GROWTH AND YIELD OF TOMATO AS INFLUENCED BY PLANT GROWTH REGULATORS

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CERTIFICATE

This is to certify that the thesis entitled **"Growth and Yield of Tomato as Influenced by Plant Growth Regulators"** submitted to the Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE** in **HORTICULTURE**, embodies the result of a piece of *bona fide* research work carried out by **H. E. M. Khairul Mazed**, Registration No. **09-03614** 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.

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The Author

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ABSTRACT

An experiment was conducted at the Horticulture farm of Sher-e-Bangla Agricultural University, Dhaka during the period from November 2013 to April 2014 to study the growth and yield of tomato as influenced by plant growth regulators. The experiment was laid out in a Randomized Complete Block Design with three replications and consisted of two factors, Factor A (3 Levels of IAA): I_0 = Control, I_1 = 25 ppm, I_2 = 35 ppm IAA and Factor B (4 Levels of GA_3): G_0 = Control, G_1 = 30 ppm, G_2 = 60 ppm and G_3 = 90 ppm GA_3 respectively. In case of IAA, I_2 treatment produced the highest yield (74.76 t/ha) and I_0 produced the lowest yield (58.69 t/ha). In case of $GA_{3,}$ G_2 produced the highest yield (76.45 t/ha) and G_0 produced the lowest yield (53.30 t/ha). The treatment combination of I_2G_2 produced the highest yield (85.42 t/ha) and I_0G_0 produced the lowest yield (47.25 t/ha). The highest (3.58) benefit cost ratio was recorded from I_2G_2. So, 35 ppm IAA with 60 ppm GA_3 was found suitable for growth and yield of tomato.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ACRONYMS

ABBREVIATIONS	ELABORATIONS
AEZ	Agro-Ecological Zone
Anon.	Anonymous
ANOVA	Analysis of Variance
@	at the rate of
Adv.	Advanced
Agric.	Agricultural
BARI	Bangladesh Agricultural Research Institute
BAU	Bangladesh Agricultural University
BBS	Bangladesh Bureau of Statistics
cm	Centimeter
CV	Coefficient of Variation
cv.	Cultivar
df	Degrees of Freedom
DMRT	Duncan`s Multiple Range Test
DAT	Days After Transplanting
^{0}C	Degree Celsius
e.g.	example
et al.	and others
etc.	etcetera
FAO	Food and Agricultural Organization
g	Gram
GA_3	Gibberellic Acid
ha	Hectare (10000 meter square)
HRC	Horticulture Research Centre
Hort.	Horticulture
IAA	Indole-3-Acetic Acid
J.	Journal

ABBREVIATIONS	ELABORATIONS
L	Liter
MoP	Muriate of Potash
mg	Milligram
ml	Milliliter
mm	Millimeter
ns	Non Significant
NAA	Naphthalene Acetic Acid
PGR	Plant Growth Regulator
pH	Hydrogen ion concentration
ppm	Parts Per Million
%	Percentage
Res.	Research
RH	Relative humidity
SAU	Sher-e-Bangla Agricultural University
SRDI	Soil Resource Development Institute
Sci.	Science 's
t	Ton (1000 kg)
Tk.	Taka (BDT)
TSP	Triple Super Phosphate
UNDP	United Nations Development Program
µg	Microgram
Vol.	Volume

CHAPTER I

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) is a solanaceous self pollinated vegetable crop. It is one of the important, popular and nutritious vegetables grown in Bangladesh in both winter and summer season around all parts of the country (Haque *et al.*, 1999). It is adapted to a wide range of climates. At present, tomato ranks third, next to potato and sweet potato, in terms of worlds vegetable production (FAO, 2013). The leading tomato producing countries of the world are China (50,000,000 tons), India (17,500,000 tons), United States (13,206,950 tons), Turkey (11,350,000 tons) Egypt (8,625,219 tons), Iran (6,000,000 tons), Italy (5,131,977 tons), Spain (4,007,000 tons), Brazil (3,873,985 tons), Mexico (3,433,567 tons), and Indonesia (FAO, 2013).

Tomato fruit can be consumed either fresh, cooked or in the form of processed products such as jam, jelly, juice, ketchup, sauce etc. It is considered as 'poor man's apple' because of its attractive appearance and very high nutritive value, containing vitamin A, vitamin C and minerals like calcium, potassium etc. Apart from these, it also contains organic acids like citric, malic and aceitic acids which found in fresh tomato fruit, promotes gastric secretion, acts as a blood purifier and works as intestinal antiseptic (Pruthi, 1993).

Tomato is a rich source of lycopene and vitamins. Lycopene may help counteract the harmful effects of substances called free radicals, which are thought to contribute to age-related processes and a number of types of cancer, including, but not limited to, those of prostate, lung, stomach, pancreas, breast, cervex, colorectum, mouth and oesophagus. (Masroor *et al.,* 1988).

It is much popular for consumption as salad in the raw state and as processed soups, juice, ketchup, pickles, sauces, conserved puree, paste, powder and other products (Ahmad, 1976; Thompson and Kelly, 1983 and Bose and Som, 1990).

Bangladesh produced 251000 tons of tomato in 23,827 hectares of land during the year 2012-2013 (BBS, 2013). The average yield of tomato in Bangladesh is quite low (10.54 t/ha) compare to that in China (48.1 t/ha), India (19.5 t/ha), Japan (52.817 t/ha), USA (81.0 t/ha), Turkey (33.1 t/ha), Egypt (34 t/ha), Italy (50.7 t/ha), Spain (74.0t/ha), Brazil (60.7 t/ha), Mexico (30.5 t/ha) respectively (Anonymous, 2011). There are some high yielding varieties of tomato in Bangladesh today and the average yield of BARI Tomato-14 is 90-95 t/ha (Razzak *et. al.*, 2011).

It is expected that improved management practices with modern technology would increase the yield considerably. The growth behavior of many crop plants could be modified and controlled by applying small amount of growth regulators. The exogenous application of growth regulator GA_3 stimulate flowering, pollination, fertilization and seed setting to yield better quality seeds. The plant growth regulators have contributed a great deal to the progress of olericulture.

IAA stimulates cell elongation by stimulating wall-loosening factors, such as elastins, to loosen cell walls and the effect is stronger if gibberellins are also present (Bunger-Kibler and Bangerth, 1983). IAA also stimulates cell division if cytokinins are present (Zhao, 2008). IAA induces the formation and organization of phloem and xylem. When the plant is wounded, the IAA may induce the cell differentiation and regeneration of the vascular tissues (Ulmasov *et. al.*, 1999). IAA promotes root initiation and induces both growth of pre-existing roots and adventitious root formation, i.e., branching of the roots (Varga and Bruinsma, 1976). As more native auxin is transported down the stem to the roots, the overall development of the roots is stimulated. The longer and branched root can uptake more nutrients from the soil which are accumulated to the plant sink and increase the yield (Wang *et. al.*, 2005). If the source of IAA is removed, such as by trimming the tips of stems, the roots are less stimulated accordingly. IAA induces shoot apical dominance and the axillary buds are inhibited by IAA (Woodward and Bartel, 2005). IAA is required for fruit growth and development and delays fruit senescence and plays also a minor role in the initiation of flowering and development of reproductive organs (Asahira *et. al.*, 1967)

The Gibberellic acid is one of the most important growth stimulating substances used in agriculture since long. It may promote cell elongation, cell division and thus helps in growth and development of tomato plant .Gibberellic acid when applied to flowers controlled fruit drop in tomato (Feofanova, 1960).

Therefore, in accordance with recent agricultural policy to increase yield vertically and to get early yield and better quality fruit, an attempt was made to study the effects of different concentrations of Gibberellic Acid (GA_3) and Indole-3-Acetic Acid (IAA) on plant growth and yield of tomato with the following objectives:

i) To study the effect of exogenous application of IAA (Indole-3-Acetic Acid) on growth and yield of tomato

ii) To study the effect of exogenous application of GA_3 (Gibberellic Acid) on growth and yield of tomato

iii) To find out the combine effects of IAA and GA_3 on tomato production.

CHAPTER II

REVIEW OF LITERATURE

Tomato is an important vegetable crop and received much attention of the researchers throughout the world to develop its suitable production technique among various research works investigations have been made in various parts of the world to determine the different levels of Indole-3-acetic acid and gibberellic acid for its successful cultivation. However, the combined effects of these production practices have not been defined clearly. In Bangladesh, there have not many studies on the influence of different levels of IAA and gibberellic acid on the growth and yield of tomato. Relevant available information in this connection has been described in this chapter.

2.1 Effect of IAA on growth and yield of Tomato

Singh *et al*. (2005) carried out an investigation to see the effects of different doses of PGRs (control, 25 or 75 ppm IAA, and 25 or 75 ppm NAA) and micronutrient (control, 2500 ppm Multiplex or 2000 ppm Humaur) mixtures and their interactions on plant growth, number of branches and yield of tomato at 35 and 70 days after transplanting (DAT). Plant growth was not affected significantly by any treatment and interaction, although the effect of Pl (25 ppm IAA) x M2 (Humaur) interaction was better in increasing the plant growth at 75 DAT. The number of branches was signiticantly and highly increased by the application of 75 ppm IAA and 25 ppm NAA. The initiation time of first flowering and first fruiting was significantly and highly increased by the interaction P4 (75 ppm NAA) x M2 (Humaur). Application of 35 ppm IAA and 2000 ppm Humaur was significantly increased the tomato yield. P4 (75 ppm NAA) x M2 (2000 ppm Humaur) was also significantly increased the yield. It can be concluded that addition of PGR and micronutrient in tomato is useful for better production.

Djanaguiraman *et al*. (2004) conducted an experiment where the plants were with four different concentrations of Nitrophenols (ATONIK) at flowering and fruit setting stage. Observations were recorded in the flowers and developing fruits. Application of nitrophenols significantly increased the activity of antioxidant enzymes namely superoxide dismutase (SOD), catalase CAT), peroxidase (POX) and auxin content coupled with decreased activity of polyphenol oxidase [catechol oxidase] (PPO) and IAA oxidase (IAAO) enzymes over the control significantly. Among the concentrations, experimented, application of nitrophenols at 0.4% during fruit set stage was found to be the most effective in recording high antioxidant enzymes activity and auxin level which was reflected in an increased number of fruit clusters per plant, fertility coefficient and yield of tomato.

Gupta and Gupta (2004) studied the plants were sprayed with 25 or 75 ppm IAA and NAA, alone or in combination with the micronutrient mixtures Multiplex 2500 ppm and 2000 ppm Humaur in a field experiment conducted in Allahahad, India to determine the effects of the treatments on the P content of tomato fruits and products. Application of 75 ppm NAA + multiplex resulted in the highest P content in tomato fruits, as well as in ketchup, and tomato puree and juice during both years.

Gupta *et al*. (2003) observed the response of plant growth regulators and micronutrient mixtures on fruit size, color and yield of tomato (*Lycopersicon esculentum* Mill.) An experiment was conducted by two years (1997-99) in Uttar Pradesh, India to determine the effect of growth regulators (25 ppm IAA and 45 ppm IAA) at 25 and 50 days after transplanting (DAT) and / or Micronutrient mixtures (2500 ppm Multiplex and 2000 ppm Humaur) at 25 and 50 DAT, respectively, on tomato cv. Krishna (F_1 hybrid). Among all Treatments , the largest fruit size (6.67 cm diameter), most attractive ripe fruit color (Phantom, 2L - 12) and the highest yield (63.61 t/ha) were observed with 45 ppm IAA + Multiplex micronutrient mixture at the maturity stage during 1998-99. The highest dry matter (12.7%) and ash content (1.0%) were obtained upon treatment with 45 ppm IAA + Humaur micronutrient mixture.

Singh *et al*. (2003) stated that the effects of 2,4-D. beta naphthoxyacetic acid [2- naphthoxyacetic acetic acid] and IAA (I, l0 or 100 ppm), applied as either as seed Treatment or plant spray, on the growth and yield of tomato cv. Pusa Ruby were in Kanpur, Uttar Pradesh, India. Seed germination varied from 8.2 to 40.2 % during the initial evaluation. Flowering was initially observed in treated plants at 77-87 days after sowing. 2,4-D at all concentrations resulted in earlier flowering, whereas I ppm BNOA and all concentrations of IAA delayed flowering. Plants treated with 100 ppm BNOA exhibited the greatest seed germination and fruit set, and the lowest number of days to flowering. BNOA applied at 100 ppm as seed treatment gave the earliest fruit ripening (earlier than the control by 15 days).

Gupta *et al*. (2002)[a] conducted an experiment on the effect of, IAA and NAA (35 and 75 ppm, respectively, at 25 and 50 days after transplanting) and the micro nutrients mixtures Multiplex and Humaur (2500 and 2000 ppm, respectively), on the tomato cultivar Krishna was evaluated in Karnataka, India during 1997-98 and 1998-99. The application of auxins and micronutrients significantly improved the fruit size (length 6.32 cm and diameter 6.78), dry matter, ash content, longest root length and yield of The greatest fruit size and yield were obtained with 75 ppm NAA + multiplex; while the highest dry matter and ash content were recorded for 75 ppm NAA + Humaur.

Gupta *et al*. (2002)[b] conducted an experiment to observed the effect of the plant growth regulators (PGRs) IAA and NAA (15 and 75 ppm), and micronutrient mixtures Multiplex (2500 ppm) [Ca, Mg, S, Fe, Zn, Mo. Mn, B and NAA] and Humaur (2000 ppm) on the nutritive value of tomato (cv. Krishna) fruits. PGRs were applied at 25 and 75 days after transplanting (DAT). Treatment with micronutrient mixtures was conducted at 25 and 75 DAT. Higher nutritive content was obtained with the application of both PGRs and micronutrient mixtures than treatment with either PGR or micronutrient mixture. NAA at 75 ppm + Multiplex increased P content by l6.l2 % and iron content by 23.33%. The application of 75 ppm NAA + Humaur increased K content by 13.80% and

Ca concentration by 52.38%. The Mg content increased by 43.84% due to the application of 25 ppm NAA + Humaur.

Singh *et al*. (2002) conducted a field experiment at Allahabad, Uttar Pradesh, India to determine the effect of plant growth regulators (PGRs) and commercially available micronutrient mixtures on growth, yield and quality of tomato cv. Gobi (F_1 Hybrid). The treatments consisted of 2 concentrations (25 and 75 ppm) each of IAA and NAA, and micronutrients Humaur at 2000 ppm and Multiplex at 2500 ppm. PGRs were applied in the form of foliar sprays at intervals of 26 and 29 days, respectively, and micronutrients were applied as a spray at 30 days after planting. Plant growth characters and fruit quality varied with the application of PGR and micronutrient mixture combinations.

Rai *et al*. (2002) conducted an experiment that application of IAA at 75 ppm along with Multiplex at 2500 ppm resulted in highest plant height and yield, and IAA at 75 ppm alone in the highest number of branches. Application of IAA at 25 ppm + Multiplex at 2500 ppm superior for ascorbic acid content. Maximum chlorophyll content and acidity were obtained with NAA at 75 ppm along with Humaur at 2000 ppm IAA at 75 ppm + Humaur at 2000 ppm were the best for total soluble solids and carotenoid content. NAA at 75 ppm along with Multiplex at 2500 ppm gave the highest sugar content.

Gupta *et al*. (2001) studied with Tomato (cv. Krishna) plants were treated with IAA (25 ppm at 25 clays alter transplanting, DAT) and NAA (75 ppm at 75 DAT), and supplied with Multiplex (2500 ppm) and Humaur (2000 ppm), in a field experiment conducted during the rabi seasons. The physicochemical characteristics of, fruits were analyzed. Maximum total soluble solid content (5.4%) in mature tomato fruits was recorded from treatments of- NAA and Humaur. The maximum lycopene and carotenoid contents were recorded from NAA and Multiplex. Reducing and non-reducing sugar contents were the highest (4 mg/l00 g and 31.5 mg/100 g) when plants were treated with NAA and Humaur.

Chung and Chori (2001) stated the foliar application of plant growth regulators affects distribution and accumulation of calcium ($45CaCl_2$) in tomato leaves. All tomato (cv. Sunroad) leaves, except the 7th and 8th or 5th to 8th leaves from the cotyledons, stem apices and the inflorescence, were removed to investigate the effect of plant growth regulators (PGR) on the leaves. The application of GA_3 to either of these leaves resulted in the accumulation of $45Ca_2$ twice as high in the treated plants as in the plants which were sprayed distilled water (control plants). When 2-(3-chloroplrenoxy) propanoic acid (CPA) was applied onto the upper leaf, than $45Ca_2$ accumulation was higher than in the control plants, whereas there was no difference when CPA was applied onto the lower leaf. IAA or NAA treated leaves showed lower amount $45Ca_2$ than the leaves of control plants, showing more inhibiting effect of NAA, in particular. The present study indicates that the application of various PGR does not interrupt the acropetal movement of calcium ion.

Sun *et al.* (2000) reported the role of growth regulators on cold water for irrigation reduces stem elongation of plug-grown tomato seedlings. The effect of growth regulators (abscisic acid, gibberellic acid (GA), paclobutrazol, ethephone, IAA and silver thiosulphate) and cold water irrigation at different treatments (5, 15, 25, 35, 45 and 55 ^{0}C) on the reduction of stem elongation and of plung -grown tomato) seedlings was investigated. Paclobutrazol, ethephon and GA reduced the stem length but increase the stem diameter of the tomatoes at several water temperatures. Cold water irrigation with the addition of 1.8 ppm GA or irrigation at room temperature could promote stem elongation. Irrigation at room temperature with the addition of 10 ppm paclobutrazol (GAs biosynthesis inhibitor) or cold water irrigation could inhibit stem elongation. The reduction in stem elongation in plung-grown tomato seedlings was due to the relationship of GAs metabolism and sensitivity.

El-Habbasha *et al*. (1999); studied the response of tomato plants to foliar spray with some growth regulators under late summer conditions. Field experiment were carried out with tomato (cv. Castelrock) over two growing seasons

(1993-94) at Shalakan, Egypt. The effects of GA_3 IAA, TPA (tolylphthalamic acid) and 4-CPA (each at 2 different concentrations) on fruit yield and quality were investigated. Many of the treatments significantly increased fruit set percentage and total fruit yield, but also the percentages of puffy and parthenocarpic fruits, compare with controls.

Sumiati (1987) reported that tomato cultivars. Gondol, Meneymaker, Intan and Ratan sprayed with 1000 ppm chlorflurenol. 100 ppm IAA, 50 ppm NAA or l0 ppm, GA_3 or left untreated, compared with controls, fruit setting was hastened by 4-5 days in all cultivars following treatment with 100 ppm IAA or l0 ppm $GA_{3.}$

Perez and Ramirez (1980) carried out an experiment with the application of IAA at 25 and 35 ppm on tomato. They found increased fruit size quality with minimum seeds.

Younis and Tigani (1977) carried out an experiment with IAA application on tomato cv. John Moran plants. They observed that when IAA was applied to field grown tomato plants, 2 applications of IAA at 10 ppm increased the fruit set significantly.

Kaushik *et al*. (1974) reported that 10 ppm of IAA increased the number and weight of fruits per plant significantly. The application of IAA at100 ppm markedly reduced fruit number and yield.

Singh and Upadhayaya (1967) studied the effect of IAA and NAA on tomato and reported that the regulators activated growth, increased the fruit set, size and yield of fruit and induced parthenocarpic fruit. The chemicals 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.

Mukharji and Roy (1966) found that application of IAA had protected the flower and premature fruit drop and increased length of size fruit in tomato plant.

Leopold (1964) observed that with the increase in concentration of auxin there was a comparable increase in percentage of flower cluster.

Chhonkar and Singh (1959) recorded increasing yield of tomato by seedling treatment with growth substances. They reported that high concentration of IAA reduced plant height but increased yield through increased flower induction and fruit set.

2.2 Effect of GA_3 on growth and yield of Tomato

Hossain (1974) investigated the effect of gibberellic acid along with parachlorophenoxy acetic acid on the production of tomato. He found that GA_3 applied at 50, 100, 150 and 200 ppm produced an increased fruit set. However, GA_3 treatment induced a small size fruit production. A gradual increase in the yield per plant was obtained with higher concentration of GA_3.

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

Kanwar *et al.* (1976) recorded significantly increased fruit length (5.15 cm) and weight with spray of GA_3 (30 ppm) at pre-bloom stage in tomato whereas, did not notice any significant increase in fruit length of chilli with GA_3 (10 ppm) sprayed at first flower opening followed by two sprays at interval of 30 days.

Mehrotra *et al.* (1970) recorded the significant increase in the plant height (95 cm) with 25 ppm GA_3 spray at flower initiation stage in tomato.

Rappaport (1960) recorded more plant height when GA_3 sprayed at the rate of 20 to 40 mg per litre of water at flower initiation stage in tomato.

Mehta and Mathi (1975) reported that GA treatments at 10 or 25 ppm improved the yield of tomato cv. “Pusa Ruby” irrespective of planting date. GA_3 gave earlier setting and maturity.

Choudhury and Singh (1960) reported the enhanced effect of GA_3 on vegetative growth in tomato by spraying at different concentrations in field condition.

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

Satti and Oebekar (1986) reported that an increase in fruit set of tomato due to application of GA_3 @ 45 ppm at various stages of inflorescence development.

Singh and Lal (1995) reported the foliar spray of GA_3 (50 ppm) at 50 percent flowering increased the fruit set and seed yield of tomato.

Sumati (1987) recorded significant increase in number of fruit per plant in tomato cv. Money maker with spraying of 10 ppm GA_3 against untreated plants. The purpose of applying gibberellins is to optimize yield by modifying growth and development and to enhance the quantitative and qualitative production. Many physiological processes and management practices involved in tomato production, those can effected by gibberellins (GA_3) in order to reduce production cost and increase yield and its quality. Gibberellins involved in many physiological processes like, controlling flowering, increasing number of branch, number of cluster, enhancing fruit set and size, dry matter content of fruits, increasing earliness, regulating sex expression and to enhance productivity of crop.

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

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

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

Sasaki *et al*. (2005) studied the effect of plant growth regulators on fruit set of tomato (*Lycopersicon esculentum* cv. Momotaro) under high temperature and in a field (Japan) under rain shelter. Tomato plants exposed to high temperature (34/20 degrees C) had reduced fruit set. Treatments of plant growth regulators reduced the fruit set inhibition by high temperature to some extent, especially with mixtures of 4-chlorophenoxyacetic acid (4-CIIA) and gibberellins (GAs). They also reported that tomatoes treated with a mixture of 4-CPA and GA_3 showed increased fruit set, dry matter content of fruit and the numbers of normal fruits were more than the plants treated with 4-CPA alone during summer.

Kataoka *et al*. (2004) conducted an experiment on the effect of uniconazole on fruit growth in tomato cv. Severianin and reported that uniconazole (30 mg/litre) reduced fruit weight when applied to parthenocarpic fruits at approximately 0, 1 and 2 weeks after anthesis, but had no effect on fruit weight when applied at approximately 3 weeks after anthesis. To determine the antagonism between gibberellic acid (GA_3) and uniconazole in the regulation of fruit growth, flower clusters were treated with uniconazole (5 mg/L) and GA_3 (5 or 50 mg/L). They reported that no notable gibberellin's activity was detected in treated fruits at 3 days to 4 weeks after treatment. The mean fresh weight of fruits at 4 weeks after treatment was lower than that of the control value. The results suggest that endogenous gibberellins in the early phase are important for fruit set and development.

Bhosle and Khrbhade (2002) reported the effects of NAA (15, 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 during the summer of 1997. They reported that 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 gihberellic acid resulted in the highest number of primary branches and plant canopy size of Dhanashree (4.16) and Rajashree (5.38), respectively. The highest marketable yield of Dhanashree and Rajashree was also found from treatment with 75 ppm 4-CPA.

Pundir and Yadav (2001) stated that GA_3 sprayed at 25 ppm significantly increased the growth characters yield and yield components and also improved the quality of tomato cv. Punjab Chhuhara. NAA application increased total soluble solids percentage significantly. Application of 2,4-D at 5 ppm also increased the yield, but retarded the growth attributes and yield at higher concentration.

Martins *et al*. (1999) studied the growth regulators and leaf anatomy in tomato (*Lycopersicon esculenlum* Mill.) cv. Angela Gigante. The plant growth regulators GA_3 (50 mg/L), NAA (100 mg/L), chlormequat (1500 mg/L.) and SADH [daminozide] (3000 mg/L) were applied to greenhouse tomato cv. Angela Gigante plants at the 4-true-leaves stage. Twenty days after treatment, the growth promoters (GA_3 and NAA) increased the number of stomata per square mm on the adaxial epiderrnis and carbon assimilation rate cornpared with untreated controls and decreased the number of epidermal cells on both sides of the leaves. The growth retardants (chlormequat and SADH) increased the thickness of the lacunary parenchyma more than the growth promoters.

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

El-Abd *et al*. (1995) studied the effect of plant growth regulators for improving fruit set of tomato. Two tomato cv. Alicante crops were produced in pots in the greenhouse. When the third flower of the second cluster reached anthesis, the cluster was sprayed with IAA, GA_3 or ABA at l0-4, 10-6 or 10-8 M each and ACC at l0-9, 10-10 or 10-11 M. All concentrations of IAA, GA_3 ACC and ABA induced early fruit set compared with controls sprayed with distilled water. For the first of the 2 crops, the highest ABA concentration (l0-5 M) accelerated fruit set, but the other 2 concentrations delayed it. For the second crop, however all ABA treatments accelerated fruit set. ABA applions also retarded red fruit color formation, more so at increasing concentrations. IAA at l0-6 M resulted in the formation of double flowers of total fruits set from treated flowers, 40 % were double. GA_3 led to the formation of leafy clusters, with the number of leaves and dry matter content of leaves increasing with GA_3 concentration.

Groot *et al*. (1987) reported that GA_3 and IAA were indispensable for the development of fertile flowers and for seed germination, but only stimulated in later stages of fruit and seed development.

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

Onofeghara (1981) conducted an experiment on tomato sprayed with GA_3 at 20-1000 ppm NAA at 25-50 ppm. He observed that GA_3 promoted flower primordia production and the number of primordia and NAA promoted flowering and fiuiting.

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

Choudhury and Faruque (1972) reported that the percentage of seedless fruit increased with an increase in GA_3 concentration from 50 ppm to 100 ppm and 120 ppm. However, the fruit weight was found to decrease by GA_3 effects.
Jansen (1970) reported that tomato plants treated with GA_3 neither increased the yield nor accelerated fruit ripening. He also mentioned that increasing concentration of GA_3 reduced both the numbers and size of the fruits.

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

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

Gustafson (1960) worked with different concentration of GA_3 and observed that when 35 and 70 ppm GA_3 were sprayed to the flowers and flower buds of the first three clusters, percentage of fruits set increased but there was a decrease in the total weight. When only the first cluster was sprayed, the number of fruit set and the total weight per cluster was increased, but this response did not occurred in subsequent clusters.

Feofanova (1960) observed that the application of growth regulators on tomato plants could produce not only seedless fruits but also could increase the size of the fruits and even could change favorably the form of the fruit trusses. He further that the application could increase total yield of tomato fruits by preventing fruit drop.

Rappaport (1960) noted that GA_3 had no significant effect on fruit weight or size either cool (11 ^{0}C) or warm (23 ^{0}C) night temperatures; but it strikingly Reduced fruit size at an optimal temperature (l7 ^{0}C).

Serrani *et al*. (2007) investigated the effect of applied gibberellin (GA_3) and auxin on fruit-set and growth in tomato (*Solanum lycopersicum* L.) cv. Micro-Tom. Unpollinated ovaries responded to GA_3 and to different auxins [indol-3-acetic acid, naphthaleneacetic acid, and 2,4-dichlorophenoxyacetic acid (2,4-D)], 2,4-D being the most efficient. Simultaneous application of GA_3 and 2,4-D produced parthenocarpic fruits similar to pollinated fruits, but for the absence of seeds, suggesting that both kinds of hormones are involved in the induction of fruit development upon pollination.

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

CHAPTER III
MATERIALS AND METHODS

This chapter deals with the materials and methods that were used in carrying out the experiment.

3.1 Location of the experimental field

The experiment was conducted at Horticultural farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during the period from November 2013 to April 2014. The location of the experimental site was at 23^0 $46'$ N latitude and 90^0 $22'$ E longitudes with an elevation of 8.24 meter from sea level.

3.2 Climate of the experimental area

The experimental area is characterized by subtropical rainfall during the month of May to September and scattered rainfall during the rest of the year. Information regarding average monthly temperature as recorded by Bangladesh Meteorological Department (climate division) during the period of study has been presented in Appendix I.

3.3. Soil of the experimental field

Soil of the study site was silty clay loam in texture belonging to series. The area represents the Agro-Ecological Zone of Madhupur tract (AEZ No. 28) with pH 5.8-6.5, ECE-25.28 (Haider, 1991). The analytical data of the soil sample collected from the experimental area were determined in the Soil Resources Development Institute (SRDI), Soil Testing Laboratory, Khamarbari, Dhaka and have been presented in Appendix II.

3.4 Plant materials collection

The tomato variety used in the experiment was "BARI Tomato-14". This is a high yielding indeterminate type variety. The seeds were collected from Olericulture division of Horticulture Research Centre, Bangladesh Agricultural Research Institute (BARI) Joydebpur, Gazipur.

3.5. Raising of seedlings

Tomato seedlings were raised in two seedbeds of 2 m x 1m size. The soil was well prepared and converted into loose friable and dried mass by spading. All weeds and stubbles were removed and 5 kg well rotten cow dung was mixed with the soil. Five (5) gram of seeds was shown on each seedbed on 20 November 2013. After sowing, seeds were covered with light soil. The emergence of the seedlings took place within 6 to 7 days after sowing. Weeding, mulching and irrigation were done as and when required.

3.6 Treatments of the experiment

The experiment consisted of two factors as follows:

Factor A: Three levels of IAA (Indole-3-Acetic acid)

I_0 = Control (No IAA)

I_1 = 25 ppm IAA

I_2 = 35 ppm IAA

Factor B: Four levels of GA_3 (Gibberellic acid)

G_0 = Control (No GA_3)

G_1 = 30 ppm GA_3

G_2 = 60 ppm GA_3

G_3 = 90 ppm GA_3

There were altogether 12 treatments combination used in each block were as follows; I_0G_0, I_0G_1, I_0G_2, I_0G_3, I_1G_0, I_1G_1, I_1G_2, I_1G_3, I_2G_0, I_2G_1, I_2G_2, I_2G_3.

3.7 Design and layout of the experiment

The experiment was laid out in Randomized Complete Block Design (RCBD) having two factors with three replications. An area of 29.1 m x 10 m was divided into three equal blocks. Each block was consists of 12 plots where 12 treatments were allotted randomly. There were 36 unit plots in the experiment. The size of each plot was 1.8 m x 2 m. The distance between two blocks and two plots were kept 1 m and 0.5 m respectively. A layout of the experiment has been shown in figure 1.

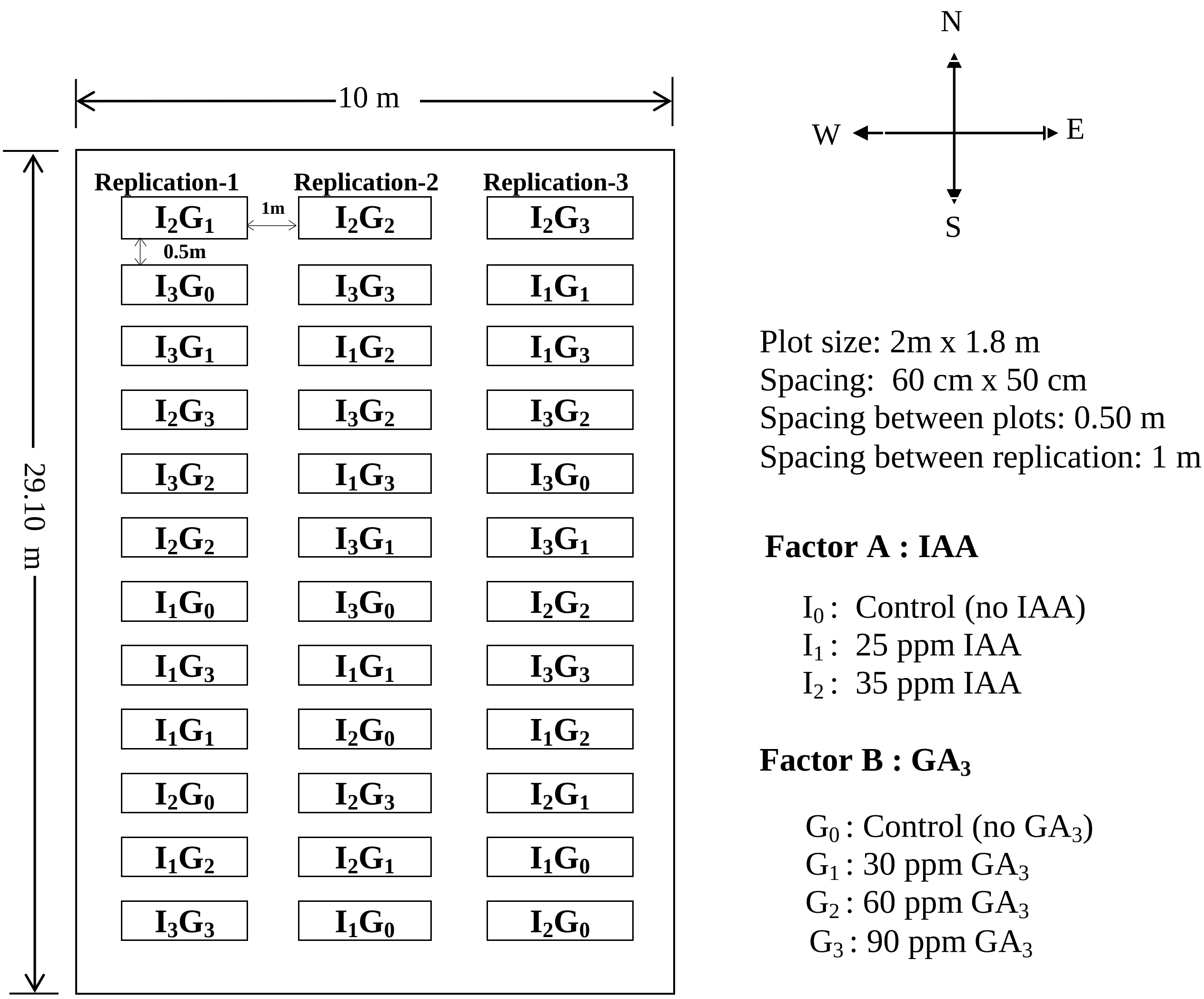


Fig. 1: Field layout of the experimental plot

3.8 Cultivation procedure

3.8.1 Land preparation

The soil was well prepared and good tilth was ensured for commercial crop production. The land of the experimental field was ploughed with a power tiller on December 2013. Later on the land was ploughed three times followed by laddering to obtain desirable tilth. The corners of the land were spaded and larger clods were broken into smaller pieces. After ploughing and laddering, all the stubbles and uprooted weeds were removed and then the land was made ready. The field layout and design was followed after land preparation.

3.8.2 Manures and fertilizers and its methods of application

Fertilizer	Quantity	Application method
Cow dung	15 t/ha	Basal dose
Urea	400 kg/ha	20, 30 and 40 DAT
TSP	300 kg/ha	Basal dose
MOP	250 kg/ha	20, 30 and 40 DAT mixed with urea

Rashid (1999).

According to Rashid (1999), the entire amount of cow dung and TSP were applied as basal dose during land preparation. Urea, TSP and MOP were applied at the rate of 400 kg/ha, 300 kg/ha and 250 kg/ha respectively. Urea and MOP were used as top dressing in equal splits at 20, 30 and 40 days after transplanting.

3.8.3 Application and preparation of IAA

The stock solution of 1000 ppm of IAA was made by mixing of 1 g of IAA with small amount of ethanol to dilute and then mixed in 1 litre of distilled water. Then as per requirement of 25 ppm and 35 ppm solution of IAA, 25 and 35 ml of stock solution were mixed with 1 litre of distilled water respectively. Application of IAA was done at 15 days interval and was applied at 25, 40, and 55 days after transplanting.

3.8.4 Application and preparation of GA_3

The stock solution of 1000 ppm of GA_3 was made by mixing of 1 g of GA_3 with small amount of ethanol to dilute and then mixed in 1 litre of distilled water. Then as per requirement of 30 ppm, 60 ppm and 90 ppm solution of GA_3, 30, 60 and 90 ml of stock solution were mixed with 1 litre of distilled water respectively. Application of GA_3 was done at 15 days interval and was applied at 20, 35, and 50 days after transplanting.

3.8.5 Transplanting of seedlings

Healthy and uniform 30 days old seedlings were uprooted separately from the seed bed and were transplanted in the experimental plots in 20 December, 2013 maintaining a spacing of 60 cm x 50 cm between the rows and plants, respectively. This allowed an accommodation of 12 plants in each plot. The seedbed was watered before uprooting the seedlings from the seedbed so as to minimize damage to the roots. The seedlings were watered after transplanting. Seedlings were also planted around the border area of the experimental plots for gap filling.

3.8.6. Intercultural operations

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

3.8.6.1 Gap filling

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

3.8.6.2 Weeding

Numbers of weeding were accomplished as and whenever necessary to keep the crop free from weeds.

3.8.6.3 Staking

When the plants were well established, staking was given to each plant by rope and plastic wire to keep them erect. Within a few days of staking, as the plants grew up, other cultural operations were carried out.

3.8.6.4 Irrigation

Number of irrigation was given throughout the growing period by garden pipe and watering cane. The first irrigation was given immediate after the transplantation where as other were applied when and when required depending upon the condition of soil.

3.8.6.5 Plant protection

From seedling to harvesting stage i.e. any stage, tomato is very sensitive to diseases and pest. After getting a maturity stage protection measure was taken against diseases and pests. So that, any insect or fungal infection and insect infestation cannot appear in the plant.

3.8.6.6 Insect pests

Bavistin 50 WP and Ripcord 10 EC were applied @ 10 ml/L against the fungal diseases, leaf curl disease and insect pests like cut worm, leaf hopper, fruit borer and others. The insecticide application was made fortnightly for a week after transplanting to two weeks before first harvesting.

3.9 Harvesting

Fruits were harvested at 7 to 8 days intervals during early ripe stage when they attained slightly red color. Harvesting was started from 8 March, 2014 and was continued up to end of 20 April 2014.

3.10 Data collection

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

3.10.1 Plant height

The plant height was measured in centimeters from the base of plant to the terminal growth point of main stem on tagged plants was recorded at 10 days interval starting from 20 days of planting up to 60 days to observe the plant height. The average height was computed and expressed in centimeter.

3.10.2 Number of leaves per plant

The number of leaves per plant was manually counted at 20, 30, 40, 50 and 60 days after transplanting from randomly selected tagged plants. The average of six plants were computed and expressed in average number of leaves per plant.

3.10.3 Number of branches per plant

The number of branches per plant was manually counted at 20, 30, 40, 50 and 60 days after transplanting from randomly selected tagged plants. The average of six plants were computed and expressed in average number of branch per plant.

3.10.4 Canopy size of the plant

The canopy size of the plant was manually counted at 20, 30, 40, 50 and 60 days after transplanting from randomly selected tagged plants. The average of six plants were computed and expressed in average canopy size of the plant.

3.10.5 Length of leaf

The Length of leaf of the plant was manually measured by centimeter scale at 20, 30, 40, 50 and 60 days after transplanting from randomly selected six tagged plants. The length of six tagged leaves were measured and expressed in average Length of leaf of the plant. The tomato plant has the compound leaf. So the higher length of compound leaf can contain the large number of leaflet on the mid rib.

3.10.6 Width of leaf

The width of leaf of the plant was manually measured by centimeter scale at 20, 30, 40, 50 and 60 days after transplanting from randomly selected six tagged plants. The width of six tagged leaves were measured and expressed in average width of leaf of the plant. The tomato plant has the compound leaf. So wider of compound leaf indicates that the bigger leaflet on the mid rib.

3.10.7 Stem diameter of the plant

The stem diameter of the plant was manually measured by slide calipers at 20, 30, 40, 50 and 60 days after transplanting from tagged plants. The average of six plants were measured and expressed in average stem diameter of the plant.

3.10.8 Number of flower clusters per plant

The number of flower clusters was counted at 50 and 60 days after transplanting from the 6 sample plants and the average number of clusters produced per plant was recorded.

3.10.9 Number of flowers per cluster

The number of flowers per cluster was counted at 50 and 60 days after transplanting from the 6 sample plants. From each plant randomly five clusters were selected and counted the number of flowers per cluster to make an average value for one plant. The final average value of number of flowers per cluster was calculated from 6 averages from six plants.

3.10.10 Number of fruits per cluster

The number of fruits per cluster was counted at 60 DAT and harvesting time from selected 6 plants. From each plant randomly five clusters were selected and counted the number of fruits per cluster to make an average value for one plant. The final average value of number of fruits per cluster was calculated from 6 averages from six plants.

3.10.11 Length of fruit

Among the total number of fruit harvested during the period from first to final harvest, the fruits, except the first and last harvest, were considered for determine the length of fruit by slide calipers. The length of fruit was calculated by making the average of five fruits from each of the six plants.

3.10.12 Diameter of fruit

Among the total number of fruits harvested during the period from first to final harvest, the fruits, except the first and last harvest, were considered for determine the diameter of fruit by slide calipers. The diameter of fruit was calculated by making the average of five fruits from each of the six plants.

3.10.13 Fresh weight of individual fruit

Among the total number of fruit harvested during the period from first to final harvest, the fruits, except the first and last harvest, were considered for determine the individual fruit weight in gram. The weight was calculated from total weight of fruits was divided by total number of fruits of every harvest and finally making the average was made from four times harvesting data.

3.10.14 Dry matter content of fruit (%)

After harvesting, randomly selected 100 gram of fruit sample previously sliced in to very thin pieces. The fruits were then dried in the sun for one day and placed in oven maintained at 60 ^{0}C for 72 hrs. The sample was then transferred into desiccators and allowed to cool down to the room temperature. The final weight of the sample was taken. The dry matter was calculation by the following formula:

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

3.10.15 Length of root

The length of root was manually measured at the time of harvest from randomly selected 6 plants. The averages root length of six sample plants were considered as root length of plant.

3.10.16 Chlorophyll percentage of leaf

The Chlorophyll percentage of leaf of the plant was measured by a SPAD meter, a product of Konica Minolta Sensing Ltd, Singapore (Appendix XVI), at 60 days after transplanting from randomly selected six tagged plants. This machine gives the direct calculated value of the chlorophyll percentage of leaf of the plant. The Chlorophyll percentage of five tagged leaves of each plant was measured and calculated the average Chlorophyll percentage of leaf of each plant of 6 sample plants.

3.10.17 Dry matter content of leaf (%)

After harvesting, randomly selected 100 gram of leaf sample previously sliced into very thin pieces were put into envelop and placed in oven maintained at 60 ^{0}C for 72 hrs. The sample was then transferred into desiccators and allowed to cool down to the room temperature. The final weight of the sample was taken. The dry matter was calculated by the following formula:

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

3.10.18 Carbon assimilation rate

The Carbon assimilation rate of the plant was measured by an automatic "LC*pro*$^+$ (advanced photosynthesis measurement system) meter" which is a product of *ADC Ltd.*, Hertfordshire EN11 0NT, United Kingdom (Appendix XVI), at 60 days after transplanting from six tagged plants of each plot. This machine gives the direct calculated result of carbon assimilation rate of the plant. The Carbon assimilation rate of five tagged leaves of each plant was measured and calculated the average Carbon assimilation rate of one plant.

3.10.19 Yield per plot (kg)

An electric balance was used to measure the weight of fruits per plot. The total fruit yield of each unit plot measured separately from each sample plant during the harvesting period and was expressed in kilogram (kg).

3.10.20 Yield per hectare (ton)

It was measured by the following formula:

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

3.11 Statistical analysis

The recorded data on various parameters were statistically analyzed using MSTAT-C statistical package program. The mean for all the treatments was calculated and analysis of variance for all the characters were performed by F-Difference between treatment means were determined by Duncan`s Multiple Range Test (DMRT) according to Gomez and Gomez, (1984) at 5% level of significance.

3.12 Economical analysis

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

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

CHAPTER IV

RESULTS AND DISCUSSION

The present study was conducted to find the growth and yield of tomato influenced by IAA and GA_3. Data on different growth and yield contributing characters were recorded. The analysis of variance (ANOVA) of the data on different growth and yield parameters are given in Appendix III-XIV. The results have been presented and discussed with the help of tables and graphs and possible interpretations were given under the following headings:

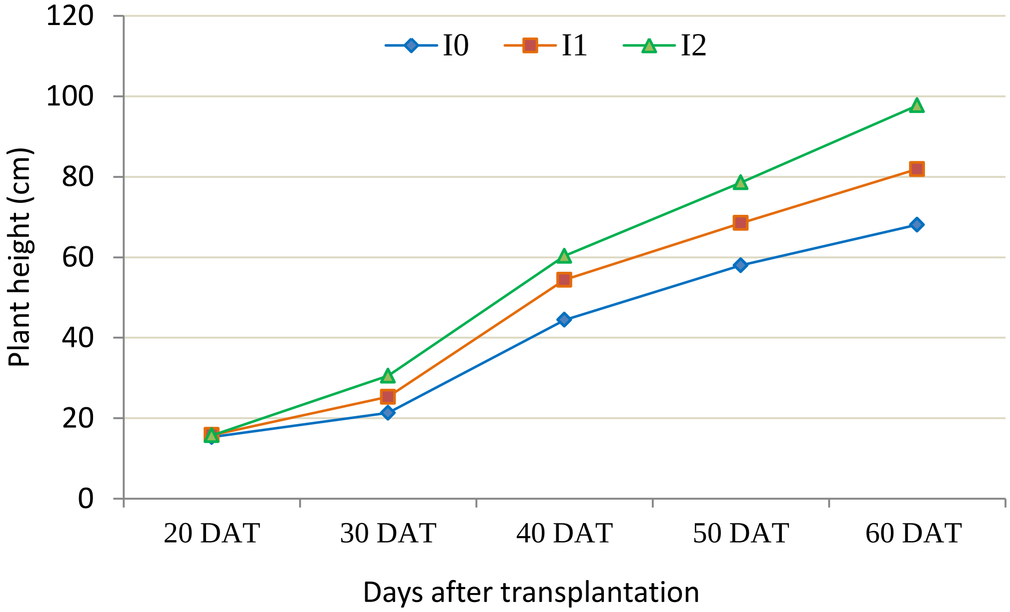
4.1 Plant height

Significant difference was observed due to the application of different levels of IAA at 30, 40, 50 and 60 DAT except 20 DAT (Appendix III). At 30 DAT, the highest plant height (30.58 cm) was recorded from I_2 (35 ppm IAA) and the shortest plant (21.33 cm) was found from I_0 (control). At 40 DAT, the longest plant (60.33 cm) was found from I_2 and the shortest plant (44.42 cm) was obtained from I_0. The longest plant (78.58 cm) was recorded from I_2 and the shortest plant (58.00 cm) was found from I_0 at 50 DAT. At 60 DAT, the longest plant (97.75 cm) was obtained from I_2 while the shortest plant (68.08 cm) was found from I_0 (control) treatment (Fig. 2). Murphy (1964) found that application of IAA increased plant height up to 65%. Rai *et al.* (2002) observed that the application of 75 ppm IAA increased the plant height significantly.

Significance difference was observed due to application of different levels of GA_3 on plant height at 30, 40, 50 and 60 DAT except 20 DAT (Appendix III). At 30 DAT, the longest plant (27.22 cm) was found from G_2 (60 ppm GA_3) which was statistically similar (26.89 cm) to G_3 (90 ppm GA_3) while the shortest (23.78 cm) plant was recorded from G_0. At 40 DAT, the longest plant (56.22 cm) was recorded from G_2 which was statistically similar (55.78 cm) to G_3 while the shortest (49.00 cm) plant was obtained from G_0 (control) which was statistically similar (51.22 cm) to G_1 (30 ppm GA_3). The longest plant (72.22 cm) was found from G_2 which was statistically similar (71.33 cm) to G_3

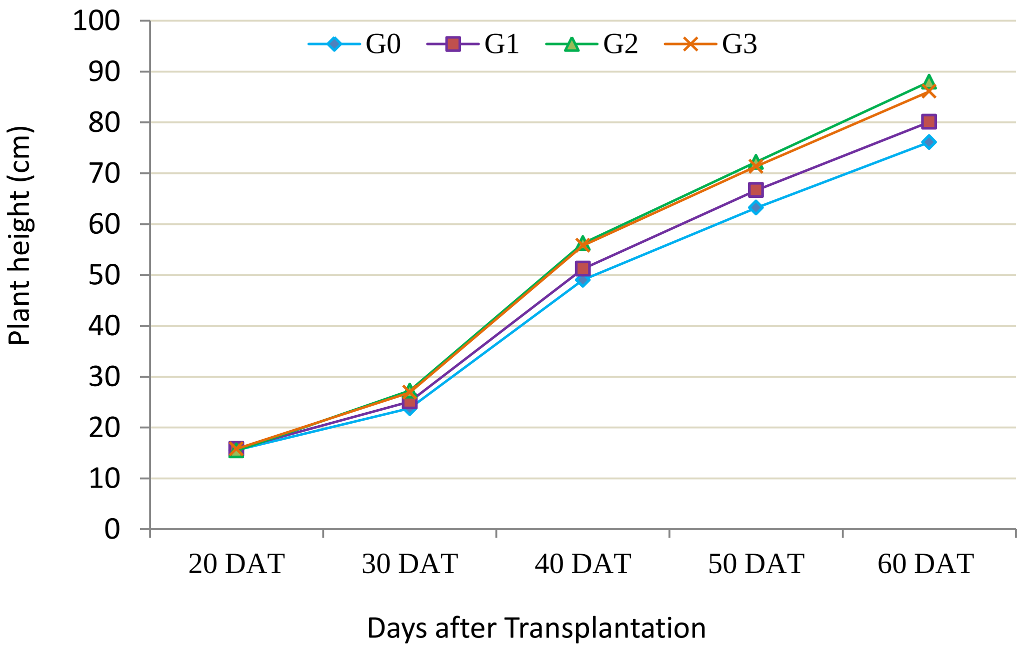
while the shortest (63.22 cm) plant was recorded from G_0 which was statistically similar to G_1 (66.67 cm) at 50 DAT. At 60 DAT, the highest plant height (88.00 cm) was recorded from G_2 which was statistically similar (86.11 cm) to G_3 while the shortest plant height (76.11 cm) was found from G_0 which was statistically similar (80.11 cm) to G_1 (Fig. 3). Khan *et al*. (2006) stated that GA_3 increased plant height up to maximum doses with an increasing trend and Probably, GA_3 ensured the availability of other essential nutrients as a result, maximum growth was occurred and the ultimate results are the maximum plant height. Mehrotra *et al.,* (1970) recorded the significant increase in the plant height (95 cm) with GA_3 spray at flower initiation stage in tomato. Wu *et al*. (1983) reported that spraying of GA_3 at 100 ppm increased the plant height. Rappaport (1960) recorded more plant height when GA_3 sprayed at the rate of 20 to 40 mg per liter of water. Tomar and Ramgiry (1997) founded that plants treated with GA_3 showed significantly greater plant height than untreated control. Nibhavanti *et al*. (2006) reported that plant height was greatest due to the treated with gibberellic acid at 25 ppm and 50 ppm (74.21 cm and 75.33 cm respectively). Bhosle and khrbhade (2002) found that GA_3 at 50 ppm significantly increase the plant height of the Manileima tomato variety.

Combined effects of IAA and GA_3 showed significant difference on plant height at all observation except 20 DAT (Appendix III). However at 30 DAT the longest plant (33.33 cm) was recorded from I_2G_2 (35 ppm IAA + 60 ppm of GA_3) and the shortest (19.33 cm) plant was found from I_0G_0 (no IAA + no GA_3) again the longest plant (64.00 cm) was recorded from I_2G_2 which was similar to I_2G_1, I_2G_3 and the shortest plant (37.33 cm) was obtained from I_0G_0 (no IAA + no GA_3) which was statistically identical to (42.67 cm) I_0G_1 at 40 DAT. At 50 DAT, the longest plant (84.00 cm) was obtained from I_2G_2 similar to I_2G_3 and the shortest plant (52.67 cm) was found from I_0G_0 similar to I_0G_1. Finally at 60 DAT the longest plant (106.00 cm) was recorded from I_2G_2 similar to I_2G_3 while the shortest (60.33 cm) was observed in I_0G_0 which was statistically similar to I_2G_3 treatment combination (Table 1).



I_0 = control, I_1 = 25 ppm IAA, I_2 = 35 ppm IAA

Fig. 2 Effect of IAA on plant height of tomato.



G_0 = control, G_1 = 30 ppm GA_3, G_2 = 60 ppm GA_3, G_3 = 90 ppm GA_3

Fig. 3 Effect of GA_3 on plant height of tomato.

Table 1. Combined effects of IAA and GA_3 on plant height of tomato

Treatments	20 DAT	30 DAT	40 DAT	50 DAT	60 DAT
I_0G_0	15.00	**19.33 h**	**37.33 f**	**52.67 g**	**60.33 g**
I_0G_1	15.33	21.3 gh	42.67 f	57.33 fg	68.00 fg
I_0G_2	15.00	22.00 g	48.67 e	61.00 ef	71.33 ef
I_0G_3	16.00	22.67 fg	49.00 e	61.00 ef	72.67 ef
I_1G_0	15.67	23.33 fg	51.67 de	63.00 ef	75.33 ef
I_1G_1	16.00	24.33 ef	52.33 c-e	66.33 de	77.67 de
I_1G_2	15.67	26.33 de	56.00 b-d	71.67 cd	86.67 cd
I_1G_3	16.00	27.33 cd	57.67 bc	73.00 b-d	88.00 c
I_2G_0	16.00	28.67 bc	58.00 bc	74.00 bc	92.67 bc
I_2G_1	16.00	29.67 b	58.67 ab	76.00 bc	94.67 bc
I_2G_2	15.67	**33.33 a**	**64.00 a**	**84.00 a**	**106.00 a**
I_2G_3	15.33	30.67 b	60.67 ab	80.00 ab	97.67 ab
LSD $_{(0.05)}$	**1.01**	**2.25**	**5.83**	**7.22**	**9.16**
CV%	**5.01**	**5.16**	**6.50**	**6.24**	**6.55**

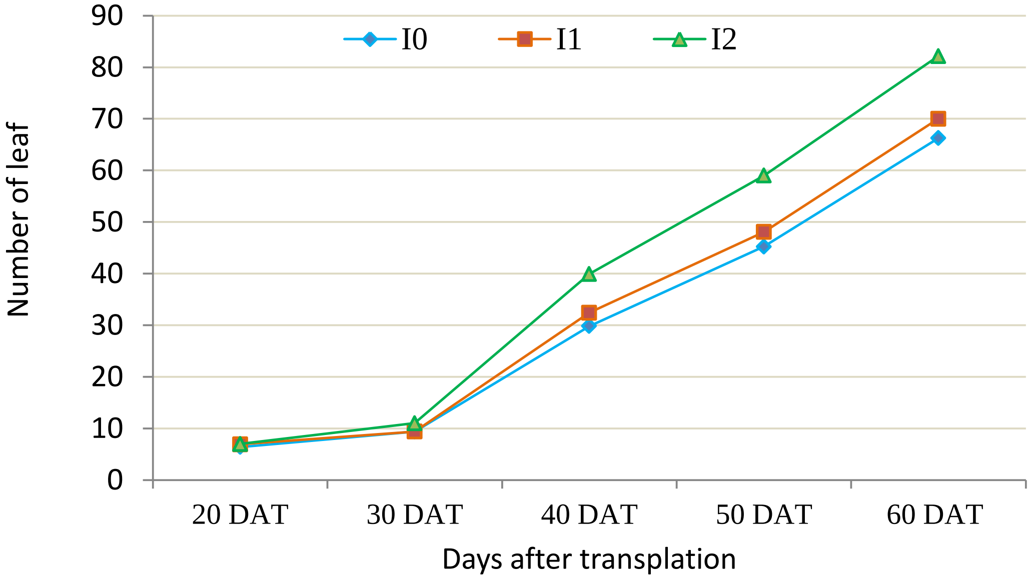
I_0 : control I_1 : 25 ppm IAA G_0 : control G_1 : 30 ppm GA_3
I_2 : 35 ppm IAA G_2 : 60 ppm GA_3 G_3 : 90 ppm GA_3

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

4.2 Number of leaves per plant

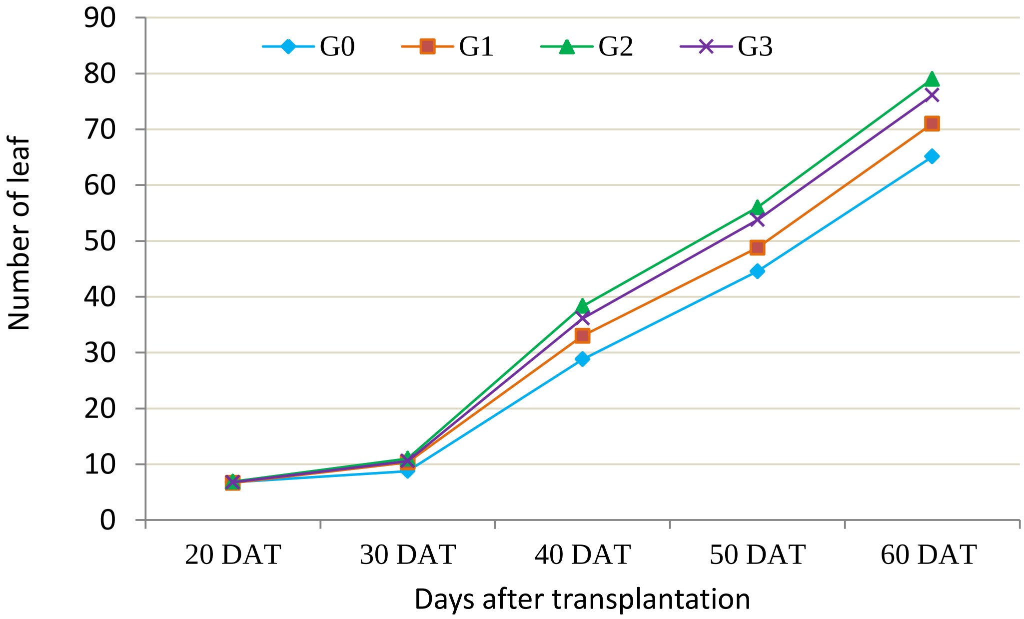
Due to the application of different concentration of IAA showed significant differences on number of leaves per plant at all observation except 20 DAT (Appendix IV). The maximum number of leaves per plant (11.67) was counted from I_2 (35 ppm IAA) and the minimum number of leaves per plant (9.41) was found from I_0 which was statistically similar (9.40) to I_1 at 30 DAT. At 40 DAT, the maximum number of leaves per plant (39.92) was recorded from I_2 which was followed by (32.42) I_1 and the minimum number of leaves per plant (29.83) was obtained from $I_{0.}$ The maximum number of leaves per plant (59.00) was found from I_2 and the minimum number of leaves per plant (45.25) was observed from I_0 which was statistically similar (48.08) to I_1 at 50 DAT. At 60 DAT, the maximum number of leaves per plant (82.17) was counted from I_2 which was followed by (70.00) I_1 and the minimum number of leaves per plant (66.25) was obtained from I_0 (Fig. 4). Harneet *et al.*, (2004) had found the effect of nitrogen and IAA application on the growth, yield and quality of tomato is better than non-treated. He recorded that there was also a significant increase in number of leaves when IAA level was increased.

The significant variation was found in 30, 40, 50, and 60 DAT due to the application of different levels of GA_3 except 20 DAT (Appendix IV). At 30 DAT, the highest number of leaves per plant (11.00) was found from G_2 (60 ppm GA_3) which was statistically similar to G_3 (10.56) while the lowest number of leaves per plant (8.77) was observed from G_0. At 40 DAT, the maximum number of leaves per plant (38.33) was recorded from G_2 while the lowest number of leaves per plant (28.78) was obtained from G_0 (control). The highest number of leaves per plant (56.00) was found from G_2 which was statistically similar to G_3 (53.78) while the lowest number of leaves per plant (44.56) was recorded from G_0 at 50 DAT and finally at 60 DAT, the maximum number of leaves per plant (79.00) was recorded from G_2 which was statistically similar to G_3 (76.11) while the minimum number of leaves per plant (65.11) was obtained from G_0 treatment (Fig. 5). Nibhavanti *et al*. (2006)



I_0 = control, I_1 = 25 ppm IAA, I_2 = 35 ppm IAA

Fig. 4 Effect of IAA on number of leaves per plant



G_0 = control, G_1 = 30 ppm GA_3, G_2 = 60 ppm GA_3, G_3 = 90 ppm GA_3

Fig. 5 Effect of GA_3 on number of leaves per plant

Table 2. Combined effects of IAA and GA_3 on number of leaves per plant

Treatments	20 DAT	30 DAT	40 DAT	50 DAT	60 DAT
I_0G_0	6.33	**8.33 f**	**24.00 f**	**38.33 d**	**56.67 e**
I_0G_1	6.33	10.33 cd	31.67 de	45.00 cd	66.67 d
I_0G_2	6.66	9.66 de	31.00 de	48.00 c	70.33 d
I_0G_3	6.33	9.33 d-f	32.67 c-e	49.67 c	71.33 d
I_1G_0	7.00	9.33 d-f	31.00 de	48.00 c	68.12 d
I_1G_1	6.66	9.34 d-f	29.00 ef	44.00 cd	65.00 de
I_1G_2	7.00	9.33 d-f	36.33 b-d	50.33 c	72.00 d
I_1G_3	7.00	9.66 de	33.33 c-e	50.00 c	73.00 cd
I_2G_0	6.90	8.66 ef	31.33 de	47.33 c	70.67 d
I_2G_1	7.00	11.33 c	38.33 bc	57.33 b	81.33 bc
I_2G_2	6.95	**14.00 a**	**47.67 a**	**69.67 a**	**94.67 a**
I_2G_3	7.00	12.67 b	42.33 ab	61.67 b	84.01 b
$LSD_{(0.05)}$	**0.76**	**1.15**	**6.35**	**6.81**	**8.51**
CV%	**6.63**	**6.69**	**11.02**	**7.92**	**6.90**

I_0 : control I_1 : 25 ppm IAA G_0 : control G_1 : 30 ppm GA_3
I_2 : 35 ppm IAA G_2 : 60 ppm GA_3 G_3 : 90 ppm GA_3
In a column means having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability.

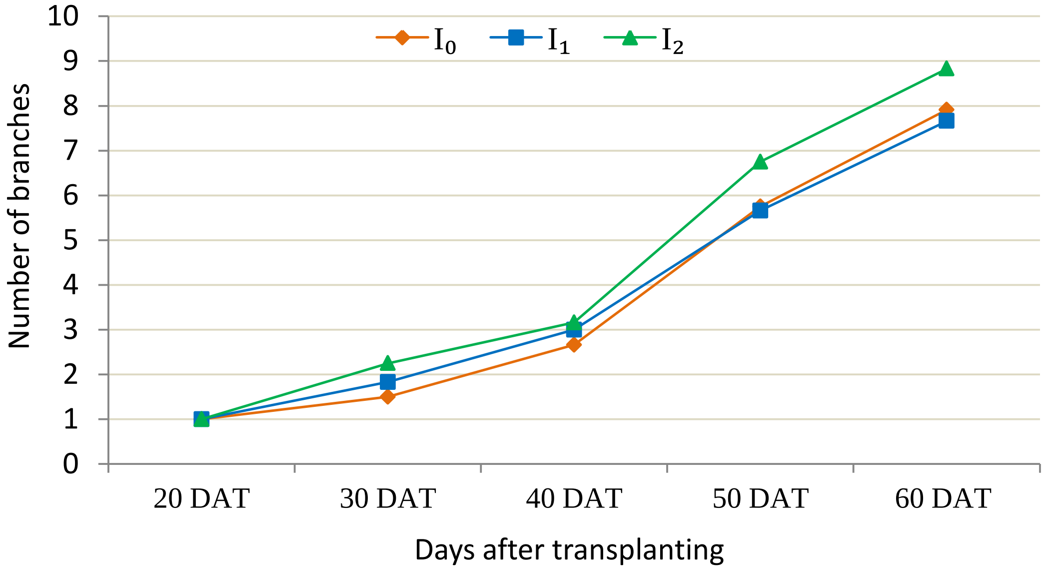
carried out an experiment on the effect of GA_3 at 25 and 50 ppm levels and reported that the number of leaves per plant increased due to the application of GA_3 at 50 ppm. El-Abd *et al*. (1995) studied the effect of the plant growth regulators for improving the tomato cv. Alicante and reported that application of GA_3 increased the number of leaves per plant and GA_3 increased the number of leaves per plant up to optimum level. Wu *et al*., (1983) found that GA_3 at 100 ppm increased plant height and leaf area. Rappaport (1960) recorded more leaves per plant occurred plant height when GA_3 sprayed at flower initiation stage in tomato. Choudhury and Singh (1960) reported the enhanced effect of GA_3 on vegetative growth in tomato.

Combined effects of indole-3-acetic acid (IAA) and gibberellic acid (GA_3) showed statistically significant differences on number of leaves per plant at 30, 40, 50 and 60 DAT except 20 DAT (Appendix IV). At 30 DAT the maximum number of leaves per plant (14.00) was counted from I_2G_2 (35 ppm IAA+ 60 ppm of GA_3) and the minimum number of leaves per plant (8.33) was found from I_0G_0 (no IAA + no GA_3) which was similar to I_0G_3, I_1G_0, I_1G_1, I_1G_2, I_2G_0. The maximum number of leaves per plant (47.67) was recorded from I_2G_2 which was similar to I_2G_3 and the minimum number of leaves per plant (24.00) was obtained from I_0G_0 similar to I_1G_1 at 40 DAT. At 50 DAT, the maximum number of leaves per plant (69.67) was obtained from I_2G_2 and the minimum number of leaves per plant (38.33) was found from I_0G_0 similar to I_0G_1, I_1G_1. Finally at 60 DAT, the maximum number of leaves per plant (94.67) was counted from I_2G_2 while the minimum number of leaves per plant (56.67) was observed in I_0G_0 Statistically similar to I_1G_1 treatment combination (Table 2).

4.3 Number of branches per plant

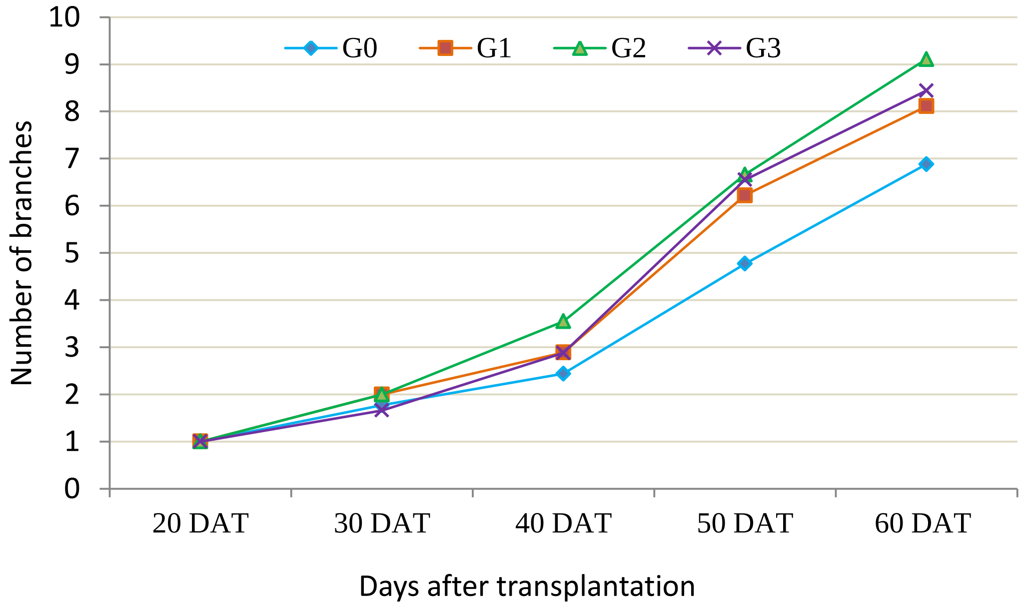
The significant variation was found in 30, 40, 50, and 60 DAT due to the application of different levels of IAA except 20 DAT (Appendix V). The maximum number of branches per plant (2.25) was counted from I_2 (35 ppm IAA), while the minimum number of branches per plant (1.50) was obtained from I_0 (no IAA) at 30 DAT. At 40 DAT, the maximum number of branches per plant (3.16) was recorded from I_2 (35 ppm IAA), while the minimum number of branches per plant (2.66) was obtained from I_0 (no IAA). The maximum number of branches per plant (6.75) was recorded from I_2 (35 ppm IAA) while the minimum number of branches per plant (5.57) was obtained from I_0 (no IAA) at 50 DAT. At 60 DAT the maximum number of branches per plant (8.83) was recorded from I_2 while the minimum number of branches per plant (7.91) was obtained from I_0 treatment (Fig. 6). Singh *et al*. (2005) found that number of branches significantly increased by the application of IAA at 75 ppm. Rai *et al*. (2002) found the highest number of branches due to the application of 75 ppm IAA.

There was significant variation observed in number of branches per plant at 30, 40, 50, and 60 DAT due to the application of different levels of GA_3 except 20 DAT (Appendix V). At 30 DAT the maximum number of branches per plant (2.00) was recorded from G_3 (90 ppm GA_3), which was similar to G_2 (60 ppm GA_3), while treatment G_0 (0 ppm GA_3) showed the minimum number of branches per plant (1.77). At 40 DAT, maximum number of branches per plant (3.55) was recorded from G_2, which was followed by G_3 (2.88) and G_1 (30 ppm GA_3), while from treatment G_0 obtained minimum number of branches per plant (2.44). At 50 DAT, the maximum number of branches per plant (6.66) was recorded from G_2 (60 ppm GA_3), while treatment G_0 showed the minimum number of branches per plant (4.77). The maximum number of branches per plant (9.11) was recorded from G_2 (60 ppm GA_3) while treatment G_0 (no GA_3) showed the minimum number of branches per plant (6.88) at 60 DAT (Fig. 7). Sumati (1987) observed that the spraying of GA_3 increased the number of branches against untreated plant. Tomar and Ramgiry (1997) found that plants treated with GA_3 showed significantly greater branch number per plant than untreated control. Bhosle and khrbhade (2002) reported that 45 ppm GA_3 spray resulted in highest number of primary branches per plant. Rai *et al*. (2006) reported the increased number of branches per plant due to the application of 50 ppm GA_3.



I_0 = control, I_1 = 25 ppm IAA, I_2 = 35 ppm IAA

Fig. 6 Effect of IAA on number of branches per plant



G_0 = control, G_1 = 30 ppm GA_3, G_2 = 60 ppm GA_3, G_3 = 90 ppm GA_3

Fig. 7 Effect of GA_3 on number of branches per plant

Table 3. Combined effects of IAA and GA_3 on number of branches per plant

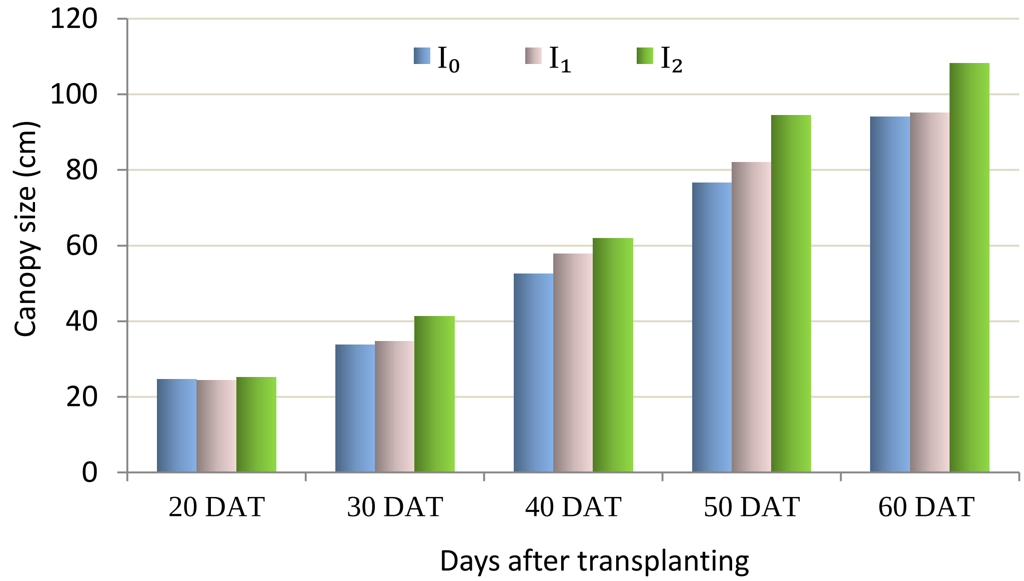
Treatments	20 DAT	30 DAT	40 DAT	50 DAT	60 DAT
I_0G_0	1.00	**1.00 d**	**2.00 d**	**4.00 c**	**6.00 e**
I_0G_1	1.00	2.00 b	3.00 b	6.33 b	8.66 a-c
I_0G_2	1.00	2.00 b	3.00 b	6.00 b	8.66 a-c
I_0G_3	1.00	2.00 b	2.66 bc	6.66 ab	8.33 bc
I_1G_0	1.00	1.30 c	2.33 cd	4.33 c	6.66 de
I_1G_1	1.00	2.00 b	3.00 b	5.66 b	7.33 c-e
I_1G_2	1.00	2.00 b	3.66 ab	6.33 b	8.66 a-c
I_1G_3	1.00	2.00 b	3.00 b	6.33 b	8.00 b-d
I_2G_0	1.00	2.00 b	3.00 b	6.00 b	8.00 b-d
I_2G_1	1.00	2.00 b	2.66 bc	6.66 ab	8.33 bc
I_2G_2	1.00	**3.00 a**	**4.00 a**	**7.66 a**	**10.00 a**
I_2G_3	1.00	2.00 b	3.00 b	6.66 ab	9.00 ab
LSD $_{(0.05)}$	**0.00**	**0.28**	**0.56**	**1.08**	**1.48**
CV%	**0.00**	**8.96**	**11.32**	**10.83**	**10.78**

I_0 : control I_1 : 25 ppm IAA G_0 : control G_1 : 30 ppm GA_3
I_2 : 35 ppm IAA G_2 : 60 ppm GA_3 G_3 : 90 ppm GA_3
In a column means having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability.

Significant differences were observed due to the combined effects of IAA and GA_3 on number of branches per plant at 30, 40, 50 and 60 DAT except 20 DAT (Appendix V). At 30 DAT the maximum number of branches per plant (3.00) was recorded from I_2G_2 (35 ppm IAA + 60 ppm GA_3) and the minimum (1.00) number of branches per plant was observed from the treatment combination of I_0G_0 (no IAA+ no GA_3). At 40 DAT the maximum number of branches per plant (4.00) was counted from I_2G_2 (35 ppm IAA + 60 ppm GA_3) similar to I_1G_2 and the minimum number of branches per plant (2.00) was recorded from the treatment combination of I_0G_0 (no IAA+ no GA_3) similar to I_1G_0. The maximum number of branches per plant (7.66) was recorded from I_2G_2 (35 ppm IAA + 60 ppm GA_3) similar to I_0G_3, I_2G_1, I_2G_3 and the minimum number of branches per plant (4.00) was observed from the treatment combination of I_0G_0 (no IAA+ no GA_3) at 50 DAT. At 60 DAT the maximum number of branches per plant (10.00) was recorded from I_2G_2 (35 ppm IAA + 60 ppm GA_3)which is statistically similar to I_0G_1, I_1G_2, I_2G_3 treatment combination and the minimum number of branches per plant (6.00) was recorded from the treatment combination of I_0G_0 which is statistically similar to I_1G_0 and I_1G_1 treatment combination (Table 3).

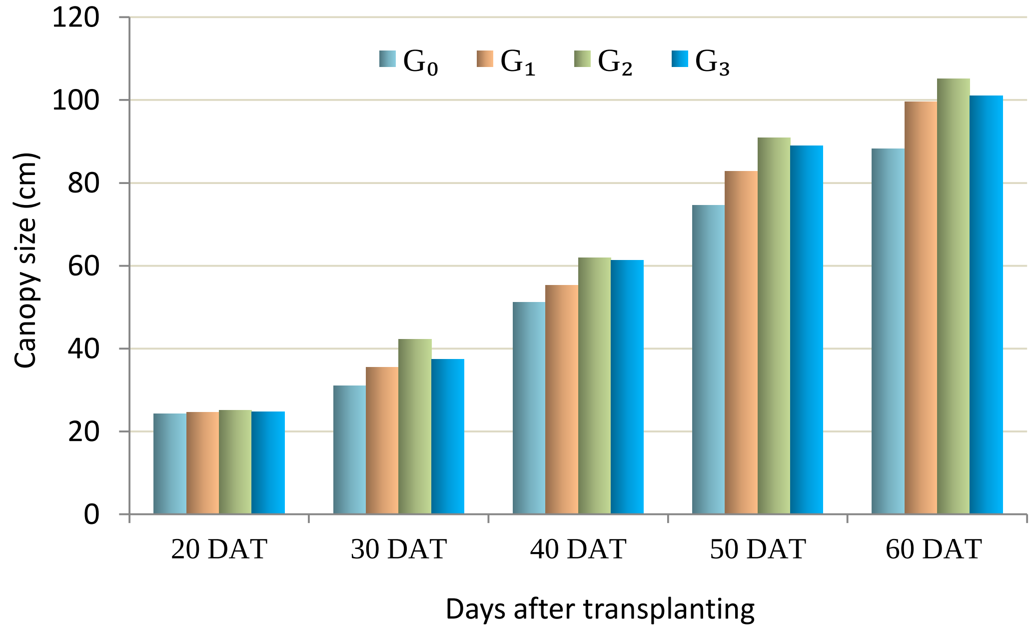
4.4 Canopy size of the plant

Significant variation was found in respect of canopy size of plant at 30, 40, 50 and 60 days after transplanting due to the application of different concentrations of IAA except 20 DAT (Appendix VI). The maximum size of canopy of the plant (41.33 cm) was observed from I_2 (35 ppm IAA), while the minimum size of canopy of the plant (33.83) was recorded from I_0 (control no IAA) at 30 DAT which is statistically similar (34.67 cm) to I_1. At 40 DAT the maximum size of canopy of the plant (62.00 cm) was founded from I_2 while the minimum size of canopy of the plant (52.58 cm) was recorded from I_0. AT 50 DAT the maximum size of canopy of the plant (94.50 cm) was observed from I_2 (35 ppm IAA), while the minimum size of canopy of the plant (76.58) was recorded from I_0 and at 60 DAT the maximum size of canopy of the plant



I_0 = control, I_1 = 25 ppm IAA, I_2 = 35 ppm IAA

Fig. 8 Effect of IAA on canopy size of the plant



G_0 = control, G_1 = 30 ppm GA_3, G_2 = 60 ppm GA_3, G_3 = 90 ppm GA_3

Fig. 9 Effect of GA_3 on canopy size of the plant

Table 4. Combined effects of IAA and GA_3 on canopy size of the plant

Treatments	20 DAT	30 DAT	40 DAT	50 DAT	60 DAT
I_0G_0	24.33	**29.00 f**	**44.67 f**	**62.33 f**	**79.33 e**
I_0G_1	24.33	35.33 c-e	51.33 e	75.00 e	95.67 cd
I_0G_2	24.33	33.67 c-f	57.67 b-e	83.33 c-e	100.70 bc
I_0G_3	25.67	37.33 b-d	56.67 c-e	85.67 cd	100.70 bc
I_1G_0	23.33	30.67 ef	54.00 de	80.33 de	89.33 d
I_1G_1	24.67	33.00 d-f	55.00 de	81.00 de	95.00 cd
I_1G_2	25.00	36.67 cd	63.00 bc	84.67 cd	97.00 cd
I_1G_3	24.67	38.33 bc	59.33 b-d	82.00 de	99.00 c
I_2G_0	25.33	33.67 c-f	55.00 de	81.33 de	96.33 cd
I_2G_1	25.00	38.33 bc	59.67 b-d	92.67 bc	108.3 ab
I_2G_2	25.00	**51.33 a**	**70.00 a**	**105.00 a**	**116.0 a**
I_2G_3	25.33	42.00 b	63.33 b	99.00 ab	112.0 a
LSD (0.05)	**4.83**	**4.71**	**6.37**	**9.38**	**8.99**
CV%	**4.38**	**7.46**	**6.55**	**6.57**	**5.36**

I_0 : control I_1 : 25 ppm IAA G_0 : control G_1 : 30 ppm GA_3
I_2 : 35 ppm IAA G_2 : 60 ppm GA_3 G_3 : 90 ppm GA_3

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

(108.2 cm) was observed from I_2 while the minimum size of canopy of the plant (94.08 cm) was obtained from I_0 which is statistically similar (95.08 cm) to I_1 treatment (Fig. 8). Singh *et al*. (2005) found that canopy size of the plant increased with IAA application at 25 and 75 ppm. Significant variation was found in respect of canopy size of plant at 30, 40, 50 and 60 DAT due to the different concentrations of GA_3 except 20 DAT (Appendix VI). The maximum size of canopy of the plant (42.33 cm) was obtained from G_2 (60 ppm GA_3), while the minimum size of canopy of the plant (31.11 cm) was recorded from G_0 (control no GA_3) at 30 DAT. At 40 DAT, the maximum size of canopy (62.00 cm) was obtained from G_2 which is statistically similar (61.33 cm) to G_3, while the minimum size of canopy of the plant (51.22 cm) was found from G_0. AT 50 DAT, the maximum size of canopy (90.89 cm) was recorded from G_2 which is statistically similar to G_3 (89.00 cm), while the minimum size of canopy of the plant (74.67 cm) was recorded from G_0 and at 60 DAT, the maximum size of canopy (105.2 cm) was recorded from G_2 which is statistically similar to G_3 (103.2 cm) while the minimum size of canopy of the plant (88.33 cm) was recorded from G_0 (Fig. 9). Rai *et al*. (2006) found that GA_3 spray at 25 ppm and 50 ppm increased the plant canopy size.

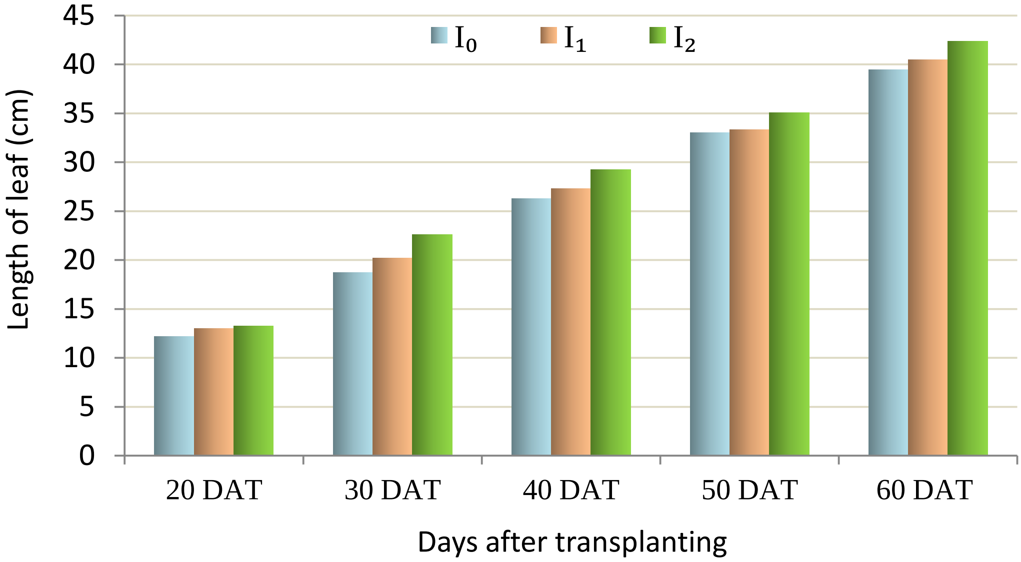
Due to the application of different concentrations of IAA and GA_3 showed significant differences on the canopy size of the plant at all different days after transplanting except 20 DAT (Appendix VI). However the maximum size of canopy (51.33 cm) was recorded from I_2G_2 (35 ppm IAA + 60 ppm GA_3), while the minimum size of canopy of the plant (29.00 cm) was obtained from I_0G_0 (control no IAA + no GA_3) at 30 DAT. At 40 DAT, the maximum size of canopy (70.00 cm) was observed from I_2G_2, while the minimum size of canopy of the plant (44.67 cm) was recorded from I_0G_0. AT 50 DAT, the maximum size of canopy (105.00 cm) was founded from I_2G_2, while the minimum size of canopy of the plant (62.33 cm) was obtained from I_0G_0 and at 60 DAT, the maximum size of canopy (116.00 cm) was observed from I_2G_2, which is statistically similar to I_2G_3 (35 ppm IAA + 90 ppm GA_3) treatment combination

(112.00 cm), while the minimum size of canopy of the plant (79.33 cm) was founded from I_0G_0 (control) treatment combination (Table 4).

4.5 Length of leaf

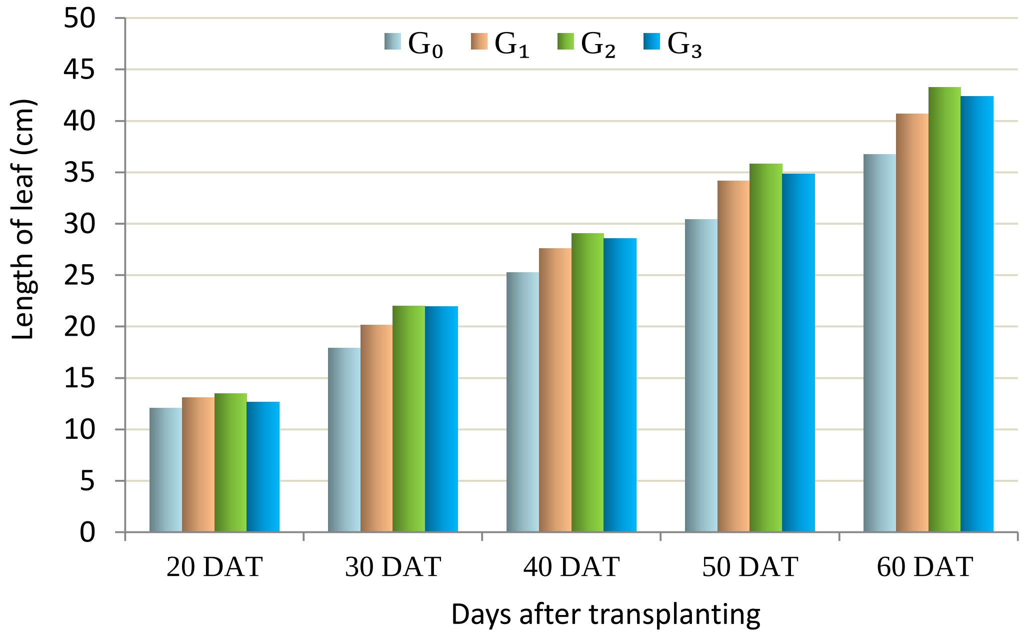
Significant variation was found in respect of length of leaf of plant at 30, 40, 50 and 60 days after transplanting due to the application of different concentrations of IAA except 20 DAT (Appendix VII). The maximum length of leaf (22.59 cm) was recorded from I_2 (35 ppm IAA), while the minimum length of leaf of the plant (18.71 cm) was recorded from I_0 (control) at 30 DAT which was statistically similar (20.19 cm) to I_1. At 40 DAT, the maximum length of leaf (29.26 cm) was obtained from I_2, while the minimum length of leaf of the plant (26.28 cm) was found from I_0. At 50 DAT, the maximum length of leaf (35.06 cm) was obtained from I_2, while the minimum length of leaf of the plant (33.02 cm) was recorded from I_0 and at 60 DAT, the maximum length of leaf of the plant (42.36 cm) was observed from I_2 while the minimum length of leaf of the plant (39.47 cm) was recorded from I_0 (Fig. 10).

Significant variation was found in respect of length of leaf of the plant at 30, 40, 50 and 60 days after transplanting due to the application of different levels of GA_3 except 20 DAT (Appendix VII). The maximum length of leaf of the plant (21.99 cm) was found from G_2 (60 ppm GA_3), which is statistically similar to G_3 (90 ppm GA_3), while the minimum length of leaf of the plant (17.93 cm) was recorded from G_0 (control) at 30 DAT. At 40 DAT, the maximum length of leaf (29.07 cm) was obtained from G_2 (60 ppm GA_3), which is statistically similar to G_3 (90 ppm GA_3), while the minimum length of leaf of the plant (25.25 cm) was recorded from G_0. The maximum length of leaf (35.79 cm) was observed in G_2, which is statistically similar to G_3 (34.86 cm) and to G_1 (34.16 cm), while the minimum length of leaf of the plant (30.43 cm) was obtained from G_0 at 50 DAT. At 60 DAT, the maximum length of leaf (43.25 cm) was observed in G_2, which is statistically similar to G_3, while the minimum length of leaf of the plant (36.76 cm) was found from G_0 treatment (Fig. 11).



I_0 = control, I_1 = 25 ppm IAA, I_2 = 35 ppm IAA

Fig. 10 Effect of IAA on leaf length



G_0 = control, G_1 = 30 ppm GA_3, G_2 = 60 ppm GA_3, G_3 = 90 ppm GA_3

Fig. 11 Effect of GA_3 on leaf length

Table 5. Combined effects of IAA and GA_3 on length of leaf of the plant

Treatments	20 DAT	30 DAT	40 DAT	50 DAT	60 DAT
I_0G_0	11.67	**16.22 d**	**23.61 d**	**28.81 d**	**34.25 c**
I_0G_1	12.05	18.56 b-d	27.00 a-d	34.89 a-d	42.09 ab
I_0G_2	12.06	18.89 b-d	25.84 b-d	32.33 a-d	39.28 a-c
I_0G_3	13.00	21.16 ab	28.67 a-c	36.05 ab	42.28 ab
I_1G_0	11.33	16.67 cd	24.72 cd	29.74 cd	37.70 bc
I_1G_1	13.56	20.39 a-d	26.17 b-d	31.67 b-d	37.56 bc
I_1G_2	14.39	22.61ab	30.00 ab	37.00 ab	44.39 ab
I_1G_3	12.72	21.11 a-c	28.33 a-c	35.00 a-c	42.22 ab
I_2G_0	13.22	20.89 a-c	27.43 a-d	32.75 a-d	39.32 bc
I_2G_1	13.61	21.45 ab	29.54 ab	35.93 ab	42.44 ab
I_2G_2	13.50	**24.48 a**	**31.37 a**	**38.04 a**	**46.09 a**
I_2G_3	12.17	23.53 a	28.71 abc	33.54 a-d	42.58 ab
LSD $_{(0.05)}$	**4.37**	**4.45**	**4.66**	**6.09**	**7.76**
CV%	**10.94**	**12.83**	**9.98**	**10.64**	**11.25**

I_0 : control I_1 : 25 ppm IAA G_0 : control G_1 : 30 ppm GA_3
I_2 : 35 ppm IAA G_2 : 60 ppm GA_3 G_3 : 90 ppm GA_3

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

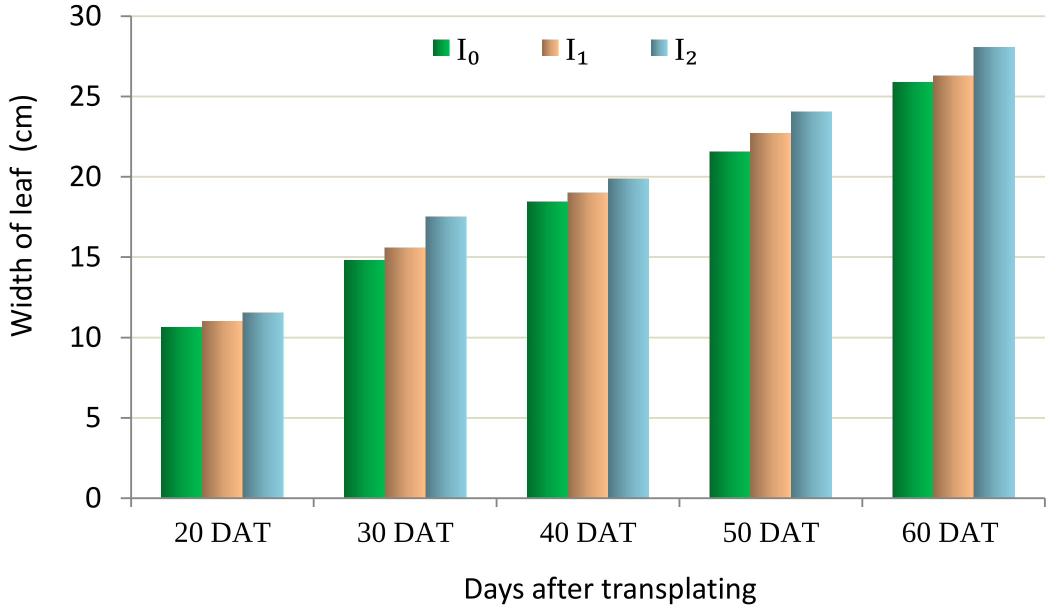
Wu *et al*. (1983) reported that GA_3 at 100 ppm increased the leaf length and the leaf breadth that means the total leaf area. Due to application of different levels of IAA and GA_3 showed significant differences on length of leaf of the plant at 30, 40, 50, and 60 DAT except 20 DAT (Appendix VII). The maximum length of leaf of the plant (24.48 cm) was obtained from I_2G_2 (35 ppm IAA + 60 ppm GA_3) which is statistically identical to I_2G_3 (23.53 cm) treatment combination (35 ppm IAA + 90 ppm GA_3) and similar to I_0G_3, I_1G_1, I_1G_2, I_1G_3, I_2G_0, I_2G_1 while the minimum length of leaf of the plant (16.22 cm) was found from I_0G_0 (control no IAA + no GA_3) at 30 DAT. Again at 40 DAT, the maximum length of leaf of the plant (31.37 cm) was observed in I_2G_2, which is statistically similar to I_0G_1, I_0G_3, I_1G_2, I_1G_3, I_2G_0, I_2G_1, I_2G_3, while the minimum length of leaf of the plant (23.61 cm) was recorded from I_0G_0. The highest length of leaf of the plant (38.04 cm) was found from I_2G_2, which is statistically similar to I_0G_1, I_0G_2, I_0G_3, I_1G_2, I_1G_3, I_2G_0, I_2G_1, I_2G_3 while the lowest length of leaf of the plant (28.81 cm) was recorded from I_0G_0 at 50 DAT and at 60 DAT, the maximum length (46.09 cm) of leaf was observed in I_2G_2 which is statistically similar to I_0G_1, I_0G_2, I_0G_3, I_1G_2, I_1G_3, I_2G_1, I_2G_3 while the minimum length (34.25 cm) of leaf of the plant was found from I_0G_0 treatment combination which is statistically similar to I_0G_2, I_1G_0, I_1G_1 and I_2G_0 treatment combination (Table 5).

4.6 Width of leaf

Significant variation was found in respect of width of leaf of plant at 30, 40, 50 and 60 days after transplanting due to the different concentrations of IAA except 20 DAT (Appendix VIII). The highest width of leaf of the plant (17.53 cm) was obtained from I_2 (35 ppm IAA), which is statistically similar to I_1 (25 ppm IAA), while the minimum width of leaf of the plant (14.80 cm) was recorded from I_0 (control) at 30 DAT. At 40 DAT, the maximum width of leaf (19.88 cm) was found from I_2, while the minimum width of leaf of the plant (18.45 cm) was recorded from I_0. At 50 DAT, the highest width of leaf (24.04 cm) was observed in I_2 (35 ppm IAA), while the minimum width of leaf of the plant (21.57 cm) was recorded from I_0 (control). The maximum width of leaf (28.06 cm) was obtained from I_2 (35 ppm IAA), while the minimum width of leaf of the plant (25.90 cm) was recorded from I_0 at 60 DAT (Fig. 12).

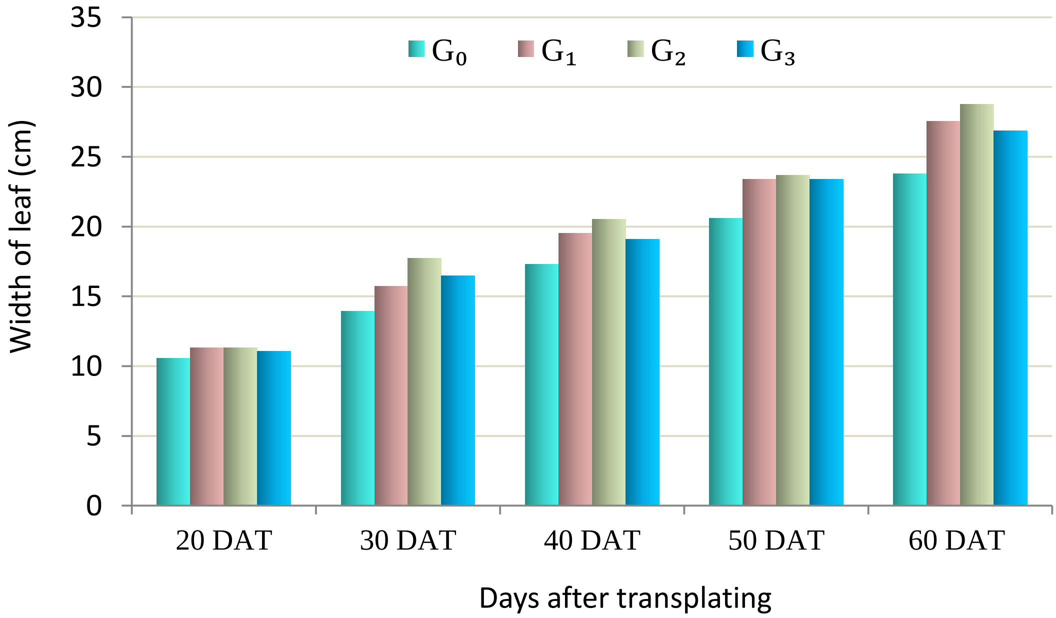
Significant variation was found in respect of width of leaf of plant at 30, 40, 50 and 60 days after transplanting due to the application of different concentrations of GA_3 except 20 DAT (Appendix VIII). The maximum width of leaf (17.73 cm) was recorded from G_2 (60 ppm GA_3) and followed by (16.47 cm) from G_3 (90 ppm GA_3), which is statistically similar (15.74 cm) to G_1 (30 ppm GA_3), while the minimum width of leaf of the plant (13.94 cm) was recorded from G_0 (control) at 30 DAT. At 40 DAT, the highest width of leaf (20.53 cm) was obtained from G_2, which is statistically similar (19.52 cm) to G_1 and (19.09 cm) G_3, while the minimum width of leaf of the plant (17.31 cm) was recorded from G_0 treatment. The highest width of leaf (23.70 cm) was observed in G_2, which is statistically similar to G_3 and G_1 (23.39 cm) while the minimum width of leaf of the plant (20.61 cm) was found from G_0 at 50 DAT. At 60 DAT, the maximum width of leaf (28.76 cm) was obtained from G_2, which is statistically similar to G_3 (26.89 cm) and to G_1 (27.57 cm), while the minimum width of leaf of the plant (23.78 cm) was recorded from G_0 (Fig. 13). Saleh and Abdul (1980) conducted an experiment with GA_3 at 25 and 50 ppm and reported that GA_3 at 50 ppm increased the plant growth as well as leaf breadth and length.

Significant variation was found due to the application of different levels of IAA and GA_3 on width of leaf of the plant at 30, 40, 50 and 60 DAT except 20 DAT (Appendix VIII). At 30 DAT, maximum width of leaf (18.43 cm) was obtained from I_2G_2 (35 ppm IAA + 60 ppm GA_3) which is statistically identical to I_2G_3 (18.30 cm) treatment combination (35 ppm IAA + 90 ppm GA_3) and similar to I_0G_3, I_1G_3, I_2G_1, while the minimum width of leaf of the plant (12.35 cm) was observed in I_0G_0 (control) which is statistically similar to I_1G_0. The highest width of leaf (21.71 cm) was found from I_2G_2 which is statistically similar to



I_0 = control, I_1 = 25 ppm IAA, I_2 = 35 ppm IAA

Fig. 12 Effect of IAA on leaf width



G_0 = control, G_1 = 30 ppm GA_3, G_2 = 60 ppm GA_3, G_3 = 90 ppm GA_3

Fig. 13 Effect of GA_3 on leaf width

Table 6. Combined effects of IAA and GA_3 on width of leaf of the plant

Treatments	20 DAT	30 DAT	40 DAT	50 DAT	60 DAT
I_0G_0	9.723	**12.35 f**	**15.83 d**	**18.72 c**	**23.22 c**
I_0G_1	10.56	14.83 de	19.22 a-c	22.67 ab	26.78 a-c
I_0G_2	10.94	15.22 de	18.61 bc	22.00 a-c	24.89 a-c
I_0G_3	11.39	16.78 a-d	20.15 a-c	22.87 ab	28.61 ab
I_1G_0	10.28	13.67 ef	17.67 cd	21.11 bc	23.33 c
I_1G_1	11.71	14.89 de	18.67 bc	23.17 ab	27.55 a-c
I_1G_2	11.33	15.84 b-e	19.95 a-c	23.00 ab	26.55 a-c
I_1G_3	10.72	18.00 ab	19.72 a-c	23.56 ab	27.83 a-c
I_2G_0	11.67	15.81 c-e	18.43 b-d	22.00 a-c	24.78 bc
I_2G_1	11.67	17.50 a-c	20.67 ab	24.33 ab	28.39 ab
I_2G_2	11.72	**18.43 a**	**21.71 a**	**25.17 a**	**29.83 a**
I_2G_3	11.11	18.30 a	18.72 bc	24.67 a	29.22 ab
LSD $_{(0.05)}$	**1.56**	**2.17**	**2.63**	**3.32**	**4.97**
CV%	**8.35**	**8.04**	**8.14**	**8.61**	**10.98**

I_0 : control I_1 : 25 ppm IAA G_0 : control G_1 : 30 ppm GA_3
I_2 : 35 ppm IAA G_2 : 60 ppm GA_3 G_3 : 90 ppm GA_3

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

I_0G_1, I_0G_3, I_1G_2, I_1G_3, I_2G_1, while the minimum width of leaf of the plant (15.83 cm) was recorded from I_0G_0 at 40 DAT. At 50 DAT, the maximum width of leaf (25.17 cm) was obtained from I_2G_2 (35 ppm IAA + 60 ppm GA_3) which is statistically identical to I_2G_3 (24.67 cm) treatment combination (35 ppm IAA + 90 ppm GA_3) and similar to I_0G_1, I_0G_2, I_0G_3, I_1G_1, I_1G_2, I_1G_3, I_2G_0, I_2G_1, while the minimum width of leaf of the plant (18.72 cm) was recorded from I_0G_0 (control) which is statistically similar to I_0G_2, I_1G_0, I_2G_0. Finally at 60 DAT, the maximum width of leaf (29.83 cm) was recorded from I_2G_2 which is statistically similar to I_0G_1, I_0G_2, I_0G_3, I_1G_1, I_1G_2, I_1G_3, I_2G_1, I_2G_3, while the minimum width of leaf of the plant (23.22 cm) was found from I_0G_0 (control) which is statistically identical to I_1G_0 (23.33 cm) and similar to I_0G_1, I_0G_2, I_1G_1, I_1G_2, I_1G_3 and I_2G_0 treatment combination (Table 6).

4.7 Stem Diameter of the plant

Significant variation was found on stem diameter of plant at 30, 40, 50 and 60 DAT except 20 DAT due to the application of different concentrations of IAA (Appendix IX). The maximum stem diameter (0.84 cm) was recorded from I_2 (35 ppm IAA), while the minimum stem diameter of the plant (0.71 cm) was found from I_0 (control) at 30 DAT. At 40 DAT, the highest stem diameter (1.46 cm) was obtained from I_2, while the minimum stem diameter of the plant (1.26 cm) was found from I_0 (control no IAA), which is statistically similar (1.30 cm) to I_1 (25 ppm IAA). At 50 DAT, the maximum stem diameter (2.02 cm) was recorded from I_2, while the minimum stem diameter of the plant (1.79 cm) was observed in I_0 and At 60 DAT, the maximum stem diameter (2.65 cm) was recorded from I_2, while the minimum stem diameter of the plant (2.30 cm) was recorded from I_0, which is statistically similar (2.35 cm) to I_1 (Table 7). Sun *et al*. (2000) reported that the application of IAA mixed with the water of 45^0c temperature on tomato plant at lower concentration increased the stem diameter.

Significant variation was found on stem diameter of plant due to the application of different levels of GA_3 at 30, 40, 50 and 60 days after transplanting except

20 DAT (Appendix IX). At 30 DAT, the maximum stem diameter (0.82 cm) was recorded from G_2 (60 ppm GA_3), which is statistically similar (0.80 cm) to G_3 (90 ppm GA_3) and followed by (0.76 cm) from G_1 (30 ppm GA_3), while the minimum stem diameter of the plant (0.70 cm) was recorded from G_0 (control). At 40 DAT, the maximum stem diameter (1.44 cm) was recorded from G_2 (60 ppm GA_3), which is statistically similar (1.37 cm) to G_3 treatment, while the minimum stem diameter of the plant (1.24 cm) was recorded from G_0 (control). The maximum stem diameter (2.02 cm) was recorded from G_2, which is statistically similar (1.99 cm) to G_3 treatment, while the minimum stem diameter of the plant (1.74 cm) was recorded from G_0 (control) at 50 DAT. At 60 DAT, the maximum stem diameter (2.55 cm) was recorded from G_2 (60 ppm GA_3), which is statistically identical (2.48 cm) to G_3 treatment, while the minimum stem diameter (2.21 cm) of the plant was recorded (Table 7) from G_0 (control) treatment. Saleh and Adul (1980) observed that the application of GA_3 at 50 ppm for three times increased the stem diameter of the tomato plant.

Combined effect of different levels of IAA and GA_3 showed significant differences on stem diameter of the plant at 30, 40, 50, and 60 DAT except 20 DAT (Appendix IX). At 30 DAT, the highest stem diameter (0.94 cm) was obtained from I_2G_2 (35 ppm IAA + 60 ppm GA_3) treatment combination, while the lowest stem diameter of the plant (0.64 cm) was found from I_0G_0 (control). At 40 DAT, the maximum stem diameter (1.68 cm) was obtained from I_2G_2, while the minimum stem diameter of the plant (1.13 cm) was recorded from I_0G_0. The highest stem diameter (2.20 cm) was recorded from I_2G_2 which is statistically similar to I_0G_3, I_1G_2, I_1G_3, I_2G_1, I_2G_3, while the lowest stem diameter (1.54 cm) of the plant was recorded from I_0G_0 which is statistically similar to I_0G_1, I_2G_0 at 50 DAT and at 60 DAT, the maximum stem diameter (3.00 cm) was found from I_2G_2 which is statistically similar to I_2G_3, while the minimum stem diameter (2.07 cm) of the plant was observed in I_0G_0, which is statistically similar to I_0G_1, I_0G_2, I_1G_0, I_1G_1, I_1G_2, I_2G_0 treatment combinations (Table 8).

4.8 Number of flower clusters per plant

The number of flower clusters per plant varied significantly due to the application of different concentrations of IAA (Appendix X). The maximum number of flower clusters per plant (25.08) was counted from I_2 (35 ppm IAA) treatment, while the minimum number of flower clusters per plant (12.33) was found from I_0 (control) treatment (Table 9). Leopold (1964) observed that with the increase in contration of auxin (IAA). There was a comparable increase in percentage of flower cluster.

Significant variation was found on number of flower clusters per plant due to the application of different levels of GA_3 (Appendix X). The highest number of flower clusters per plant (20.89) was recorded from G_2 (60 ppm GA_3) treatment, which is statistically identical (20.68) to G_3 (90 ppm GA_3), while the lowest (14.11) number of flower clusters per plant was obtained from G_0 (control) treatment (Table 9). Sumiati (1987) recorded the significant increase in number of flower cluster per plant I tomato cv. Money maker with spraying of 10 ppm GA_3 against untreated. Khan *et al*. (2006) observed that irrespective of its concentrations spray of gebberellic acid (GA_3) proved the beneficial for increased number of flower cluster of tomato plant.

Combined effect of different levels of IAA and GA_3 showed significant differences on number of flower clusters per plant (Appendix X). The treatment combination of I_2G_2 (35 ppm IAA + 60 ppm GA_3) performed the maximum number of flower clusters per plant (29.33) and the treatment combination of I_0G_0 (control) performed the minimum number of flower clusters per plant (9.66) which is statistically identical (11.33) to I_0G_1 (no IAA + 30 ppm GA_3) treatment and similar to I_1G_0 (Table 10).

Table 7. Single effect of IAA and GA_3 on stem diameter of the plant

Treatments	20 DAT	30 DAT	40 DAT	50 DAT	60 DAT
I_0	0.55	**0.71 c**	**1.26 b**	**1.79 b**	**2.30 b**
I_1	0.59	0.76 b	1.30 b	1.92 ab	2.35 b
I_2	0.61	**0.84 a**	**1.46 a**	**2.02 a**	**2.65 a**
LSD $_{(0.05)}$	**0.06**	**0.03**	**0.07**	**0.14**	**0.16**
G_0	0.57	**0.70 c**	**1.24 c**	**1.74 b**	**2.21 b**
G_1	0.58	0.76 b	1.33 b	1.89 ab	2.40 ab
G_2	0.59	**0.82 a**	**1.44 a**	**2.02 a**	**2.55 a**
G_3	0.60	0.80 a	1.37 ab	1.95 a	2.48 a
LSD $_{(0.05)}$	**0.03**	**0.04**	**0.08**	**0.17**	**0.19**
CV%	**2.35**	**6.05**	**6.33**	**9.23**	**8.10**

I_0 : control I_1 : 25 ppm IAA G_0 : control G_1 : 30 ppm GA_3
I_2 : 35 ppm IAA G_2 : 60 ppm GA_3 G_3 : 90 ppm GA_3

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

Table 8. Combined effects of IAA and GA_3 on stem diameter of the plant

Treatments	20 DAT	30 DAT	40 DAT	50 DAT	60 DAT
I_0G_0	0.55	**0.64 e**	**1.13 e**	**1.54 d**	**2.07 f**
I_0G_1	0.55	0.71 d	1.29 cd	1.83 cd	2.34 c-f
I_0G_2	0.55	0.74 d	1.32 cd	1.87 bc	2.38 b-f
I_0G_3	0.57	0.77 cd	1.33 b-d	1.91 a-c	2.41 b-e
I_1G_0	0.56	0.75 d	1.29 cd	1.88 bc	2.22 ef
I_1G_1	0.58	0.73 d	1.28 d	1.86 bc	2.32 c-f
I_1G_2	0.62	0.78 cd	1.33 b-d	1.90 a-c	2.26 d-f
I_1G_3	0.62	0.78 cd	1.33 b-d	2.03 a-c	2.61 bc
I_2G_0	0.60	0.72 d	1.33 b-d	1.80 cd	2.37 b-f
I_2G_1	0.61	0.83 bc	1.42 bc	1.97 a-c	2.55 b-d
I_2G_2	0.61	**0.94 a**	**1.68 a**	**2.20 a**	**3.00 a**
I_2G_3	0.60	0.88 ab	1.47 b	2.13 ab	2.68 ab
LSD (0.05)	**0.20**	**0.07**	**0.14**	**0.29**	**0.33**
CV%	**2.35**	**6.05**	**6.33**	**9.23**	**8.10**

I_0 : control I_1 : 25 ppm IAA G_0 : control G_1 : 30 ppm GA_3
I_2 : 35 ppm IAA G_2 : 60 ppm GA_3 G_3 : 90 ppm GA_3

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

4.9 Number of flowers per cluster

Significant variation was found on the number of flowers per cluster due to application of different concentrations of IAA (Appendix X). The maximum number of flowers per cluster (6.81) was found from I_2 (35 ppm IAA) treatment, while the minimum number of flowers per cluster (5.43) was found from I_0 (control) treatment (Table 9). Chhonkar and Singh (1959) reported that high concentration IAA increased yield through increased flower induction and fruit set.

Number of flowers per cluster varied significantly due to the application of different levels of GA_3 (Appendix X). The highest number of flowers per cluster (6.43) was counted from G_2 (60 ppm GA_3) treatment, which is statistically similar (6.22) to G_3 (90 ppm GA_3), while the lowest (5.82) number of flowers per cluster was obtained from G_0 (control) treatment which is statistically similar to G_1 treatment (Table 9). Singh and Lal (1995) reported the foliar spraying of GA_3 (50 ppm) at 50 percent flowering increased the fruit set and seed yield of tomato. Groot *et al*. (1987) reported that GA_3 and IAA were indispensable for the development of the fertile flowers at the medium and the lower concentration respectively. Bhosle and khrbhade (2002) observed that the effect of auxin (NAA) at 50 ppm and GA_3 45 ppm and 50 ppm CPA increased the number of flower per cluster of Dhananshree tomato cultivar.

Significant variation was found on number of flowers per cluster due to the combined effects of different levels of IAA and GA_3 (Appendix X). The treatment combination of I_2G_2 (35 ppm IAA + 60 ppm GA_3) performed the maximum number of flowers per cluster (7.23) which is statistically similar to I_2G_0 and I_2G_1 while the minimum (4.77) number of flowers per cluster was obtained from the treatment combination of I_0G_0 (Table 10).

4.10 Number of fruits per cluster

Number of fruits per cluster varied significantly due to application of different concentrations of IAA (Appendix X) The maximum number of fruits per cluster (6.33) was recorded from I_2 (35 ppm IAA) treatment, while the minimum number of fruits per cluster (4.25) was found from I_0 treatment (Table 9). Chandra *et al.,* (2004) found that the number of fruits per cluster increased with the increase in the rate of indole-3-acetic acid. Younis and Tigani (1977) observed that when IAA applied to the field grown tomato plants. 2 application of IAA 10 ppm increase the fruit set significantly. Kaushik *et al*. (1974) reported that 10 ppm of IAA increased the number and weight of fruits per plant significantly.

Significant variation was found on number of fruits per cluster due to the application of different levels of GA_3 (Appendix X). Treatment G_2 (60 ppm GA_3) performed the maximum number of fruits per cluster (6.27), which is statistically identical (6.16) to G_3 (90 ppm GA_3), while the minimum (5.22) number of fruits per cluster was obtained from G_0 (0 ppm GA_3) treatment (Table 9). Satti and Oebekar (1986) reported an increase in fruit set of tomato due to application of GA_3 @ 25 ppm at various stages of inflorescence development. Tomar and ramgiry (1997) found that plants treated with GA_3 showed significantly greater number of fruits per cluster than untreated controls. Sasaki *et al*. (2005) reported that tomatoes treated with a mixture of 4 –CPA and GA_3 showed increased fruit set per cluster and number of normal fruits were more than plants treated with 4-CPA alone during summer. Kaushik *et al*. (1974) reported that GA_3 increased the number of fruit per cluster due to the application of high concentration of GA_3 like 100 ppm. Adlakha and Verma (1965) observed when the first four clusters of tomato plants were sprayed 3 times with GA_3 at 50 and 100 ppm the fruit setting increased by 5 % with the lower concentration than higher.

Combined effect of different level of IAA and GA_3 showed significant differences on number of fruits per cluster (Appendix X). The treatment combination of I_2G_2 (35 ppm IAA + 60 ppm GA_3) performed the maximum number of fruits per cluster (9.33) while the treatment combination of I_0G_0 (control) performed the minimum number of fruits per cluster (3.66) per plant which is statistically identical to I_1G_0, I_0G_2 and similar to I_0G_1 treatment combination (Table 10). El-Habbasha *et al*. (1999) found that the number of fruit per cluster increased due to the application GA_3 and IAA on tomato (cv. Castelrock).

4.11 Length of fruit

In the length of fruit, significant variation was found due to the application of different concentrations of IAA (Appendix X). The highest length of fruit (5.88 cm) was obtained from I_2 (35 ppm IAA) treatment, while the lowest length of fruit (5.02 cm) was found from I_0 (control) treatment, which is statistically identical to I_1 (5.31 cm) treatment (Table 9). Gupta *et al*. (2002)[a] observed that the application of 35 ppm IAA and micronutrients significantly improved the fruit size (length 6.32 cm). Mukharji and Ray (1966) found that the application of IAA increased the length of fruit in tomato plant.

The length of fruit varied significantly due to the application of different levels of GA_3 (Appendix X). The highest length of fruit (5.85 cm) was recorded from G_2 (60 ppm GA_3) treatment which is statistically identical (5.65 cm) to G_3 (90 ppm GA_3) and (5.34 cm) to G_1 (30 ppm GA_3) while the lowest length of fruit (4.76 cm) was obtained from G_0 treatment (Table 9). Kanwar *et al*. (1976) recorded significantly increased fruit length (5.15 cm) width spray of GA_3 (30 ppm) at pre-bloomed stage in tomato.

Significant variation was found on length of fruit due to the combined effects of different levels of IAA and GA_3 (Appendix X). The treatment combination of I_2G_2 (35 ppm IAA + 60 ppm GA_3) performed the highest length of fruit (6.32 cm) which is statistically similar to I_0G_2, I_0G_3, I_1G_2, I_1G_3, I_2G_0, I_2G_1, I_2G_3, while the minimum length of fruit (3.86 cm) was obtained from the treatment combination of I_0G_0 treatment combination (Table 10).

4.12 Diameter of fruit

The diameter of fruit varied significantly due to the application of different concentrations of IAA (Appendix X). The maximum diameter of fruit (6.36 cm) was recorded from I_2 treatment which is statistically similar to I_1 treatment, while the minimum diameter of fruit (5.65 cm) was found from I_0 (control) treatment (Table 9). Gupta *et al*. (2003) reported that the largest fruit size (6.67 cm diameter) was observed with application of 45 ppm and IAA and multiple micro nutrient mixtures at maturity stage. Gupta *et al*. (2002)[a] observed that the application of 35 ppm IAA and micronutrients significantly improved the fruit size (diameter 6.78 cm).

Significant variation was found on diameter of fruit due to the application of different levels of GA_3 (Appendix X). The highest diameter of fruit (6.33 cm) was recorded from G_2 (60 ppm GA_3) treatment, which is statistically identical to G_3 (6.19 cm) and similar to G_1 (5.91 cm) treatment, while the minimum diameter of fruit (5.58 cm) was obtained from G_0 (control) treatment, which is statistically similar to G_1 treatment (Table 9). Sumati (1987) reported that the significant increase of fruit size (diameter) of tomato due to the application of GA_3.

Combined effects of different levels of IAA and GA_3 showed significant differences on diameter of fruit (Appendix X). The treatment combination of I_2G_2 (35 ppm IAA + 60 ppm GA_3) performed the maximum diameter of fruit (6.86 cm) which statistically similar to I_0G_2, I_0G_3, I_1G_1, I_1G_3, I_2G_0, I_2G_3, while the minimum diameter of fruit (4.85 cm) was obtained from the treatment combination of I_0G_0 which statistically similar to I_0G_1 and I_1G_0 treatment combination (Table 10).

Table 9. Single effect of IAA and GA_3 at different concentrations on yield characteristics of tomato plant

Treatments	Number of clusters/plant	Number of flowers/cluster	Number of fruits/cluster	Length of fruit	Diameter of fruit
I_0	**12.33 c**	**5.43 c**	**4.25 c**	**5.02 b**	**5.65 b**
I_1	17.33 b	6.13 b	5.75 b	5.31 b	6.00 ab
I_2	**25.08 a**	**6.81 a**	**6.33 a**	**5.88 a**	**6.36 a**
LSD $_{(0.05)}$	**1.17**	**0.34**	**0.34**	**0.45**	**0.39**
G_0	**14.11 c**	**5.82 c**	**5.22 c**	**4.76 b**	**5.58 b**
G_1	17.22 b	6.01 bc	5.77 b	5.34 a	5.91 ab
G_2	**20.89 a**	**6.43 a**	**6.27 a**	**5.85 a**	**6.33 a**
G_3	20.68 a	6.22 ab	6.16 a	5.65 a	6.19 a
LSD $_{(0.05)}$	**1.35**	**0.40**	**0.39**	**0.52**	**0.45**
CV%	**7.59**	**6.71**	**6.63**	**9.96**	**7.83**

I_0 : control　　I_1 : 25 ppm IAA　　G_0 : control　　G_1 : 30 ppm GA_3
I_2 : 35 ppm IAA　　G_2 : 60 ppm GA_3　　G_3 : 90 ppm GA_3

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

Table 10. Combined effects of IAA and GA_3 on yield characteristics of tomato of plant

Treatments	Number of clusters/plant	Number of flowers/cluster	Number of fruits/cluster	Length of fruit	Diameter of fruit
I_0G_0	**9.66 h**	**4.77 f**	**3.66 e**	**3.86 d**	**4.85 e**
I_0G_1	11.33 h	5.53 e	4.33 de	5.04 bc	5.28 de
I_0G_2	14.00 fg	5.80 de	4.00 e	5.58 a-c	6.28 a-c
I_0G_3	14.33 fg	5.61 de	5.00 d	5.60 a-c	6.21 a-c
I_1G_0	12.00 gh	6.08 c-e	4.00 e	4.85 c	5.60 c-e
I_1G_1	16.33 f	5.94 c-e	5.00 d	5.19 bc	6.42 ab
I_1G_2	19.00 e	6.27 b-d	7.00 c	5.67 a-c	5.85 b-d
I_1G_3	22.00 cd	6.22 b-e	7.00 c	5.52 a-c	6.12 a-c
I_2G_0	20.67 de	6.61 a-c	8.00 b	5.58 a-c	6.29 a-c
I_2G_1	24.00 bc	6.57 a-c	8.00 b	5.79 ab	6.04 b-d
I_2G_2	**29.33 a**	**7.23 a**	**9.33 a**	**6.32 a**	**6.86 a**
I_2G_3	26.33 b	6.85 b	8.00 b	5.83 ab	6.26 a-c
$LSD_{(0.05)}$	**2.34**	**0.69**	**0.68**	**0.91**	**0.79**
CV%	**7.59**	**6.71**	**6.63**	**9.96**	**7.83**

I_0 : control I_1 : 25 ppm IAA G_0 : control G_1 : 30 ppm GA_3
I_2 : 35 ppm IAA G_2 : 60 ppm GA_3 G_3 : 90 ppm GA_3

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

4.13 Fresh weight of individual fruit

The fresh weight of fruit varied significantly due to the application different concentrations of IAA (Appendix XI). The maximum fresh weight of fruit (88.83 g) was obtained from I_2 (35 ppm IAA) treatment, while the minimum fresh weight of fruit (67.33 g) was found from I_0 (control) treatment, which is statistically identical to I_1 (Table 11). Perez and Ramirez (1980) carried out an experiment with the application of IAA at 25 and 35 ppm on tomato which resulted   increased fruit size and weight with minimum seed. Singh and Upadhayaya (1967) founded that the application of IAA and NAA increased the fruit size and individual fruit weight of tomato.

Significant variation was found on fresh weight of individual fruit due to the application of different levels of GA_3 (Appendix XI). The treatment G_2 performed the maximum fresh weight of fruit (88.11 g), which is statistically identical to G_3 (82.78 g) treatment, while the minimum fresh weight of fruit (66.33 g) was obtained from G_0 (control) treatment, which is statistically identical to G_1 (Table 11). Kanwar *et al.* (1976) reported that the application of GA_3 at 50 ppm recorded significantly increased the fruit weight of tomato. Adlakha and Verma (1965) observed that the tomato plants were sprayed three times at unspecified intervals with 50 ppm and 100 ppm the individual fruit weight increased 35 % from the untreated plants.

Combined effect of different levels of IAA and different concentration of GA_3 showed significant differences on fresh weight of fruit (Appendix XI). The maximum (108.0 g) fresh weight of fruit was recorded from I_2G_2 (35 ppm IAA + 60 ppm GA_3) and the minimum (51.0 g) fresh weight of fruit was obtained from the treatment combination of I_0G_0 which is statistically similar to I_0G_1, I_1G_1 treatment combination (Table 12).

4.14 Dry matter content of fruit (%)

Significant variation was found on dry matter content of fruits due to the application of different concentrations of IAA (Appendix XI). The maximum dry matter content of fruit (13.02 %) was recorded from I_2 (35 ppm IAA) treatment, while the minimum dry matter content of fruit (11.78 %) was found from I_0 (control) treatment, which is statistically similar to I_1 (11.92 %) treatment (Table 11).

The dry matter content of fruits varied significantly due to the application of different levels of GA_3 (Appendix XI). The maximum dry matter content of fruit (13.64 %) was recorded from G_2 treatment, while the minimum dry matter content of fruit (10.81 %) was obtained from G_0 treatment (Table 11). Sumati (1987) found that the GA_3 involved in many physiological process and dry matter content of fruits increased with the increasing levels of GA_3. Saski *et al.* (2005) reported that tomatoes treated with a mixture of 4 CPA and GA_3 showed increased dry matter content of fruit. Tomar and Ramgiry (1997) observed that the application of GA_3 at seedling stage performed the greater dry matter content of fruit. Kaushik *et al.* (1974) found that GA_3 increased the dry matter content of fruit.

Combined effect of different levels of IAA and GA_3 showed significant variation on dry matter content of fruits (Appendix XI). The treatment combination of I_2G_2 (35 ppm IAA + 60 ppm GA_3) performed the maximum dry matter content of fruit (14.07 %) which is statistically similar to I_0G_1, I_0G_2, I_1G_3, I_2G_1, I_2G_3, while the minimum dry matter content of fruit (9.04 %) was obtained from the treatment combination of I_0G_0 treatment combination (Table 12).

4.15 Length of root

The length of root varied significantly due to the application of different concentrations of IAA (Appendix XI). The highest length of root (34.83 cm) was obtained from I_2 (35 ppm IAA) treatment, while the lowest length of root (26.75 cm) was found from I_0 treatment (control), which is statistically identical (29.42 cm) to I_1 treatment (Table 11). Gupta *et al.* (2002)[a] observed that the application of IAA and micronutrients significantly improved the dry matter content and root length of the tomato plant. Varga and Bruinsma (1976) found that IAA promotes root initiation and induces both growth of pre-existing roots and adventitious root formation, i.e., branching of the roots.

Significant variation was found on root length due to the application of different levels of GA_3 (Appendix XI). The highest length of root (31.89 cm) was recorded from G_2 (60 ppm GA_3) treatment, which is statistically identical (31.22 cm) to G_3 (90 ppm GA_3) treatment, while the minimum length of root (27.78 cm) was obtained from G_0 treatment, which is statistically similar to G_1 treatment (Table 11). Saleh and Abdul (1980) reported that application of GA_3 increased the vegetative growth with the root length of the plant.

Combined effect of different level of IAA and GA_3 showed significant differences on length of root (Appendix XI). The treatment combination of I_2G_2 (35 ppm IAA + 60 ppm GA_3) performed the maximum length of root (38.00 cm) which is statistically similar to I_2G_1 and I_2G_3 treatment combination, while the minimum length of root (24.67 cm) was recorded from the treatment combination of I_0G_0 which is statistically similar to I_0G_1, I_0G_2, I_0G_3, I_1G_0, I_1G_1, I_1G_2 and I_2G_0 treatment combination (Table 12).

4.16 Chlorophyll percentage of leaf

Significant variation of chlorophyll percentage of leaf was found due to the application of different concentrations of IAA (Appendix XI). The maximum Chlorophyll percentage of leaf (53.71 %) was recorded from I_2 (35 ppm IAA) treatment while the minimum Chlorophyll percentage of leaf (49.35 %) was found from I_0 (control) which is statistically similar (53.47 %) to I_1 (Table 11).

There was significant difference on chlorophyll percentage of leaf due to the application of different levels of GA_3 (Appendix XI). The highest Chlorophyll percentage of leaf (56.04 %) was recorded from G_2 (60 ppm GA_3) treatment which is statistically similar to G_3 (90 ppm GA_3) treatment, while the lowest Chlorophyll percentage of leaf (49.87 %) was obtained from G_0 (control) treatment, which is statistically identical to G_1 treatment (Table 11).

Combined effect of different levels of IAA and GA_3 showed significant differences on chlorophyll percentage of leaf (Appendix XI). The treatment combination of I_2G_2 (35 ppm IAA + 60 ppm GA_3) performed the maximum Chlorophyll percentage of leaf (60.92 %) which is statistically similar to I_0G_1, I_1G_0, I_1G_1, I_2G_0 treatment combination and the minimum Chlorophyll percentage of leaf (42.82 %) was obtained from the treatment combination of I_0G_0 treatment combination which is statistically similar to I_0G_2, I_0G_3, I_1G_2, and I_2G_3 treatment combination (Table 12).

4.17 Dry matter content of leaf (%)

There was significant difference on dry matter content of the leaf due to the application of different concentrations of IAA (Appendix XI). The maximum dry matter content of leaf (16.08 %) was recorded from I_2 (35 ppm IAA) treatment which is statistically similar to I_1treatment, while the minimum dry matter content of leaf (14.49 %) was found from I_0 (control) treatment which is statistically similar to I_1 treatment (Table 11).

The dry matter content of leaf differed significantly due to the application of different levels of GA_3 (Appendix XI). The treatment G_2 (60 ppm GA_3) performed the maximum dry matter content of leaf (16.39 %) which is statistically similar to G_1 and G_2 treatment, while the minimum dry matter content of leaf (13.81 %) was obtained from G_0 (control) treatment which is statistically similar to G_1 treatment (Table 11). Tomar and Ramgiry (1997) found that tomato plants treated with GA_3 showed significantly greater dry matter content of leaves than untreated controls.

Combined effect of different levels of IAA and GA_3 showed significant differences on dry matter content of leaf (Appendix XI). The treatment combination of I_2G_2 (35 ppm IAA + 60 ppm GA_3) performed the maximum dry matter content of leaf (17.60 %) which is statistically similar to I_0G_1, I_0G_2, I_0G_3, I_1G_2, I_1G_3, I_2G_0, I_2G_1 and I_2G_3 treatment combination, while the minimum dry matter content of leaf (12.02 %) was performed by the treatment combination of I_0G_0 (control) treatment combination which is statistically similar to I_1G_0, and I_1G_1 treatment combination (Table 12).

4.18 Carbon assimilation rate

The carbon assimilation rate varied significantly due to the application of different concentrations of IAA (Appendix XII). The maximum carbon assimilation rate (9.30) was found from I_2 (35 ppm IAA) treatment, while the minimum (4.48) carbon assimilation rate was recorded from I_0 (Table 13).

Significant difference was found on carbon assimilation rate due to the application of different levels of GA_3 (Appendix XII). The treatment G_2 (60 ppm GA_3) performed the maximum carbon assimilation rate (7.95) while the minimum carbon assimilation rate (5.30) was obtained from the treatment of G_0 (Table 13). Khan *et al*. (2006) reported that the carbon assimilation rate increased due to the application of GA_3 on growth stage of tomato plant. Martins *et al*. (1999) observed that the carbon assimilation increased with the application of 50 mg/L on tomato plant.

Combined effects of different levels of IAA and GA_3 showed significant differences on carbon assimilation rate (Appendix XII). The treatment combination of I_2G_2 (35 ppm IAA + 60 ppm GA_3) performed the maximum carbon assimilation rate (10.53), which is statistically similar (9.11) to I_2G_3 (35 ppm IAA + 90 ppm GA_3) while the minimum (3.12) carbon assimilation rate was obtained from the treatment combination of I_0G_0 (Table 14).

4.19 Yield per plot (kg)

The yield per plot varied significantly due to the application of different concentrations of IAA (Appendix XII). The maximum yield per plot (26.91 kg) was obtained from I_2 (35 ppm IAA) treatment, while the minimum yield per plot (21.13 kg) was found from I_0 (control) treatment which is statistically identical to I_1 treatment (Table 13).

Table 11. Single effect of IAA and GA_3 at different concentrations on yield characteristics of tomato plant

Treatments	Fresh weight of individual fruit	Dry matter content of fruit (%)	Length of root	Chlorophyll percentage of leaf	Dry matter content of leaf (%)
I_0	**67.33 b**	**11.78 b**	**26.75 b**	**49.35 b**	**14.49 b**
I_1	72.17 b	11.92 b	29.42 b	53.47 ab	14.73 ab
I_2	**88.83 a**	**13.02 a**	**34.83 a**	**53.71 a**	**16.08 a**
LSD $_{(0.05)}$	**6.45**	**0.95**	**2.88**	**4.13**	**1.35**
G_0	**66.33 b**	**10.81 c**	**27.78 b**	**49.87 b**	**13.81 b**
G_1	67.22 b	12.20 b	30.44 ab	51.12 b	14.93 ab
G_2	**88.11 a**	**13.64 a**	**31.89 a**	**56.04 a**	**16.39 a**
G_3	82.78 a	12.31 b	31.12 a	53.66 ab	15.27 ab
LSD $_{(0.05)}$	**7.45**	**1.10**	**3.33**	**4.76**	**1.56**
CV%	**10.02**	**9.24**	**11.23**	**9.35**	**10.62**

I_0 : control I_1 : 25 ppm IAA G_0 : control G_1 : 30 ppm GA_3
I_2 : 35 ppm IAA G_2 : 60 ppm GA_3 G_3 : 90 ppm GA_3

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

Table 12. Combined effects of IAA and GA_3 on yield characteristics of tomato of plant

Treatments	Fresh weight of individual fruit	Dry matter content of fruit (%)	Length of root	Chlorophyll percentage of leaf	Dry matter content of leaf (%)
I_0G_0	**51.00 h**	**9.04 e**	**24.67 e**	**42.82 d**	**12.02 c**
I_0G_1	61.00 f-h	12.19 a-d	28.00 de	54.60 a-c	15.69 ab
I_0G_2	74.33 c-e	12.10 a-d	27.67 de	51.00 b-d	15.10 ab
I_0G_3	83.00 b-d	13.78 ab	26.67 de	48.97 cd	16.12 ab
I_1G_0	80.67 cd	11.46 cd	29.00 de	58.10 ab	13.79 bc
I_1G_1	55.00 gh	11.25 d	28.00 de	53.54 a-c	13.58 bc
I_1G_2	82.00 b-d	11.87 cd	30.00 c-e	50.20 b-d	14.13 ab
I_1G_3	71.00 d-f	13.13 a-d	30.67 b-d	52.03 bc	15.46 ab
I_2G_0	67.33 e-g	11.94 b-d	29.67 c-e	54.70 a-c	14.63 ab
I_2G_1	85.67 bc	13.17 a-c	35.33 a-c	51.23 bc	15.50 ab
I_2G_2	**108.0 a**	**14.07 a**	**38.00 a**	**60.92 a**	**17.60 a**
I_2G_3	94.33 b	12.98 a-d	36.33 ab	47.97 cd	15.58 ab
LSD $_{(0.05)}$	**12.91**	**1.91**	**5.77**	**8.25**	**2.71**
CV%	**10.02**	**9.24**	**11.23**	**9.35**	**10.62**

I_0 : control I_1 : 25 ppm IAA G_0 : control G_1 : 30 ppm GA_3
I_2 : 35 ppm IAA G_2 : 60 ppm GA_3 G_3 : 90 ppm GA_3

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

Significant variation was found on yield per plot due to the application of different levels of GA_3 (Appendix XII). The maximum yield per plot (26.80 kg) was recorded from G_2 (60 ppm GA_3) treatment, while the minimum yield per plot (19.19 kg) was obtained from G_0 (control) treatment (Table 13). Hossain (1974) found that a gradual increase in the yield per plant was obtained with higher levels of GA_3.

Combined effects of different levels of IAA and GA_3 showed significant variation on yield per plot (Appendix XII). The treatment combination of I_2G_2 (35 ppm IAA + 60 ppm GA_3) performed the maximum yield per plot (30.75 kg) which is statistically similar to I_2G_3 treatment combination, while the minimum yield per plot (17.01 kg) was obtained from the treatment combination of I_0G_0 (control) treatment combination which is statistically similar to I_0G_1 and I_1G_0 treatment combination (Table 14).

4.20 Yield per hectare

Significant difference was found on yield per hectare due to the application of different levels of IAA (Appendix XII). The maximum yield per hectare (74.76 t/ha) was obtained from I_2 (35 ppm IAA) treatment, while the minimum yield per hectare (58.69 t/ha) was found from I_0 treatment which is statistically identical to I_1 treatment (Table 13). Singh *et al*. (2005) investigated that the application of 35 ppm IAA and 2000 humaur was significantly increased the tomato yield. Gupta *et al*. (2003) observed that the highest yield (63.61 t/ha) obtained by the application of 45 ppm IAA and multiple nutrient mixture on "Krishna" tomato variety. Rai *et al*. (2002) recorded the highest yield of tomato due to the application of 75 ppm IAA. Sing and Upadhayaya (1967) reported that the application of IAA increased the total yield and induced parthenocarpic fruit.

The yield per hectare varied significantly due to the application of different levels of GA_3 (Appendix XII). The treatment G_2 (60 ppm GA_3) performed the maximum yield per hectare (76.45 t/ha), while the minimum yield per hectare

(53.30 t/ha) was obtained from the treatment of G_0 (Table 13). Tomar and Ramgiry (1997) found that the plants treated with GA_3 showed the significantly greater yield than untreated plant. Bhosle and khrbhade (2002) reported that the application of 45 ppm GA_3 resulting the highest yield. Adlakha and Verma (1965) observed that when tomato plants were sprayed three times with at 50 ppm GA_3 the total yield increased by 23 % than the untreated plants.

Significant variation was found on yield per hectare due to the combined effects of IAA and GA_3 (Appendix XII). The treatment combination of I_2G_2 (35 ppm IAA + 60 ppm GA_3) performed the maximum yield per hectare (85.42 t/ha) which is statistically similar (79.27 t/ha) to I_2G_3 (35 ppm IAA + 90 ppm GA_3) while the minimum yield per hectare (47.25 t/ha) was obtained from the treatment combination of I_0G_0 treatment combination which is statistically similar to I_0G_1 and I_1G_0 treatment combination (Table 14). In Bangladesh the average yield of BARI Tomato-14 is 90-95 t/ha (Razzak *et. al.*, 2011) when all the environmental conditions remain favorable. Feofanova (1960) observed that the application of growth regulators on tomato plants could increase the total yield of tomato fruits by preventing the fruit drop.

4.21 Economic analysis

Input costs for land preparation, seed cost, fertilizer, irrigation and man power required for all the operations from sowing to harvesting of tomato were recorded for unit plot and converted into cost per hectare (Appendix XIII & XIV). Prices of tomato were considered to the whole sale market rate of Karwan Bazar, Dhaka. The economic analysis was done to find out the gross and net return and the benefit cost ratio (BCR) in the present experiment and presented under the following headings:

Table 13. Single effect of IAA and GA_3 at different concentrations on yield of tomato

Treatments	Carbon assimilation rate	Yield per plot (kg)	Yield per hectare (Ton)
I_0	**4.48 c**	**21.13 b**	**58.69 b**
I_1	6.83 b	22.30 b	61.94 b
I_2	**9.30 a**	**26.91 a**	**74.76 a**
LSD $_{(0.05)}$	**0.71**	**1.34**	**3.72**
G_0	**5.30 d**	**19.19 d**	**53.30 d**
G_1	6.21 c	21.98 c	61.05 c
G_2	**7.95 a**	**26.80 a**	**76.45 a**
G_3	7.06 b	24.82 b	71.72 b
LSD $_{(0.05)}$	**0.82**	**1.54**	**4.30**
CV%	**12.28**	**6.76**	**6.75**

I_0 : control I_1 : 25 ppm IAA G_0 : control G_1 : 30 ppm GA_3
I_2 : 35 ppm IAA G_2 : 60 ppm GA_3 G_3 : 90 ppm GA_3

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

Table 14. Combined effects of IAA and GA_3 on yield of tomato

Treatments	Carbon assimilation rate	Yield per plot (kg)	Yield per hectare (Ton)
I_0G_0	**3.12 g**	**17.01 g**	**47.25 g**
I_0G_1	5.14 f	18.80 fg	52.23 fg
I_0G_2	4.95 f	23.20 de	64.44 de
I_0G_3	5.43 f	25.50 cd	70.85 cd
I_1G_0	5.99 ef	19.18 fg	53.28 fg
I_1G_1	6.14 ef	20.14 f	55.95 f
I_1G_2	8.08 cd	23.51 de	65.31 de
I_1G_3	7.14 de	26.36 bc	73.23 bc
I_2G_0	7.79 cd	21.37 ef	59.37 ef
I_2G_1	8.77 bc	26.99 bc	74.97 bc
I_2G_2	**10.53 a**	**30.75 a**	**85.42 a**
I_2G_3	9.11 ab	28.54 ab	79.27 ab
LSD $_{(0.05)}$	**1.43**	**2.68**	**7.44**
CV%	**12.28**	**6.76**	**6.75**

I_0 : control I_1 : 25 ppm IAA G_0 : control G_1 : 30 ppm GA_3
I_2 : 35 ppm IAA G_2 : 60 ppm GA_3 G_3 : 90 ppm GA_3

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

4.21.1 Gross return

In the combination of IAA and GA_3 showed different gross return under the different trials. The highest gross return per hectare (Tk. 8,54,200) was obtained from I_2G_2 (35 ppm IAA + 60 ppm GA_3) and the second highest gross return (Tk. 7,92,700) was recorded from I_2G_3 (35 ppm IAA + 90 ppm GA_3). The lowest gross return (Tk. 4,72,500) was recorded from I_0G_0 (control) treatment (Table 15).

Gross return = (Total yield of produce × Market rate of per unit produce) Tk.

Calculation:

Gross return from I_2G_2 treatment combination = (85,420 × 10) Tk.

= 85,4,200 Tk.

4.21.2 Net return

In case of net return different treatment combinations were showed different amount of net return. The highest net return (Tk. 6,15,714/ha) was recorded from the treatment combination of I_2G_2 (35 ppm IAA + 60 ppm GA_3) and the second highest net return (Tk. 5,48,281/ha) was recorded from the treatment combination of I_2G_3 (35 ppm IAA + 90 ppm GA_3). The lowest net return (Tk. 2,70,795/ha) was recorded from the treatment combination of I_0G_0 that is control treatment (Table 15).

Net return = (Gross return – Total cost of production) Tk.

Calculation:

Net return from I_2G_2 treatment combination = (8,54,200 – 2,38,487) Tk.

= 6,15,714 Tk.

Table 15. Cost and return of tomato production influenced by IAA and GA_3

Treatment combination	Cost of Production (Tk. /ha)	Yield of Tomato (t/ha)	Gross return (Tk. /ha)	Net Return (Tk. /ha)	BCR
I_0G_0	**2,01,705**	**47.25**	**4,72,500**	**2,70,795**	**2.34**
I_0G_1	2,13,570	52.23	5,22,300	3,08,730	2.45
I_0G_2	2,19,503	64.44	6,44,400	4,24,898	2.94
I_0G_3	2,25,435	70.85	7,08,500	4,83,065	3.14
I_1G_0	2,13,570	53.28	5,32,800	3,19,230	2.49
I_1G_1	2,25,435	55.95	5,59,500	3,34,065	2.48
I_1G_2	2,31,368	65.31	6,53,100	4,21,733	2.82
I_1G_3	2,37,300	73.23	7,32,300	4,95,000	3.09
I_2G_0	2,20,689	59.37	5,93,700	3,73,011	2.69
I_2G_1	2,32,554	74.97	7,49,700	5,17,146	3.22
I_2G_2	**2,38,487**	**85.42**	**8,54,200**	**6,15,714**	**3.58**
I_2G_3	2,44,419	79.27	7,92,700	5,48,281	3.24

I_0 : control
I_1 : 25 ppm IAA
I_2 : 35 ppm IAA

G_0 : control
G_1 : 30 ppm GA_3
G_2 : 60 ppm GA_3
G_3 : 90 ppm GA_3

4.21.3 Benefit cost ratio (BCR)

The benefit cost ratio (BCR) was different from each other among all the treatment combinations of IAA and GA_3. The highest (3.58) benefit cost ratio was obtained from I_2G_2 and the lowest benefit cost ratio (2.34) was recorded from I_0G_0 (control) treatment (Table 15). From the economic point of view, it was apparent from the above results treatment combination of I_2G_2 that is 35 ppm IAA and 60 ppm GA_3 was more profitable compare to others.

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

Calculation:

$$\text{BCR of } I_2G_2 \text{ treatment combination} = \frac{8{,}54{,}200 \text{ Tk.}}{2{,}38{,}487 \text{ Tk.}}$$

$$= 3.58$$

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted in the Horticultural Farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during the period from November 2013 to April 2014 to find out the effect of different concentrations levels of IAA and GA_3 on the growth and yield of tomato. The experiment consisted of two factors: Factor A: Three levels of IAA. The treatments are I_0: 0 ppm IAA (control), I_1: 25 ppm IAA and I_2: 35 ppm IAA. Factor B: Four levels of GA_3. The treatments are G_0: 0 ppm GA_3 (control); G_1: 30 ppm GA_3; G_2: 60 ppm GA_3 and G_3: 90 ppm GA_3. There were 12 treatment combinations. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Data on different growth and yield contributing characters and yield were recorded to find out the optimum level of IAA and GA_3 on tomato.

At 60 days after transplanting the longest plant height (97.75 cm), maximum number of leaves per plant (82.17), maximum number of branches per plant (8.83), maximum size of canopy (108.2 cm), maximum size of stem diameter (2.65 cm), the longest length of leaf (42.36 cm), maximum width of leaf (28.06 cm), maximum number of clusters per plant (25.08), the highest number of flowers per cluster (6.81), maximum number of fruits per cluster (6.33), the highest length of fruit (5.88 cm), the highest diameter of fruit (6.36 cm), maximum fresh weight of fruit (88.83 g), the highest dry matter percentage of fruit (13.02 %), the highest length of root (34.83 cm), maximum chlorophyll percentage of leaf (53.71 %), maximum dry matter percentage of leaf (16.08 %), the highest carbon assimilation rate (9.30), maximum yield of fruit per plot (26.91 kg), and the highest yield of fruit per hectare (74.76 t/ha) were recorded from the treatment of 35 ppm Indole-3-acetic acid (IAA) that is I_2 treatment. On the other hand the shortest plant height (68.08 cm), minimum number of leaves per plant (66.25), minimum number of branches per plant (7.66), minimum size of canopy (94.08 cm), minimum size of stem diameter (2.30

cm), the shortest length of leaf (39.47 cm), minimum width of leaf (25.90 cm), minimum number of clusters per plant (12.33), minimum number of flowers per cluster (5.43), minimum number of fruits per cluster (4.25), lowest length of fruit (5.02 cm), lowest diameter of fruit (5.65 cm), minimum fresh weight of fruit (67.33 g), the lowest dry matter percentage of fruit (11.78 %), the lowest length of root (26.75 cm), minimum chlorophyll percentage of leaf (49.35 %), minimum dry matter percentage of leaf (14.49 %), the lowest carbon assimilation rate (4.48), minimum yield of fruit per plot (21.13 kg), and the lowest yield of fruit per hectare (58.69 t/ha) were recorded from I_0 (control) treatment.

At 60 days after transplanting the longest plant height (88.0 cm), maximum number of leaves per plant (79.0), maximum number of branches per plant (9.11), maximum size of canopy (105.2 cm), the longest length of leaf (43.25 cm), maximum width of leaf (28.76 cm), the maximum size of stem diameter (2.55 cm), maximum number of clusters per plant (20.89), maximum number of flowers per cluster (6.43), maximum number of fruits per cluster (6.27), the highest length of fruit (5.85 cm), the highest diameter of fruit (6.33 cm), maximum fresh weight of individual fruit (88.11 g), the highest dry matter percentage of fruit (13.64 %), the highest length of root (31.89 cm), maximum chlorophyll percentage of leaf (56.04 %), maximum dry matter percentage of leaf (16.39 %), the highest carbon assimilation rate (7.85), maximum yield of fruit per plot (26.82 kg), and the highest yield of fruit per hectare (76.45 t/ha) were recorded from the treatment of 60 ppm gibberellic acid (GA_3) that is G_2 treatment. On the other hand the shortest plant height (76.11 cm), minimum number of leaves per plant (65.11), minimum number of branches per plant (6.88), minimum size of canopy (88.33 cm) , minimum size of stem diameter (2.21 cm), the shortest length of leaf (36.76 cm), minimum width of leaf (23.78 cm), minimum number of clusters per plant (14.11), minimum number of flowers per cluster (5.82), minimum number of fruits per cluster (5.22), the lowest length of fruit (4.76 cm), the lowest diameter of fruit (5.58 cm), minimum fresh weight of fruit (66.33 g), the lowest dry matter percentage of fruit (10.81 %), the lowest length of root (27.78 cm), minimum chlorophyll percentage of leaf (49.87 %), minimum dry matter percentage of leaf (13.81 %), the lowest carbon assimilation rate (5.30), minimum yield of fruit per plot (19.19 kg), and the lowest yield of fruit per hectare (53.30 t/ha) were recorded from G_0 (control) treatment.

At 60 days after transplanting the longest plant height (106.0 cm), maximum number of leaves per plant (94.67), maximum number of branch per plant (10.00), maximum size of stem diameter (3.00 cm), the maximum size of canopy (116.0 cm), the highest length of leaf (46.09 cm), maximum width of leaf (29.83 cm), maximum number of clusters per plant (29.33), maximum number of flowers per cluster (7.23), maximum number of fruits per cluster (9.33), the highest length of fruit (6.32 cm), the highest diameter of fruit (6.86 cm), maximum fresh weight of fruit (108.0 g), the highest dry matter percentage of fruit (14.07 %), the highest length of root (38.00 cm), maximum chlorophyll percentage of leaf (60.92 %), maximum dry matter percentage of leaf (17.60 %) the highest carbon assimilation rate (10.53), maximum yield of fruit per plot (30.75 kg), and the highest yield of fruit per hectare (85.42 t/ha) were recorded from the treatment combination of 35 ppm Indole-3-acetic acid (IAA) and 60 ppm gibberellic acid (GA_3) that is I_2G_2 treatment. On the other hand the shortest plant height (60.33 cm), minimum number of leaves per plant (56.67), minimum number of branch per plant (6.00), minimum size of canopy (79.33 cm) , minimum size of stem diameter (2.07 cm), the shortest length of leaf (34.25 cm), minimum width of leaf (23.22 cm), minimum number of clusters per plant (9.66), minimum number of flowers per cluster (4.77), minimum number of fruits per cluster (3.66), the shortest length of fruit (3.86 cm), shortest diameter of fruit (4.85 cm), minimum fresh weight of fruit (51.00 g), lowest dry matter percentage of fruit (9.04 %), lowest length of root (24.67 cm), minimum chlorophyll percentage of leaf (42.82 %), minimum dry matter percentage of leaf (12.02 %), the lowest carbon assimilation rate (3.12), minimum yield of fruit per plot (17.01 kg), and the lowest yield of fruit per hectare (47.25 t/ha) were recorded from the treatment combination of 0 ppm Indole-3-acetic acid (IAA) and 0 ppm gibberellic acid (GA_3) that is I_0G_0 (control) treatment.

The highest gross return (Tk. 8,54,200/ha), net return (Tk. 6,15,714/ha), benefit cost ratio (3.58), was recorded from the combination of 35 ppm IAA and 60 ppm GA_3 that is I_2G_2 treatment whereas the lowest gross return (Tk. 4,72,500/ha), net return (Tk. 2,70,795/ha) and benefit cost ratio (2.34) was recorded from the combination of 0 ppm IAA and 0 ppm GA_3 that is I_0G_0 (control) treatment.

Conclusion

Based on the result of the present study it was found that application of 35 ppm IAA and 60 ppm GA_3 (I_2G_2) treatment combination performed the highest yield (85.42 t/ha) and highest (BCR) benefit cost ratio (3.58) for tomato production. Considering the findings of the experiment, it can be concluded that -

- The combination of 35 ppm IAA (Indole-3-Acetic Acid) and 60 ppm GA_3 (Gibberellic Acid) that is I_2G_2 treatment combination will be the appropriate practice for tomato production and also for highest economic return.

Recommendation

The cumulative effect of IAA and GA_3 was positive up to 35 ppm IAA and 60 ppm GA_3 respectively. On the other hand the cumulative effect of 35 ppm IAA and 90 ppm GA_3 was antagonistic. So the optimum concentration of GA_3 was 60 ppm when IAA was 35 ppm. Due to some limitations it was unable to find out the effect of further increasing concentration of IAA with GA_3. So the recommendation is –

- Further research should be conducted by setting more treatments of IAA up to a certain level with GA_3 to find out the optimum concentration of IAA for the highest positive cumulative effect.

CHAPTER VI

REFERENCES

Adlakha, P. A. and Verma, S. K. 1964. Effect of gibberellic acid on the quality of fiuit. *Panjab Hort. J.,* **4**: 148-51.

Adlakha, P. A. and Verma, S. K. 1965. Effect of gibberellic acid on fruiting and yield of tomato. *Science and Culture*, **31**: pp. 301-303.

Ahmad, K. U. 1976. "Phul Phal O Shak-Sabjee" 3rd Edn. Alhaj Kamisuddin Ahmed Banglow No. 2, Farmgate, Dhaka-15, Bangladesh. p. 544.

Alam, M. S., Iqbal, T. M. T ., Amin, M. and Gaffar, M. A. 1989. Krishitattic Fasaler Utpadan O Unnayan (In Bengali). T. M. Jubair Bin Iqbal, Sirajganj. pp. 231-239.

Anonymous. 2011. Tomato productivity in India. Indian Horticulture Database. http://apeda.gov.in/agriexchange/market%20profile/MOA/Product/Tomato.pdf

Asahira T., Takeda, Y., Nishio, T., Hirabayashi, M. and Tsukamoto, Y. 1967. Studies on fruit development in tomato. I. Ovule development and content of diffusible auxin- and gibberellin-induced parthenocarpic tomato fruits in relation to their development. Memoirs of the Research Institute for Food Science, Kyoto University **28**: pp. 47–74.

BBS. 2013. Monthly Statistical Bulletin of Bangladesh Bureau of Statistics, Ministry of planning, Govt. of the people's republic of Bangladesh, Dhaka. P. 154.

Bhosle, A. B. and Khrbhade, S. B. 2002. Effect of growth hormones on growth, yield of summer tomato (*Lycopersicon esculentum* Mill.). *Orissa J.Hort*., **30** (2): pp. 63-65.

Bima, P., Surati, F. M., Soressi, G. P., Terzi, M., Cella, R., and Falavigna, A. 1995. Effect of gibberellic acid and micropropagation on auxiliary shoot induction in monostem genotype of tomato (*Lycopersicon esculentum* Mill.). *Adv. Hort. Forest.*, **4**: pp. 73-84.

Bose, T. K. and Som, M. G. 1990. Vegetable Crops in India. Published by B. Mitra and Naya Prokash, 206 Bidlran Sarani, Kolkata, India. p. 241 and 249.

Bunger-Kibler S. and Bangerth F. 1983. Relationship between cell number, cell size and fruit size of seeded fruits of tomato (*Lycopersicon esculentum* Mill.), and those induced parthenocarpically by the application of plant growth regulators. Plant Growth Regulation **1**: pp. 143–154.

Chandra, P., Singh, A. K., Behera, T. K. and Srivastava, R. 2004. Influence of graded levels of phosphorus and indole-3-acetic acid on the yield and quality of tomato (*Lycopersicon esculentum*) hybrids grown in a polyhosue. *Indian J. Agric. Sci.,* **73** (9): pp. 497-499.

Chhonkar, V. S. and S. N. Singh. 1959. Effect of alpha naphthalene acetic acid on growth, quality and yield of tomato. *India. J. Hort*., **l6**: pp. 236-242.

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

Choudhury. G. and Singh, V.V. 1960. Effect of GA on growth and yield of tomato. *Indian Hort*. **2** (1): pp. 36-42.

Chung, H. D. and Y. Z. Chori. 2001. Foliar application of plant growth regulators affects distribution and accumulation of calcium ($45CaCl_2$) in tomato leaves. *Korean J. Hort. Sci.,* **42** (6): pp. 656-660.

Djanaguiraman, M., Devi, D. D., Sheeba, J. A., Bangarusamy, U. and Babu, R. C. 2004. Effect of oxidative stress on abscission of tomato fruits and regulation by Nitrophenols. *Trop. Agri. Res.,* **16:** pp. 25-36.

El-Abd, S. 0., Singer, S. A., Ilelmy, Y. I. and Beltagv, M. S. E. 1995. Plant growth regulators for improving fruit set of tomato. *Egypt J. Hort.*, **22** (2): pp. 163-173.

El-Habbasha, H., Shadeque, A. and Baruah, P. J. 1999. Effect of plant growth regulators on yield and quality of tomato. *Veg. Sci.*, **18** (1): pp. 93-96.

FAO. 2013. FAO Production Yearbook. Basic Data Unit, Statistics Division, FAO, Rome, Italy. **56**: pp. 142-144.

Feofanova, N.D. 1960. The effect of giberellin on fruit development in tomatoes. *Bot. j*., **45**: pp. 1781-1786

Gomez, K. A. and Gomez, A. A. 1984. Statistical Procedures for Agricultural Research (2nd Edn.). John Willey and Sons, Singapore. pp. 28-92.

Groot, S. P. C., Bruibsma, J. and Karssen, C. M. 1987. The role of endogenous gibberellic in seed and fruit development of tomato (*Lyropersicon esculentum* Mill.). Studies with a gibberellic deficient mutant. Physiologia Planetarium, **71** (2): pp. 184-190.

Gupta, P. K. and Gupta, A. K. 2004. Influence of auxins and micronutrient formulations on phosphorus content in tomato (*Lycopersicon Esculentum* Mill.) fruits and its products. *Adv. Pl. Sci*., **l7** (1): pp. 129-132.

Gupta, P. K., Gupta, A. K. and Reddy, S. 2002[a]. Efficacy of auxins (IAA & NAA) and micronutrient mixtures (Multiplex & Humaur) on yield, dry weight and ash content of tomato fruits. *Bionotes.*, **4** (l): pp. l7-18.

Gupta, P. K., Gupta, A. K. and Reddy, S. 2002[b]. Efficacy of PGR (IAA and NAA) and micronutrient (Multiplex and Humaur) on mineral. *Bionotes.*, **5** (l): pp. l8-20.

Gupta, P. K., Gupta, A. K. and Reddy, S. 2003. Response of plant growth regulators and micronutrient mixtures on fruit size, color and yield of tomato (*Lycopersicon esculentum,* Mill.). *Ann. Agric. Res.,* **24** (1): pp. 100-103.

Gupta, P.K., Gupta, A. K. and Varshney, M. L. 2001. Effect of auxins (IAA & NAA) and micronutrient mixtures (Multiplex and Humaur) on biochemical parameters of tomato fruits. *Bionotes.,* **3** (2): p. 38.

Gustafson, F. G. 1960. Influence of gibberellic acid on setting and development of fruits in tomato. *Plant Physiology.*, **35**: pp. 521-23.

Haider, E. A. 1991. Agro Ecological Region of Bangladesh. Land Resources Appraisal of Bangladesh Agricultural Development. *Plant Physiology.*, **31**: pp. 312-323.

Haque, M. S., Islam, M. T. and Rahman, M. 1999. Studies on the presentation of semi-concentrated tomato juice. *Bangladesh J. Agril. Sci*., **26** (1): pp. 37-43.

Harneet, K., Thakur, J. C. and Chawla, N. 2004. Effect of nitrogen and IAA on growth, yield and quality of tomato (*Lycopersicon esculentum* Mill.) cv. Punjab Upma. *Haryana J. Hort. Sci*., **32** (3/4): 286-288.

Hossain, M. A. E. 1974. Studies on the effect of parachlorophenoxy acetic acid and gibberellic acid on the production of tomato. An M. Sc. thesis Dept. of Hort., BAU, Mymensingh. pp. 25.

Jansen, H. 1970. Effect of gibberellic acid and CCC on the yield of tomato. Gortenbauwissenchaft, **35**: pp. 303-306.

Kanwar, J.S., Saimvhi, M. S., Saimbhi, M. S. and Nandapuri, K. S. 1976. Increasing fruit set and yield in tomatoes. *The Punjab Veg. Grow*., **11**: pp. 41-43.

Kataoka, K., Uernachi, A., Nonaka, I. and Yazawa, S. 2004. Effects of endogenous gibberellins in the early stages of fruit growth and development of the 'Severianian' tomato. *J. Hort. Sci. Biotech.,* **79** (1): pp. 54-58.

Kaushik, M. P., J. K. Sharma and I. Singh. 1974. Effect of alpha naphthalene acetic acid, gibberellic acid, kinetin and norphactin on yield of tomato. *Pl. Sci*., **6**: pp. 51-53.

Khan, M. M. A., Champa, G., Eiroz, M., Siddiqui, M. H., Naeem, M. and Khan, M. N. 2006. Effect of gibberellic acid spray on performance of tomato. *Turkish J. Biochem*., **30** (1): pp. 11-16.

Leonard, M., Killet, K. M., Bodson, M. and Bemier, G. 1983. Enhanced inflorescence development in tomato by growth substance treatment in relation to C14 assimilates distribution. *Physiologia Planetarium*., **57** (1): pp. 85-89.

Leopold. A. C. 1964. Plant growth and development. Mc Graw Hill Book Company. New York. pp. 259-267.

Martins, M. B. C. and Castro, P. R. C. 1999. Morphological and anatomical aspects of frits of tomato 'A gigante', submitted to treatments with plant growth regulators. *Bragantia*., **56** (2): pp. 225-36.

Masroor , A., Khan, M., Champa, I., Firoz, M., Manzer, H., Naeem, M. and Nasir, M. 1988. Effect of Gibberellic Acid Spray on Performance of Tomato. *Turk J. Biol*., **30**: pp. 11-16.

Mehrotra, O., Garg, M. N. and Singh, R.C. 1970. Growth, fruiting and quality of tomato (*Lycopersicon esculentum* Mill.) as influenced by growth regulators. *Prog. Horc.,* **2**: pp. 56-64.

Mehta, A.K. and Mathi, D.J. 1975. Effects of growth regulators on summer tomato (*Lycopersicon esculentum* Mill.) *Haryana Hort. Sci*., **4** (2): pp. 167-176.

Mukharji, S. K. and Roy, B. K. 1966. Reducing fruit drop in west Bengal. *World Crops*., **18** (3): p. 34.

Murphy, W. S. 1964. Phosphorus and IAA of southern tomato transplants. *Proc. Amer. Soc. Hort. Sci.,* **85:** pp. 478-483.

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

Onofeghara, F. A. 1981. Tl1e effects of growth substance on flowering and fruiting of tomato (*Lycopersicon esculentum* Mill.). *Phyton Argentina*., **40** (1): pp.107-116.

Perez, Z. M. and Ramirez, O. G. 1980. Effect of season and growth regulators on flowering, fruit-set and development of the tomato. *Puerto Rico J. Agric*., **64** (4): pp. 460-473.

Pruthi, J. S. 1993. Major spices of India. Crop management and post harvest technology. *Indian j. Agric. Res*., New Delhi.

Pundir, J. P. S. and Yadav, P. K. 2001. On effect of GA_3, NAA and 2, 4-D on growth, yield and quality of tomato var. Punjab Chhuhara. *Current Agric*., **25** (1/2): pp. 137-138.

Rai, G. K., Jagdish, S., Sunil, S. and Gupta, A. K. 2002. Effect of plant growth regulators (IAA & NAA) and micronutrient mixtures (Humaur and Multiplex) on growth, yield and quality of tomato (*Lycopersicon esculentum* Mill.). *Ann. Bio*., **18** (1): pp.13-17.

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

Rappaport, L. 1960. Effect of temperature and gibberelic acid on growth of tomato fruits. *Nature Wis-Ssesnshafam.*, **47**: pp.285-286.

Rashid , M. 1999. Sabji Bigyan, (In Bbengali) Published by, Rashid Publishing House, 94, DOHS, Dhaka-1216. p. 191.

Razzak, M. A., Sattar, M. A., Amin, M. S., Kyum, M. A. and Alam, M, S. 2011. Krishi Projukti Hatboi (5^{th} edn.). Bangladesh Agricultural Research Institute (BARI), Gazipur 1701, Bangladesh, p. 384.

Saleh, M.M.S. and Abdul, K.S. 1980. Effects of gibberellic acid cycocel on growth, flowering and fruiting of tomato (*Lycopersicon esculentum* Mill.) *Plants Mesopotamiaj of Agric*. **15** (1): pp.137-166.

Sasaki, H., Yano, T. and Yanrasaki, A. 2005. Reduction of high temperature inhibition in tomato fruit set by plant growth regulators. *JARQ, Japan Agric. Res. Q.,* **39** (2): pp.135-138.

Satti, S. M and Oebekar, N. P. 1986. Effect of benzyl adenine and gibberellin on flowering and fruit set of tomato over high temperature. *Acta Hort*ic., **190**: pp. 347-354.

Serrani, J. C., Fos, M., Atares, A., Garcia and Martinez, J. L. 2007. *J. of Plant Growth Regulation.* **26** (3): pp.211-221.

Singh, B., Singh, N., Singh, S. K. and Kumar, S. 2003. Effects of phytohormones with different methods of application on the growth and yield of tomato (*Lycopersicon esculentum* Mill.) *Prog. Agric.,* **3** (1/2): pp.33-35.

Singh, D. K. and Lal, G. 1995. Effect of plant growth regulators on the fruit set, yield quality of chilli. (*Capsicum annuum* L) *Advan. Hort Fores.,* **4** : pp.133-141.

Singh, J., Singh, K. P. and Kalloo, G. 2002. Effect of some plant growth regulators on fruit set and development under cold climatic conditions in tomato (*Lycopersicon esculentum* Mill.) *Prog. Hort*., **34** (2): pp. 211-214.

Singh, K. and Upadhayaya, S. K. 1967. A comparative study of soil and foliar application of IAA and NAA on several response of tomato. *Horticulturist*., **2**: pp.3-9.

Singh, R., Sant, A. K. and Singh, L. 2005. Effect of plant growth regulators and micro-nutrient mixture on growth and yield of tomato (*Lycopersicon esculentum* Mill.). *Bioved*, **16** (1/2): pp. 101-105

Sumati. 1987. Effect of pruning on yield, quality of tomato cv Gandal and Intan. *Bull. Penelit. Hortic.*, **15**: pp. 48-54.

Sumiati, E. 1987. Effects of plant growth regulators on flowering and yield of tomatoes in the lembang Highlands. *Bulletin- Penelition- Horticultura*. **15** (1): pp. 134-143.

Sun, Y. W., Chen, J., Tseng, M., Chang, W. and Sheen, T. 2000. The role of growth regulators on cold water for irrigation reduces stem elongation of plug-grown tomato seedlings. *Chinese J. Agro meteorology*, **7** (4): pp. 61-68.

Thompson, H. C. and Kelly, W. C. 1983. Vegetable Crops. 5th Edn. Tata McGraw Hill Publishing Co. Ltd. New Delhi. p. 611.

Tomar, I.S and Ramgiry, S. R. 1997. Effect of growth reguletor on yield and yield attributes n tomato (*Lycopersicon esculentum* Mill).*Adv. plant Sciences*., **10** (2): pp. 29-31.

Ulmasov, T., Hagen, G. and Guilfoyle T.J. 1999. Dimerization and DNA binding of auxin response factors. *The Plant Journal*., **19**: pp. 309–319.

Varga, A. and Bruinsma, J. 1976. Roles of seeds and auxins in tomato fruit growth. *Zeitschrift fur Pflanzenphysiologie*., **80**: pp. 95–104.

Wang, H., Jones, B., Li., Frasse, P., Delalande, C., Regad, F., Chaabouni, S., Latche, A., Pech, J., and Bouzayen, M. 2005. The tomato Aux/IAA transcription factor IAA9 is involved in fruit development and leaf morphogenesis. *The Plant Cell*., **17**: pp. 2676–2692.

Woodward, A.W. and Bartel, B. 2005. Auxin: regulation, action, and interaction. *Annals of Botany*., **95**: pp. 707–735.

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

Younis, M. E. and Tigani, L. S. E. 1977. Comparative effects of growth substance on the growth, flowering and fruiting of tomato (*Lycopersicon esculentum* Mill.) plants. *Acta Agronomica Academiae Scientiarum ientiarum Hungaricae.*, **26**: pp. 89-103.

Zhao, Y. 2008. The role of local biosynthesis of auxin and cytokinin in plant development. *Current Opinion in Plant Biology*., **11**: pp. 16–22.

APPENDICES

Appendix I. Monthly average temperature, relative humidity and total rainfall of the experimental site during the period from October 2013 to April 2014

Month	Air temperature (^{0}C)		R. H. (%)	Total rainfall (mm)
	Maximum	Minimum		
October ,13	29.18	18.26	81	39
November,13	25.82	16.04	78	0
December,13	22.4	13.5	74	0
January,14	24.5	12.4	68	0
February ,14	27.1	16.7	67	3
March ,14	31.4	19.6	54	11
April , 14	35.3	22.4	51	15

Source: Bangladesh Metrological Department (Climate and weather division) Agargaon, Dhaka

Appendix II. Results of morphological, mechanical and chemical analysis of soil of the experimental plot

A. Morphological Characteristics

Morphological features	Characteristics
Location	Horticulture Farm, SAU, Dhaka
AEZ	Modhupur Tract (28)
General Soil Type	Shallow redbrown terrace soil
Land Type	Medium high land
Soil Series	Tejgaon
Topography	Fairly leveled
Flood Level	Above flood level
Drainage	Well drained

B. Mechanical analysis

Constituents	Percentage (%)
Sand	27
Silt	43
Clay	30

C. Chemical analysis

Soil properties	Amount
Soil pH	5.8
Organic carbon (%)	0.45
Total nitrogen (%)	0.03
Available P (ppm)	20
Exchangeable K (%)	0.1
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI)

Appendix-III. Analysis of variance of data on plant height at different DAT of tomato plant

Source of variation	Degrees of freedom (df)	Mean square of plant height at				
		20 DAT	30 DAT	40 DAT	50 DAT	60 DAT
Replication	2	2.694	9.250	46.861	114.528	235.083
Factor A (Indole-3-acetic acid)	2	0.861	258.250 **	776.694 **	1271.194 **	2644.333 **
Factor B (Gibrellic acid)	3	0.250	23.287 **	111.741 **	159.065 **	269.361**
Interaction (A X B)	6	0.417	2.509 *	13.657 *	5.231 **	23.333 *
Error	22	0.361	1.765	11.891	18.194	29.265

** : Significant at 1% level of probability; * : Significant at 5% level of probability

Appendix-IV. Analysis of variance of data on number of leaves at different DAT of tomato plant

Source of variation	Degrees of freedom (df)	Mean square of number of leaves at				
		20 DAT	30 DAT	40 DAT	50 DAT	60 DAT
Replication	2	0.444	1.583	0.694	13.361	6.361
Factor A (Indole-3-acetic acid)	2	1.194	20.250 **	329.194 **	632.528 **	830.861 **
Factor B (Gibrellic acid)	3	0.074	8.407 **	154.481**	236.963 **	335.287 **
Interaction (A X B)	6	0.046	4.657 **	32.120 *	61.602 **	89.898 *
Error	22	0.202	0.462	14.088	16.179	25.270

** : Significant at 1% level of probability; * : Significant at 5% level of probability

Appendix-V. Analysis of variance of data on number of branches per plant at different DAT of tomato plant

Source of variation	Degrees of freedom (df)	Mean square of number of branches at				
		20 DAT	30 DAT	40 DAT	50 DAT	60 DAT
Replication	2	0.0	0.028	0.111	2.528	5.861
Factor A (Indole-3-acetic acid)	2	0.0	1.694 **	0.778 **	4.361 **	4.528 **
Factor B (Gibrellic acid)	3	0.0	0.250 **	1.889 **	6.852 **	7.806 **
Interaction (A X B)	6	0.0	0.917 **	0.333 *	0.769 *	0.861 *
Error	22	0.0	0.028	0.111	0.407	0.770

** : Significant at 1% level of probability; * : Significant at 5% level of probability

Appendix-VI. Analysis of variance of data on canopy size at different DAT of tomato plant

Source of variation	Degrees of freedom (df)	Mean square of canopy size at				
		20 DAT	30 DAT	40 DAT	50 DAT	60 DAT
Replication	2	5.083	6.861	25.444	293.694	143.694
Factor A (Indole-3-acetic acid)	2	1.750	202.778 **	267.194 **	1013.194 **	741.028 **
Factor B (Gibrellic acid)	3	1.213	194.407 **	237.139 **	480.843 **	512.148 **
Interaction (A X B)	6	0.935	23.963 *	20.750 *	85.454 *	31.398 *
Error	22	1.174	7.467	14.172	30.694	28.240

** : Significant at 1% level of probability; * : Significant at 5% level of probability

Appendix-VII. Analysis of variance of data on length of leaf at different DAT of tomato plant

Source of variation	Degrees of freedom (df)	Mean square of length of leaf at				
		20 DAT	30 DAT	40 DAT	50 DAT	60 DAT
Replication	2	15.705	6.165	4.054	11.244	11.144
Factor A (Indole-3-acetic acid)	2	3.658	45.961 **	27.519 *	14.444 *	25.748 *
Factor B (Gibrellic acid)	3	3.287	33.137 *	25.807 *	49.675 *	74.341 *
Interaction (A X B)	6	2.323	3.471 **	6.096 **	15.192 *	16.265 *
Error	22	1.965	6.918	7.600	12.954	21.030

** : Significant at 1% level of probability; * : Significant at 5% level of probability

Appendix-VIII. Analysis of variance of data on width of leaf at different DAT of tomato plant

Source of variation	Degrees of freedom (df)	Mean square of width of leaf at				
		20 DAT	30 DAT	40 DAT	50 DAT	60 DAT
Replication	2	1.694	1.039	0.457	2.772	9.175
Factor A (Indole-3-acetic acid)	2	2.398	23.632 **	6.252 *	18.438 *	15.827 *
Factor B (Gibrellic acid)	3	1.171	22.581 **	16.303 **	18.863 **	40.701**
Interaction (A X B)	6	0.894	1.001*	2.429 *	0.899 **	1.927 **
Error	22	0.855	1.649	2.419	3.846	8.627

** : Significant at 1% level of probability; * : Significant at 5% level of probability

Appendix-IX. Analysis of variance of data on stem diameter of tomato plant at different DAT

Source of variation	Degrees of freedom (df)	Mean square of stem diameter of plant at				
		20 DAT	30 DAT	40 DAT	50 DAT	60 DAT
Replication	2	0.001	0.002	0.004	0.017	0.047
Factor A (Indole-3-acetic acid)	2	0.009	0.050 **	0.134 **	0.169 *	0.428 **
Factor B (Gibrellic acid)	3	0.001	0.026 **	0.067 **	0.145 *	0.237 **
Interaction (A X B)	6	0.001	0.006 *	0.020 *	0.025 *	0.070 **
Error	22	0.000	0.002	0.007	0.031	0.039
** : Significant at 1% level of probability; * : Significant at 5% level of probability						

Appendix-X. Analysis of variance of data on yield Characteristics of tomato plant

Source of variation	Degrees of freedom (df)	Mean square of				
		Number of clusters/ plant	Number of flowers/cluster	Number of fruits/cluster	Length of fruit	Diameter of fruit
Replication	2	1.444	0.644	9.194	1.742	0.021
Factor A (Indole-3-acetic acid)	2	99.361 **	5.769 **	51.194 **	2.303 **	1.499 **
Factor B (Gibrellic acid)	3	31.657 **	0.630 *	4.963 **	2.035 **	0.995 *
Interaction (A X B)	6	5.657 **	0.159 *	2.046 **	0.321 **	0.622 *
Error	22	0.535	0.169	0.164	0.290	0.221
** : Significant at 1% level of probability; * : Significant at 5% level of probability						

Appendix-XI. Analysis of variance of data on yield Characteristics of tomato plant

Source of variation	Degrees of freedom (df)	Mean square of				
		Fresh weight of individual fruit	Dry matter content of fruit (%)	Length of root	Chlorophyll percentage of leaf	Dry matter content of leaf (%)
Replication	2	58.528	3.726	13.583	32.594	4.133
Factor A (Indole-3-acetic acid)	2	1526.778 **	5.568 *	203.583 **	72.122 *	8.783 *
Factor B (Gibrellic acid)	3	1089.185 **	11.979 **	29.259 *	32.469 *	10.163 *
Interaction (A X B)	6	423.519 **	2.039 **	10.398 *	83.489 *	2.969 *
Error	22	58.104	1.278	11.614	23.792	2.572

** : Significant at 1% level of probability; * : Significant at 5% level of probability

Appendix-XII. Analysis of variance of data on yield Characteristics of tomato plant

Source of variation	Degrees of freedom (df)	Mean square of		
		Carbon assimilation rate	Yield per plot (kg)	Yield per hectare (Ton)
Replication	2	11.677	1.075	8.286
Factor A (Indole-3-acetic acid)	2	69.542 **	112.244 **	865.613 **
Factor B (Gibrellic acid)	3	10.889 **	111.504 **	860.656 **
Interaction (A X B)	6	1.225 **	7.341 **	56.659 **
Error	22	0.713	2.510	19.347

** : Significant at 1% level of probability; * : Significant at 5% level of probability

Appendix-XIII. Input cost

Treatments Combination	Labour Cost (TK.)	Ploughing Cost (TK.)	Seedling cost (TK.)	Irrigation Cost (TK.)	Pesticides cost (TK.)	GA_3 cost (TK.)	IAA cost (TK.)	Manure and fertilizers cost (TK.)				Sub Total (A)
								Cowdung	Urea	TSP	MP	
I_0G_0	72000	8000	4500	15000	3500	0	0	15000	7500	1000	4500	131000
I_0G_1	72000	8000	4500	15000	3500	10000	0	15000	7500	1000	4500	141000
I_0G_2	72000	8000	4500	15000	3500	15000	0	15000	7500	1000	4500	146000
I_0G_3	72000	8000	4500	15000	3500	20000	0	15000	7500	1000	4500	151000
I_1G_0	72000	8000	4500	15000	3500	0	10000	15000	7500	1000	4500	141000
I_1G_1	72000	8000	4500	15000	3500	10000	10000	15000	7500	1000	4500	151000
I_1G_2	72000	8000	4500	15000	3500	15000	10000	15000	7500	1000	4500	156000
I_1G_3	72000	8000	4500	15000	3500	20000	10000	15000	7500	1000	4500	161000
I_2G_0	72000	8000	4500	15000	3500	0	16000	15000	7500	1000	4500	147000
I_2G_1	72000	8000	4500	15000	3500	10000	16000	15000	7500	1000	4500	157000
I_2G_2	72000	8000	4500	15000	3500	15000	16000	15000	7500	1000	4500	162000
I_2G_3	72000	8000	4500	15000	3500	20000	16000	15000	7500	1000	4500	167000

Appendix- XIV. Total cost of production

Treatments Combination	Cost of lease of land for 6 months (13% of value of land Tk. 6,00000/year) (B)	Sub Total Cost of production (A+B)	Interest on running capital for 6 months (Tk. 13% of cost/year) (C)	Total (A+B+C) (TK.)	Miscellaneous cost (Tk.) 5% of the input cost	Grand Total Cost of Production (TK.)
I_0G_0	39000	170000	22100	192100	9605	201705
I_0G_1	39000	180000	23400	203400	10170	213570
I_0G_2	39000	185000	24050	209050	10453	219503
I_0G_3	39000	190000	24700	214700	10735	225435
I_1G_0	39000	180000	23400	203400	10170	213570
I_1G_1	39000	190000	24700	214700	10735	225435
I_1G_2	39000	195000	25350	220350	11018	231368
I_1G_3	39000	200000	26000	226000	11300	237300
I_2G_0	39000	186000	24180	210180	10509	220689
I_2G_1	39000	196000	25480	221480	11074	232554
I_2G_2	39000	201000	26130	227130	11357	238487
I_2G_3	39000	206000	26780	232780	11639	244419

Appendix XV. Panoramic view of the research work

Photograph showing, the seedlings are uprooting from seedbed for transplanting in the main field.

Photograph showing, 30 days old seedlings are planting in the main field.

Photograph showing, the field view at 20 DAT.

Photograph showing, first data collection at 20 DAT.

Photograph showing, spraying of GA_3 at 35 DAT.

Photograph showing, data collection with LC*pro* + Meter for measuring carbon assimilation rate.

Appendix XVI. Production, Equipments and harvesting photographs

Photograph: SPAD meter, a product of Konica Minolta Sensing Ltd., Singapore.

Photograph: LC*pro*[+] (APMS) meter, a product of *ADC Ltd.*, United Kingdom.

Photograph showing, first flowering of the plant under the treatment of I_2G_2.

Photograph showing, a cluster of fruits are at ripening stage.

Photograph : Harvested fruit in the field.

Photograph : Grading of harvested fruit.