer season, white fly infested the crop at early reproductive stage, which was controlled by means of spraying with Admire 200 SL @ 0.5 ml/L of water at 7 days interval for 2 weeks.

3.4.7.6 Preparation of different levels of GA_3 and NAA

20 ppm solution of GA_3 was prepared by dissolving 20 mg of GA_3 in 1L distilled water. Prior to adding distilled water the granular chemical was dissolved in 20 ml ethanol.20 ppm solution of NAA was prepared by dissolving 20 mg of NAA in 1L distilled water. Prior to adding distilled water the granular chemical was dissolved in 20 ml ethanol and a small amount of 1N KOH.

3.4.7.8 Application of GA_3 andNAA

GA_3 and NAA with the specific concentration were applied at vegetative and flowering stages according to the design of the experiment. Spraying was done in the afternoon with the help of a hand sprayer.

3.4.7.9 Harvesting

Harvesting of tomato (1st June, 2018 sowing) was started from5thSeptember, 2018 and was continued up to 26th October, 2018. Harvesting of tomato (1st July, 2018 sowing) was started from 2thOctober, 2018 and was continued up to 28th November, 2018.

3.5 Data collection

The following data were recorded

i. Plant height (cm) at harvest

ii. Root dry weight plant^{-1} (g)

iii. Shoot dry weight plant^{-1} (g)

iv. Leaf area index

v. Chlorophyll content of leaf

vi. No. of flower plant^{-1}

vii. Total number of fruits plant^{-1}

viii. Volume of fruit plant^{-1}

ix. Length of fruit (cm)

x. Breath of fruit (cm)

xi. Fruit volume (cm^3)

xii. Percentage of total soluble solid (% TSS) of fruit

xiii. No. of seed fruit^{-1}

xiv. Chlorophyll content of fruit

xv. Fruit yield plant^{-1}

3.6 Detailed procedures of data collection

3.6.1 Plant height

The height was recorded at final harvest (110 DAT). Plant height was measured from sample plants in centimeter from the ground level to the tip of the longest stem and the mean value was calculated.

3.6.2 Root and shoot dry weight plant^{-1}

After the final harvest (100 DAT) the total plant fresh biomass was collected. The shoot was collected by cutting the plant at soil level with the help of a sharp knife. The root was collected by washing out soil from pot through high-pressure water flow and roots were washed in fresh water to remove soil particles and other adhesive substances. After collecting, the plant parts were sun-dried and put into paper bag separately. Then the collected plant parts were dried in oven for 72 hours at 70^{o}C. Root, shoot and total vegetative dry weights were taken with the help of an electronic balance.

3.6.3 Leaf area index

LAI is a ratio of total surface area of leaves to a unit area of lands

LAI= LA/P

3.6.4 Determination of chlorophyll content

Chlorophyll was estimated following the procedure of Arnon (1949). The .05 g of freash leaves was measured separately. Samples were macerated in 80⁒ acetone. Then these were centrifuged for 5 minutes and finally made 5ml volume with 80⁒ acetone. The optical density was measured at 663nm and 645nm with a spectrophotometer. The total chlorophyll content was measure as follows:

Total chlorophyll = (20.2× D 645+8.02×D 663) ×5/1000×0.05

3.6.5 Flower plant^{-1}

$$\text{Flower plant}^{-1} = \frac{\text{Total no of flowers from three sample}}{3}$$

3.6.6 Fruit plant^{-1}

$$\text{Fruit plant}^{-1} = \frac{\text{Total no. of fruits from three sample}}{3}$$

3.6.7 Fruit diameter

Diameter of fruit was measured at the middle portion of 30 randomly selected fruit from three sample plants of each replication with the help of a slide calipers.

3.6.8 Fruit yield plant^{-1}

It was measured by the following formula:

$$\text{Fruit weight plant}^{-1} = \frac{\text{Total weight of fruits from three sample plants in kilogram}}{3}$$

3.6.9 Total soluble solid (%TSS) content of fruit

ATAGO Master Refractometer was used to determine percent total soluble solid (%TSS). For each value, a ripe fruit was sliced into two halves horizontally with a sharp knife and a small quantity of juice from them was used to determine total soluble solid (%TSS) in percentage with the Refractometer.

3.6.10 Number of seed fruit^{-1}

15 fruits were collected from each of the three samples. Seeds were separated from those fruits and were counted them manually.

3.6.11 Fruit volume

Fruit volume was measured by water displacement method.

3.6.12 Carotene content

According to Nagata and Yamashita (1992), at first 15-20g flesh of sample was taken and crushed by mortar and pastel. Then 5g paste was taken in a plastic container having airtight lid. There after 50ml mixture (Acetone: n-Hexane = 2:3) was poured in the container by measuring cylinder and the container was placed in a vertical shaker for 10 minutes. Then the solution was centrifuged at 5000-6000 rpm. After centrifuge, the supernatant (clear and transparent) was taken in as glass vial. Then

spectrophotometers reading was recorded at four different nanometer length viz. 663nm, 645nm, 505nm and 453nm.

3.7 Statistical analysis

The data collected on various parameters were statistically analyzed to obtain the level of significance using the Statistix10 statistical computer package program. Analysis of variance was done following complete randomized block design (CRD). The mean differences among the varieties were compared by least significant difference (LSD) test at 5% level of significance. Raw data management, tabulation and graphical presentation were done by using Microsoft Office Word and Microsoft Excel programs.

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted with seven different concentration of NAA and GA_3 applied at two stages of growth to study the change of yield and quality of summer tomato var. BARI Tomato-10, sown on two different dates of one month apart. Some of there relevent results have been presented in tables and other in figures for ease of discussion, comparison and understanding.

4.1 Plant height

The effect of concentrations of NAA and GA_3 on plant height varied significantly. The tallest plant (88.588cm) and (87.468cm) was obtained from T_1 and T_2 respectively (Figure: 1). Other concentrations showed statistically similar results. The tallest plant (89.367 cm) was obtained in D_2T_2which were sowed in 1st July and treated with 20 ppm GA_3 at vegetative stage. The shortest plant (80.063 cm) was obtained in control plants which were sowed in 1st June (Figure: 2).This might be due to the influence of plant growth regulators on the expansion and enlargement of meristematic cells. GA_3 promotes vegetative growth by active cell division and elongation especially in the apical portion of the plants. Taiz & Zeiger (2009) reported that by promoting cell growth and division, the gibberellin stimulates elongation of internodes. Yang *et al*. (1996) observed that auxin and gibberellin control separate processes that, when combined, contribute to stem elongation and fruit set (including ovary growth), suggesting an additive effect, in which the auxin stimulates growth by cell expansion and cell division while gibberellins acts in the expansion as well as in the number of cells. Gibberellins are the key regulators in shoot elongation in plants

and this might be the reason to have tallest plant in D_2T_2.Similar kind of result was reported by Nibhavanti *et al*. (2004) and our result is in agreement with their findings.

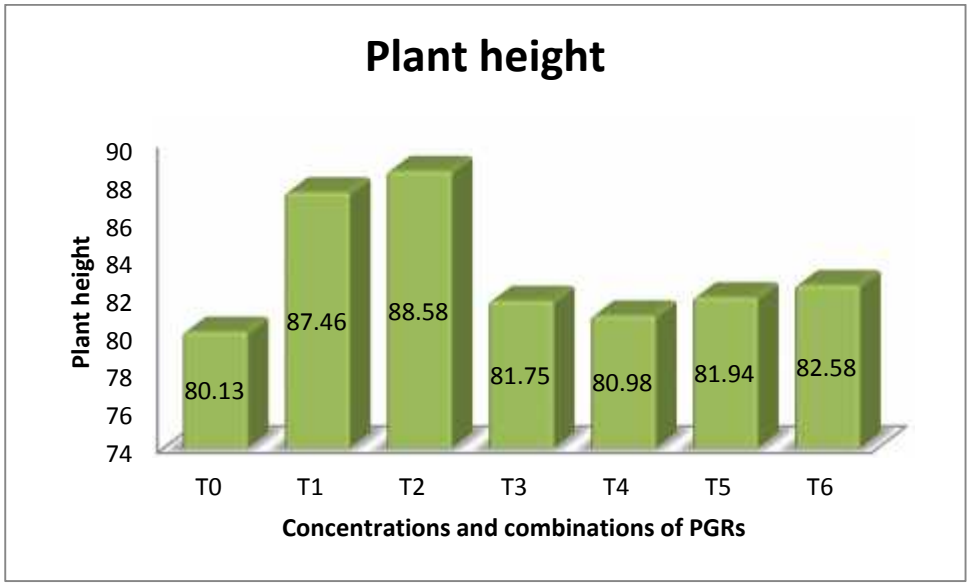

Figure1: Effect of concentrations and combinations of NAA and GA_3 on plant height at final harvest

Here, T_0 = Control (no growth regulators applied), T_1 = 20 ppm NAA applied in vegetative stage, T_2 = 20 ppmGA_3 applied in vegetative stage, T_3 = 20 ppm NAA+ 20 ppm GA_3 applied vegetative stage, T_4 = 20ppm NAA applied in the flower cluster initiation stage, T_5 = 20 ppm GA_3 applied in the flower cluster initiation stage, T_6 = 20 ppm NAA+ 20 ppm GA_3applied in the flower cluster initiation stage.

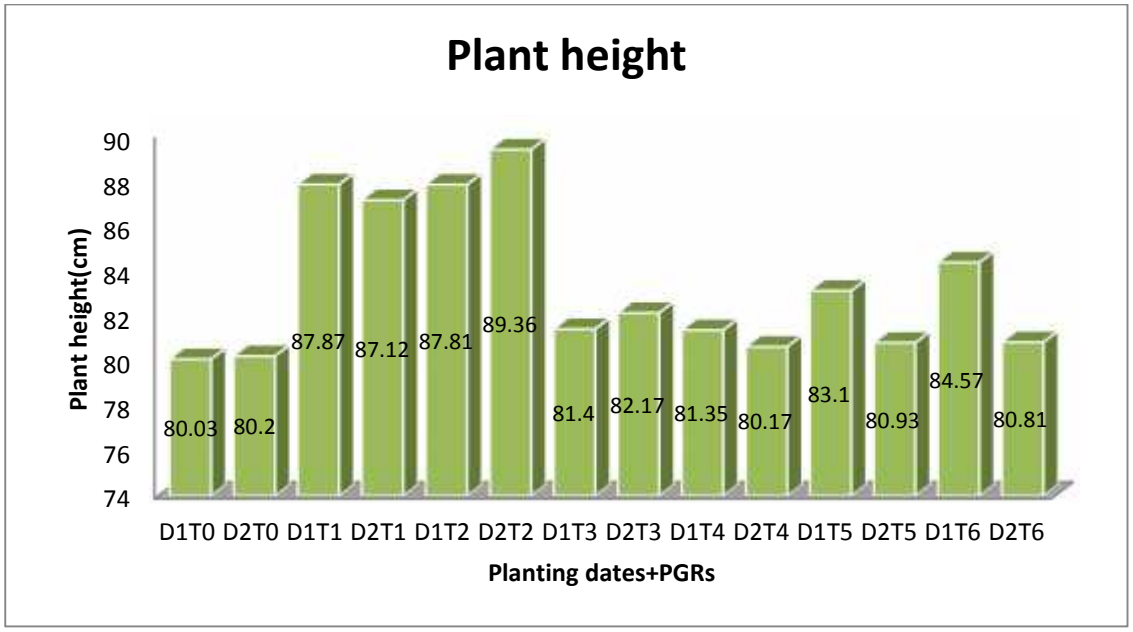

Figure 2: Combine effects of planting date and PGR (NAA+GA_3) on plant height at final harvest

Table 1: Effect of planting date on shoot dry matter weight, root dry matter weight, leaf area index and chlorophyll content

Planting date	Shoot dry matter weight(g $plant^{-1}$)	Root dry matter weight (g $plant^{-1}$)	Leaf area index	Chlorophyll content(mgg^{-1}fw)	Plant height(cm)
D1	13.327 a	2.7714 a	14.981 a	1.6300 a	80.
D2	13.045 a	2.7900 a	15.022	1.6329 a	83.04
$LSD_{0.05}$	0.4117	0.0198	0.0963	0.039	0.674
CV	10.12	2.31	8.30	1.60	2.62

Here, D_1 = 1st June (seed sowing), D_2 = 1st July (seed sowing)

4.2 Shoot dry matter

The variation in shoot dry matter accumulation per plant at final harvest due to the application of different concentrations of NAA and GA_3on tomato was statistically significant. The maximum accumulation of shoot dry matter (16.86 g plant^{-1}) was found after application of 20 ppm GA_3 at vegetative stage which was statistically similar to 20 ppm NAA application at vegetative stage but varied significantly with the other concentrations. The minimum accumulation of shoot dry matter (12.05 g plant^{-1}) was found in the control (Table: 2). Statistically similar results were found for two different planting dates (Table: 1). Transplanted on 1st July and 1st August and treated with 20 ppm GA_3 at vegetative stage gave the highest shoot dry matter weight. The lowest shoot dry matter weight was found in control treatment (Table: 2). It might be the results of the stimulatory effect of GA_3 on plant growth due to cell elongation and rapid cell division in growing portion and there are number of reports showing that gibberellins and naphthalene acetic acid promote growth of intact plants. These results are in conformity with the findings of Arora *et al.* (1999) and Chovatia *et al*. (2010). Uddain *et al.* (2009) reported the increased length of internode and number of branches due to the application of NAA and GA3.Therefore, increased internode, number of branches with increased vegetative growth might be the reason for higher shoot dry weight. Similar result was reported by Ali *et al*. (2012) and Patel *et al.* (2012).

4.3 Root dry matter

The maximum accumulation of root dry matter (2.82 g plant^{-1}) accumulation was found after application of 20 ppm GA_3 + 20 ppm NAA at vegetative stage which was

statistically similar to 20 ppm NAA and 20ppm GA_3 at vegetative stage application but varied significantly with the other concentrations. Application of 20 ppm GA_3 gave lowest root dry matter (Table: 2). There were no significant difference between two planting time found (Table: 1).This might be due to the ameliorative effect of NAA in root growth. Cato *et al.* (2013) reported the increased root dry matter content of tomato due to the synergistic effect of Auxin and Gibberellins. Chauhan *et al.* (2017) reported the increased root dry weight of tomato due to the application of plant growth regulator and our finding is consistent with their findings.

Table 2: effect of different concentrations of NAA and GA_3 on shoot dry matter weight, root dry matter weight, leaf area index and chlorophyll content of BARI tomato-10

concentrations	Shoot dry matter weight	Root dry matter weight (g plant^{-1})	Leaf area index	Chlorophyll content(mgg^{-1}fw)
T_0	12.05 d	2.75 ab	6.02 a	1.63 ab
T_1	16.04 a	2.79 a	5.45 d	1.60 b
T_2	16.86 a	2.70 b	5.87 c	1.63 ab
T_3	12.80 bcd	2.82 a	6.01 a	1.64 a
T_4	12.46 cd	2.78 ab	5.94 b	1.64 a
T_5	13.57 bc	2.82 a	6.01 a	1.61 b
T_6	14.00 b	2.77 ab	6.04 a	1.65 a
$LSD_{0.05}$	0.665	0.037	0.037	0.015
CV	8.30	2.31	0.54	1.60

4.4 Leaf area index

Leaf area index was calculated 40 DAT after transplanting. Maximum leaf area index were obtained in control, 20 ppm NAA + 20 ppm GA_3 at vegetative stage, 20 ppm GA_3 at flowering stage and 20 ppm NAA + 20 ppm GA_3 at flowering stage. Minimum leaf area index was obtained after application of 20 ppm GA_3 at vegetative stage (table 1). Two planting times gave statistically similar results (Table: 1). Maximum leaf area index (6.06) was found when plants were transplanted in 1st July and treated with 20 ppm NAA + 20 ppm GA_3 at the 2nd flower cluster initiation stage (Table: 3). Bora and Selman (1969) reported that GA_3 increased leaf area index. Application of GA_3 at vegetative stage had resulted highest leaf area index. Higher level of GA_3 had drastically reduced leaf area index. The maximum leaf area index might occur due to the variation in number of leaves, the expansion of leaves and the number of branches plant^{-1}.

4.5 Chlorophyll content

Maximum chlorophyll content were obtained from application of 20 ppm NAA+ 20 ppmGA_3 at vegetative stage, 20ppm NAA at flowering stage and 20ppm NAA+20ppm GA_3 at flowering stage. Minimum result was found after application of 20 ppm NAA at vegetative stage and 20ppmGA_3 at flowering stage(table 1). This might be due to the gibberellins and auxin stimulated cell division and cell elongation, therefore the combining foliar spray of these growth substances in the present study significantly increased chlorophyll content in leaves. Rahman *et al.* (2015) Chlorophyll content increased with increased concentrations of GA_3.

Table 3: Combine effect of PGR and planting time on shoot dry matter weight, root dry matter weight, leaf area index and chlorophyll content of BARI Tomato-10

PGR× planting date	Shoot dry matter weight	Root dry matter weight (g plant^{-1})	Leaf area index	Chlorophyll content(mg/gfw)
D_1T_0	11.90 f	2.77 abc	6.03 ab	1.63 ab
D_2T_0	12.20 f	2.74 abcd	6.02 ab	1.62 ab
D_1T_1	16.17 ab	2.75abcd	5.41 g	1.60 b
D_2T_1	15.92bc	2.83 ab	5.86 e	1.61 ab
D_1T_2	14.16 cde	2.73 bcd	6.02 ab	1.65 a
D_2T_2	16.93 a	2.75 abcd	5.87 e	1.63 ab
D_1T_3	12.54 ef	2.83 ab	6.02 ab	1.64 a
D_2T_3	13.06 def	2.82 abc	6.01 b	1.64 ab
D_1T_4	12.66 def	2.72 cd	5.93 d	1.63 ab
D_2T_4	12.27 ef	2.84 a	5.95 cd	1.65 a
D_1T_5	14.55 bcd	2.83 ab	6.02 ab	1.61 ab
D_2T_5	12.60 ef	2.81 abc	6.00 bc	1.61 ab
D_1T_6	13.84 def	2.82 abc	6.06 a	1.65 a
D_2T_6	14.16 cde	2.73 bcd	6.02 ab	1.65 a
$LSD_{0.05}$	0.946	0.052	0.025	0.021
CV	8.30	2.31	8.30	1.60

Here, T_0 = Control (no growth regulators applied), T_1 = 20 ppm NAA applied in vegetative stage, T_2 = 20 ppm GA_3 applied in vegetative stage, T_3 = 20 ppm NAA+ 20 ppm GA_3 applied vegetative stage, T_4 = 20 ppm NAA applied in the flower cluster initiation stage, T_5 = 20 ppm GA_3 applied in the flower cluster initiation stage, T_6 = 20 ppm NAA+ 20 ppm GA_3applied in the flower cluster initiation stage, D_1 = 1st June (seed sowing), D_2 = 1st July (seed sowing).

4.6 Number of flowers plant $^{-1}$

Analysis of variance indicated that the effect of concentrations of NAA and GA_3 on flower numbers per plant was varied significantly during two planting dates. It was found that maximum no. of flower plant^{-1} (39.00) was produced in plants which is sowed in 1stJuly and treated with 20ppm NAA+20ppm GA_3during flower cluster initiation stage which was significantly higher than the other treatments. On the other hand, minimum numbers of flower (15) was produced by control plants (Figure: 4). No. of flower significantly varied with planting dates. Maximum flowers produced by plants which are sowed in 1stJuly (20.74). This might be caused because GA_3promotes flower premordia production in tomato plant which was confirmed by Uddain *et al.* (2009). Rahman *et al.* (2015) reported that, increased number of flower due to the application of plant growth regulators which is similar with our findings.

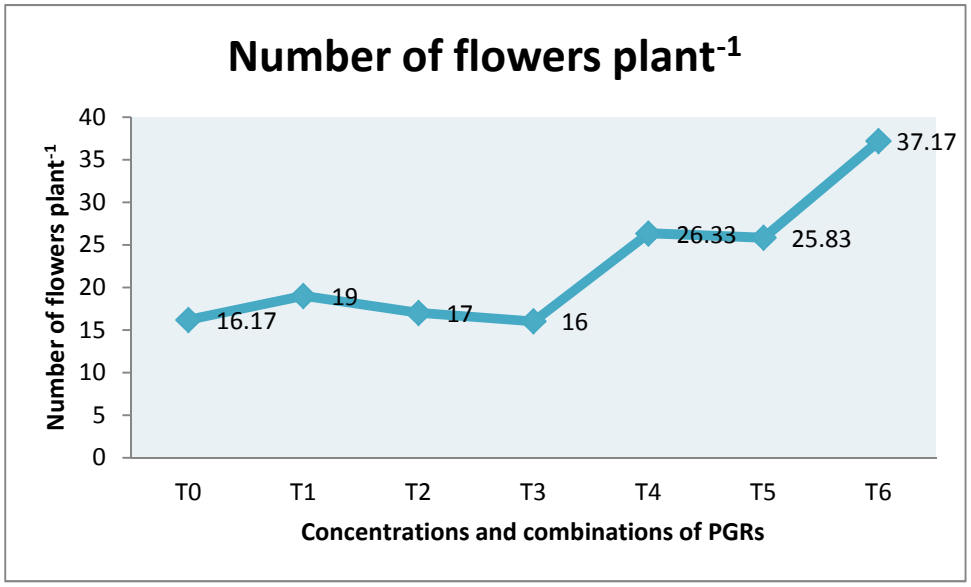

Figure3: Effect of concentrations and combinations NAA and GA_3 on No. of flowers plant^{-1}

Here, T_0 = Control (no growth regulators applied), T_1 = 20 ppm NAA applied in vegetative stage, T_2 = 20 ppm GA_3 applied in vegetative stage, T_3 = 20 ppm NAA+ 20 ppm GA_3 applied vegetative stage, T_4 = 20 ppm NAA applied in the flower cluster initiation stage, T_5 = 20 ppm GA_3 applied in the flower cluster initiation stage, T_6 = 20 ppm NAA+ 20 ppm GA_3applied in the flower cluster initiation stage

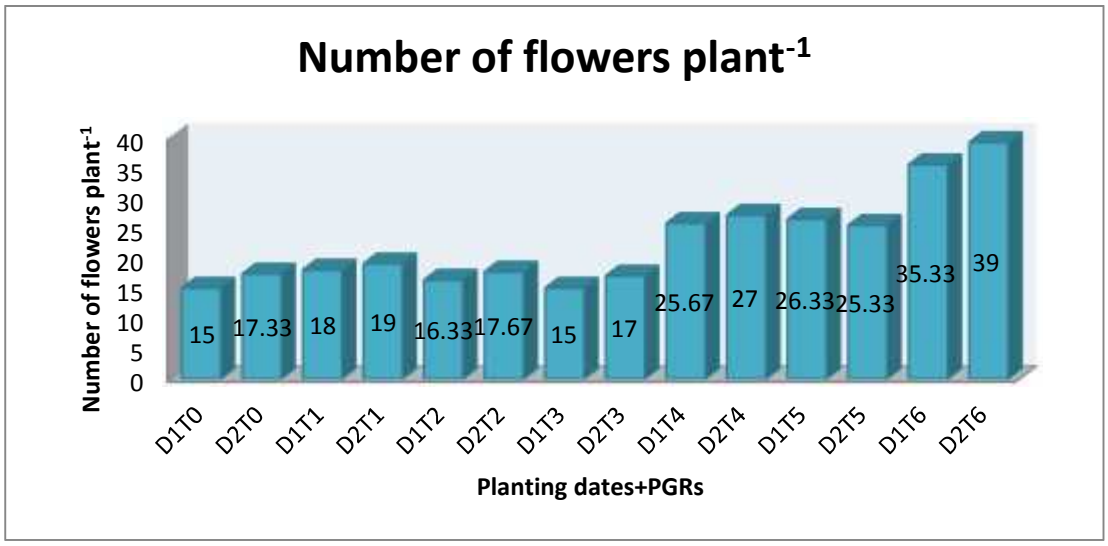

Figure4: Combine effect of concentrations and combinations NAA and GA_3 and planting dates on No. of flowers plant^{-1}

Here, T_0 = Control (no growth regulators applied), T_1 = 20 ppm NAA applied in vegetative stage, T_2 = 20 ppm GA_3 applied in vegetative stage, T_3 = 20 ppm NAA+ 20 ppm GA_3 applied vegetative stage, T_4 = 20 ppm NAA applied in the flower cluster initiation stage, T_5 = 20 ppm GA_3 applied in the flower cluster initiation stage, T_6 = 20 ppm NAA+ 20 ppm GA_3applied in the flower cluster initiation stage, D_1 = 1st June (seed sowing), D_2 = 1st July (seed sowing).

4.7 Number of fruits plant $^{-1}$

Analysis of variance indicated that the effect of concentrations of NAA and GA_3 on flower numbers per plant was varied significantly between two sowing dates. It was found that maximum number of fruits plant^{-1} (35.66) was produced in plants which is sowed in 1stJuly and treated with 20ppm NAA+20ppm GA_3 at flowering stage which was significantly higher than the other treatments (Figure: 5). On the other hand, minimum number of fruit (13) was produced those plants which were no treated with any PGRs (Figure: 4). Number of fruits significantly varied with planting times. Maximum fruits produced by plants which are sowed in 1stJuly (17.14). The improvement in fruit formation due to the foliar spray of GA_3 and NAA in our study

might be because of the fact that they increases the metabolic activity in plant, which resulted in enhancement of reproductive phase in tomato. Chovatia *et al.* (2010) reported that application of NAA at the time of flowering prevents pre-harvest flower abscission by increasing the available plant hormone (auxin) concentration at this critical phase of reproductive development in tomato plants which ultimately increases the number of fruits. The results are in comformity with the finding of Nibhavanti *et al.* (2004), Rai*et al.* (2002), Choudhury *et al.* (2013) and Alam and Khan (2002).

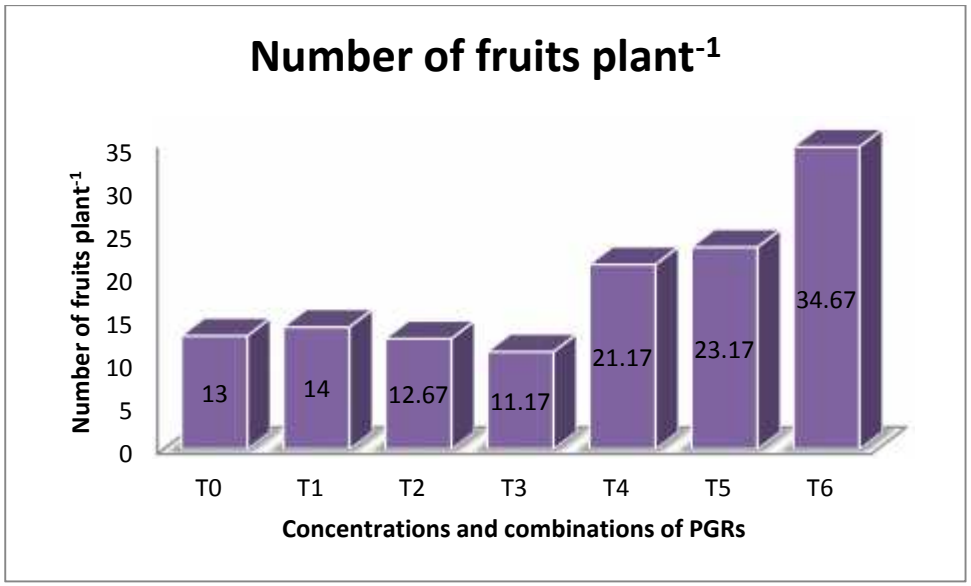

Figure 4: Effect of concentrations and combinations of NAA and GA_3 on Number of fruits plant^{-1}

Here, T_0 = Control (no growth regulators applied), T_1 = 20 ppm NAA applied in vegetative stage, T_2 = 20 ppm GA_3 applied in vegetative stage, T_3 = 20 ppm NAA+ 20 ppm GA_3 applied vegetative stage, T_4 = 20 ppm NAA applied in the flower cluster initiation stage, T_5 = 20 ppm GA_3 applied in the flower cluster initiation stage, T_6 = 20 ppm NAA+ 20 ppm GA_3applied in the flower cluster initiation stage

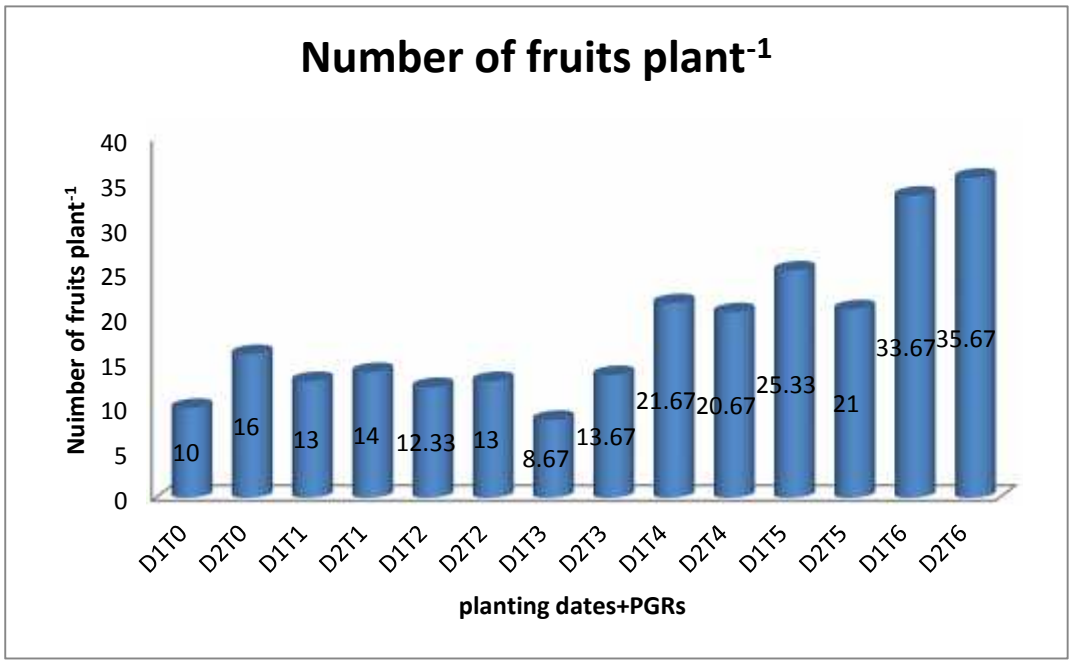

Figure 5: Combine effect of planting dates and PGRs on Number of fruits plant^{-1}

Here, T_0 = Control (no growth regulators applied), T_1 = 20 ppm NAA applied in vegetative stage, T_2 = 20 ppm GA_3 applied in vegetative stage, T_3 = 20 ppm NAA+ 20 ppm GA_3 applied vegetative stage, T_4 = 20 ppm NAA applied in the flower cluster initiation stage, T_5 = 20 ppm GA_3 applied in the flower cluster initiation stage, T_6 = 20 ppm NAA+ 20 ppm GA_3applied in the flower cluster initiation stage, D_1 = 1st June (seed sowing), D_2 = 1st July (seed sowing).

4.8 No. of seed fruit^{-1}

All concentrations and combination showed statistically similar result. Plantings time also showed statistically different results from each other. 1stJuly sowed plant gave fruits with maximum seed. This might be caused because application of GA_3 increased fruit set percentage and total fruit yield as well as percentage of puffy and parthanocarpic fruit which was confirmed by Habbasha *et al.* (1999).

4.9 Yield plant^{-1}

Maximum yield (659.37gm plant^{-1}) was obtained from the plants which were treated with 20 ppm NAA + 20 ppm GA_3 at flower cluster initiation stage. Minimum yield (341.10gm) was obtained from the control plants (Table: 4). Planting times showed statistically similar result (Table: 5). Thatmight be due to the combined application of NAA and GA_3 application. Baliyan *et al*. (2013) reported that the plant remained physiologically more active to build up sufficient food stocks for developing flowers, fruit and resulted in increased fruit set, which ultimately lead to higher yields.

4.10 Carotene content

Application of 20ppm GA_3 and 20ppm NAA+20ppm GA_3 at flower cluster initiation stage were produced fruits with maximum (0.48µmg/100g) carotene content. Minimum (0.19µmg/100g) carotene content occurred when plant treated with 20 ppm NAA+ 20 ppm vegetative stage (Table: 4). This result might be caused because of application of GA_3. Graham and Ballesteros (2006) reported that GA_3 increased proteins, soluble carbohydrates, ascorbic acid, starch and β-carotene in the tomato.

4.11 Total soluble solid (%TSS) content of fruit

Different concentrations and combinations of PGRs showed statistically similar results. 20ppm NAA+20ppm GA_3 at the flower cluster initiation stage showed maximum %TSS (5.39%) (Table: 4). (1.17%) was minimum %TSS which was found from the plants did not treated with PGRs (Table: 4). Two different planting dates showed statistically similar result. This result might be caused because of application of GA_3. Graham and Ballesteros (2006) reported that GA_3 increased proteins, soluble

carbohydrates, ascorbic acid, starch and β-carotene in the tomato. Kumar *et al.* (2014) also observed the highest ascorbic acid and total soluble solid (TSS) in tomato plant treated with GA_3 @ 50 ppm. The beneficial effect of NAA at 100 ppm on fruit TSS was also observed by Pandita *et al.* (1978).

Table 3: Effect of different concentrations of NAA and GA_3 on yield, No. of seed $fruit^{-1}$, carotene content and %TSS (Total soluble solid) of BARI Tomato -10

concentrations	Fruit yield per plant(gm)	No. of seed per fruit	Carotene content(µmg/100g)	%TSS
T_0	341.10 f	43.33 b	0.446	5.36
T_1	409.46 e	51.34 a	0.457	5.62
T_2	466.32 d	50.02 a	0.473	5.38
T_3	487.54 d	51.74 a	0.442	5.43
T_4	545.64 c	55.12 a	0.433	5.38
T_5	597.58 b	53.47 a	0.483	5.32
T_6	659.37 a	54.52 a	0.48	5.39
$LSD_{0.05}$	16.570	5.92	NS	NS
CV	11.04	9.97	2.73	2.59

Here, T_0 = Control (no growth regulators applied), T_1 = 20 ppm NAA applied in vegetative stage, T_2 = 20 ppm GA_3 applied in vegetative stage, T_3 = 20 ppm NAA+ 20 ppm GA_3 applied vegetative stage, T_4 = 20 ppm NAA applied in the flower cluster initiation stage, T_5 = 20 ppm GA_3 applied in the flower cluster initiation stage, T_6 = 20 ppm NAA+ 20 ppm GA_3applied in the flower cluster initiation stage

Table4: Combine effect of planting dates and PGRS on yield per plant, no. of seed plant^{-1}, carotene content and% TSS (Total soluble solid) of BARI Tomato-10.

PGR× planting date	Fruit yield per plant(gm)	No. of seed per fruit	Carotene content(µmg/100g)	% TSS
D_1T_0	314.46 f	54.44	0.449	5.35
D_2T_0	367.73 e	55.02	0.477	5.38
D_1T_1	376.62 e	55.44	0.452	5.43
D_2T_1	397.50 e	55.34	0.448	5.39
D_1T_2	407.40 d	54.97	0.408	5.37
D_2T_2	431.71 d	56.23	0.413	5.40
D_1T_3	441.97 d	55.50	0.493	5.13
D_2T_3	449.28 d	56.33	0.486	5.21
D_1T_4	481.81 d	56.84	0.446	5.31
D_2T_4	526.52 c	55.39	0.421	5.45
D_1T_5	578.86 c	56.84	0.484	5.32
D_2T_5	619.33 b	57.37	0.484	5.32
D_1T_6	655.42 a	56.23	0.477	5.37
D_2T_6	663.33 a	57.23	0.480	5.40
$LSD_{0.05}$	23.433	NS	NS	NS
CV	11.04	9.97	2.73	2.59

Here, T_0 = Control (no growth regulators applied), T_1 = 20 ppm NAA applied in vegetative stage, T_2 = 20 ppm GA_3 applied in vegetative stage, T_3 = 20 ppm NAA+ 20 ppm GA_3 applied vegetative stage, T_4 = 20 ppm NAA applied in the flower cluster initiation stage, T_5 = 20 ppm GA_3 applied in the flower cluster initiation stage, T_6 = 20 ppm NAA+ 20 ppm GA_3applied in the flower cluster initiation stage, D_1 = 1st June (seed sowing), D_2 = 1st July (seed sowing).

Table 5: Effect of planting date on number of flowers plant^{-1}, number of fruits plant^{-1}, fruit yield plant^{-1} and carotene content

Planting date	Number of flowers plant^{-1}	Number of fruits plant^{-1}	Fruit yield plant^{-1}(gm)	Carotene content(µmg/100g)
D_1	19.095 b	15.952 b	265.42 a	0.3506 a
D_2	20.476 a	17.143 a	254.28 a	0.3473 a
$LSD_{0.05}$	0.3434	0.2130	8.8569	0.941
CV	5.62	4.17	11.04	2.73

Here, D_1 = 1st June (seed sowing), D_2 = 1st July (seed sowing).

CHAPTER V

SUMMARY AND CONCLUSION

The research was comprised of pot-culture experiment conducted at the research farm of Sher-e-Bangla Agricultural University (SAU) during June-November of 2018. The treatments of the experiment was two selected growth regulators (NAA and GA_3) and their different combination and concentrations. The experiment was laid out in complete randomized design (CRD) having two factors with three replications. Data were taken on the effect of different concentrations of two growth regulators and their combination and application stages on growth, yield contributing characters and yield in order to study morpho-physiological as well as yield attributes of BARI tomato-10 during two different sowing date.

The effect of different concentrations and combination of two selected growth regulators NAA and GA_3 was found to be significant for almost all the parameters. The tallest plant at final harvest was (88.58cm) and (87.46cm) was obtained from 20 ppm GA_3 and 20 ppm NAA applied at vegetative stage respectively. Significant variation in dry matter accumulation in plant parts at final harvest was observed. The highest root dry matter weight (2.82 g plant^{-1}) was found after application of 20 ppm GA_3 + 20 ppm NAA applied at the vegetative stage which was statistically similar to the application 20 ppm NAA in vegetative stage and 20ppm GA_3 in flowering stage but varied significantly with the other concentrations. But highest shoot dry matter weight (16.86g plant^{-1}) accumulation was found after application of 20 ppm GA_3 given at the vegetative stage which was statistically similar to 20 ppm NAA application at vegetative stage. Two different sowing dates showed statistically similar results. Maximum leaf area index (6.06) found when plants were sowed in 1st

June and treated with 20 ppm NAA + 20ppm GA_3 at flowering stage. Maximum chlorophyll content was obtained from 20 ppm NAA + 20 ppm GA_3 application at vegetative stage, 20 ppm NAA at flowering stage and 20 ppm NAA + 20ppm GA_3 application at flowering stage. Analysis of variance indicates that the effect of concentrations of NAA and GA_3 on flower numbers per plant was varied significantly between two sowing dates. It was found that maximum no. of flower per plant (39) was produced in plants which were sown 1stJuly and treated with 20ppm NAA + 20ppm GA_3 at flowering stage, which was significantly higher than that were obtained from other varieties. Minimum seed was obtained from control (54.44). Maximum seed was obtained from application of 20 ppm NAA+ 20 ppm GA_3 at vegetative stage. Maximum yield (659.37 g) was obtained from the plants which were treated with 20 ppm NAA + 20 ppm GA_3 at flowering stage. Plants sowed in 1stJuly gives higher yield. Application of 20ppm GA_3 and 20 ppm NAA + 20 ppm GA_3 at flowering stage were produced fruits with maximum carotene content. 20 ppm NAA+ 20 ppm GA_3 at the flower cluster initiation stage showed maximum %TSS (5.39%). 20ppm GA_3 at flowering stage, control and 20 ppm GA_3 at vegetative stage showed statistically similar results. Maximum fruit length was obtained from the plants which are treated with 20 ppm NAA (3.23cm) at flowering stage. Maximum fruit breath was obtained from the plants which were treated with 20ppm NAA (2.98cm) at flowering stage.

Conclusion and recommendations

Based on the findings of the present study, it may be concluded that concentration, combination and stages of application of PGRs have remarkable influence on yield attributes of BARI Tomato-10. Among the different concentrations of plant growth

regulators treated with the combined application of 20 ppm NAA and 20 ppm GA_3 at flowering stage showed an increased number of flowers plant^{-1}, number of fruits plant^{-1}and fruit yield as compared to the plants treated with the same treatments applied at the vegetative stage. Seed sown on 1st July showed maximum number of flowers per plant, number of fruits and yield as compared to the seeds sowed on 1st June. Therefore it may be concluded that application of 20 ppm NAA along with 20ppm GA_3 at flowering stage and sowing seeds on 1stJuly were effective in enhancing growth and yield of BARI Tomato-10.

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APPENDICES

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

The map of Bangladesh showing experimental site

Appendix II: Monthly average air temperature, total rainfall, relative humidity and sunshine hours of the experimental site during the period from October 2017 to march 2018

Year	Month	Average Air temperature (^{0}C)			Total rainfall (mm)	Average RH (%)	Total Sun shine hours
		Maximum	Minimum	Mean			
2017	October	34.8	18.0	77	227	80	34.8
	November	32.3	16.3	69	0	65	32.3
	December	29.0	13.0	79	0	68	29.0
2018	January	28.1	11.1	72	1	66	28.1
	February	33.9	12.2	55	1	66	33.9
	March	34.6	16.5	67	45	68	34.6
	April	35.7	17.8	68	65	67	35.1

Source: Meterological Centre, Agargaon, Dhaka (Climate Division)

B. Mechanical analysis:

Constituents	Percent
Sand	45
Silt	30
Clay	25
Textural class	Sandy loam

B. Chemical composition:

Soil characters	Value
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total nitrogen (%)	0.07
Phosphorus	22.08 µg/g soil
Sulphur	25.98 µg/g soil
Magnesium	1.00 meq/100 g soil
Boron	0.48 µg/g soil
Copper	3.54 µg/g soil
Zinc	3.32 µg/g soil
Potassium	0.30 µg/g soil

Source: Soil Resources Development Institute (SRDI), Khamarbari, Dhaka