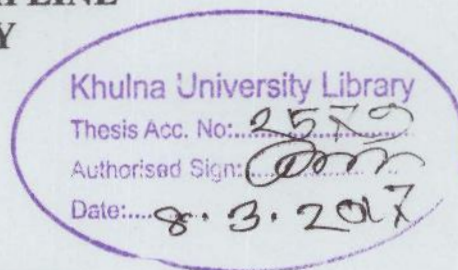


**EFFECT OF GROWTH REGULATOR (4-CPA) ON GROWTH AND
YIELD PERFORMANCE OF SUMMER TOMATO**

**A THESIS
SUBMITTED TO
AGROTECHNOLOGY DISCIPLINE
KHULNA UNIVERSITY
KHULNA-9208**



**By
Examination Roll No.: MS-150801**

In partial fulfillment of the requirements for the degree of

**MASTER OF SCIENCE (M.S.)
IN
HORTICULTURE**



**AGROTECHNOLOGY DISCIPLINE
KHULNA UNIVERSITY
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BANGLADESH**

DECEMBER, 2016

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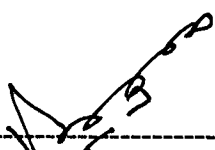
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Approved as to style and content

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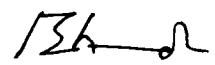
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DEDICATED TO
MY
BELOVED PARENTS

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ABSTRACT

An experiment was conducted to find out the effect of growth regulator (4-CPA) on growth and yield performance of summer tomato at the Germplasm Centre, Agrotechnology Discipline, Khulna University, Khulna during the period from May 2016 to September 2016. The single factor experiment comprised of different number of hormone application viz., T₀ (Control), T₁ (one time on 21 DAT), T₂ (two times on 21 and 28 DAT), T₃ (three times on 21, 28 and 35 DAT), T₄ (four times on 21, 28, 35 and 42 DAT) and T₅ (five times on 21, 28, 35, 42 and 49 DAT). The Experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. After 60 DAT, maximum plant height (110.00 cm) was recorded from the treatment T₅ and the minimum plant height (77.02 cm) was found from the treatment T₀. Maximum number of flowers per plant on 45 DAT (14.00) was recorded from the treatment T₄ and the minimum (6.67) was found from the treatment T₀. Maximum number of fruits per plant on 60 DAT (10.00) was found from the treatment T₁ and the minimum (6.00) was recorded from the treatment T₀. The maximum yield (15.58 t/ha) and benefit cost ratio (4.22) were found in the treatment T₃ whereas the minimum yield (9.32 t/ha) and benefit cost ratio (2.61) were recorded from the treatment T₀. The treatment T₃ could be recommended for summer tomato cultivation.



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LIST OF ABBREVIATIONS

AEZ	Agro-ecological Zone
AIS	Agricultural Information Service
BARI	Bangladesh Agricultural Research Institute
BARC	Bangladesh Agricultural Research Council
BBS	Bangladesh Bureau of Statistics
BCR	Benefit Cost Ratio
BINA	Bangladesh Institute of Nuclear Agriculture
CV (%)	Coefficient of Variation (%)
DAT	Days after Transplanting
DMRT	Duncan's New Multiple Range Test
FAO	Food and Agriculture Organizations of the United Nations
t/ha	Ton per hectare
LSD	Least Significance Difference
MoP	Muriate of Potash
ppm	Parts per million
RH	Relative humidity
RARS	Regional Agricultural Research Station
SRDI	Soil Resource Development Institute
TSP	Triple Super phosphate

CHAPTER I

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) is one of the most popular and nutritious vegetable crops in Bangladesh. It belongs to the family Solanaceae which is widely grown not only in Bangladesh but also in many countries of the world for its taste and nutritional status. It is cultivated in almost all home garden and also in the field for its adaptability to a wide range of soil and climate in Bangladesh. Tomato ranks next to potato and sweet potato in respect of vegetable production in the world (FAO, 2007). In Bangladesh it ranks 2nd which is next to potato (BBS, 2009) and top of the list of canned vegetables (Rashid, 2004).

Recent data show that the cultivated area under tomato in Bangladesh was 50,000 acre with a total production of 1,51,000 MT having an average of 2.98 t/ha (BBS, 2009). World production of the crop in 2013 was estimated to be 70 million tons from 2.7million hectare (FAO, 2013). However, in Bangladesh average yield of tomato is very low as compared to neighbouring country like India and Pakistan (Halder *et al.*, 2003). The low yield of tomato in Bangladesh, however, is not an indication of low potentiality of this crop, but it may be due to a number of reasons, viz. unavailability of quality seeds of improved varieties and improper agronomic management practices.

The food value of tomato is very rich because of higher contents of vitamin A, B and C including calcium and carotene (Bose and Som, 1986). The popularity of tomato and it's product is rising continuously. It is a delicious vegetable used in salad, soups and processed into stable products like ketchup, sauce, pickles, paste, chutney and juice. It also has a high medicinal value.

With the increase of population, the demand of tomato in our country is increasing day by day.

By producing more tomato we can earn a considerable amount of foreign exchange through exporting it. Further, for the food processing industries (juice, ketchup, sauces, chutney etc.), higher yield as well as year around tomato production is necessary. So, by increasing tomato producing area, we can fulfil our demand but due to limitations of lands, it is not possible. The most logical way to increase the total production of tomato at the national level from our limited land resources is to increase yield per unit area and increase tomato cropping intensity through growing in summer.

Tomato is considered to be a day neutral plant but it is not productive under high temperature ($> 30^{\circ}\text{C}$) due to thermo-sensitiveness for flowering. The crop performs better under an average monthly temperature of $20\text{-}25^{\circ}\text{C}$. But commercially, it may grow at temperature ranging from $15\text{-}27^{\circ}\text{C}$ (Haque *et al.*, 1999). Plant could set fruit abundantly when the night temperature is between $15^{\circ}\text{-}20^{\circ}\text{C}$ and the day temperature at about $22\text{-}25^{\circ}\text{C}$ (Kalloo, 1985). In Bangladesh, congenial atmosphere remains for tomato production during November to March. So, tomato is widely grown in Bangladesh usually in winter season. High temperature during day and night above 32° and 21°C were respectively recorded as limiting factor to fruit set due to impaired complex physiological processes in the pistil which results on floral or fruit abscission (Picken, 1984) during summer season. Both day and night temperature in Bangladesh is very high which is the major environmental challenges for tomato cultivation in summer season (Chowdhury, 1989). Therefore, it is very essential to find out the suitable varieties/genotypes those are tolerant to high temperature. In this regard, the scientists of different research Institutes in Bangladesh mainly Bangladesh Agricultural Research Institute (BARI) are successful in developing tomato varieties namely BARI tomato-3, BARI tomato-4, BARI tomato-10 (Anupama), BARI tomato-

13 (Shrabony) etc those are suitable for summer season and has been cultivated commercially for few years in Bangladesh.

However, the yield performance of summer tomato varieties is very poor. So, it is urgent to increase tomato yield by proper management and cultural practices. Plant growth regulators (PGRs) are one of the most important factors for increasing crop yield. Application of hormone has good management effect on growth and yield of tomato (AVRDC, 1990). On the other hand, flower and fruit abortion are common phenomenon in tomato. A large proportion of tomato reproductive structures abscise before reaching maturity, which is the primary cause of lowering yield in summer season (Mondal *et al.*, 2010). Fruit yield of tomato can be increased through reducing reproductive abscission. Hormones regulate abscission process and synthetic hormone may reduce abscission and ultimately increase yield of tomato (Abdel *et al.*, 1996).

Application of plant growth regulator seems to be one of the important practices in view of convenience, cost and labour efficiency. Recently, there has been global realization of the important role of PGRs in agriculture for better growth and yield of crops. Like other crop plants, the physiological mechanisms of tomato growth are hormonally mediated. Application of plant growth regulators has been shown to improve growth, fruit setting and yield in tomato (AVRDC, 1990). Sprays of hormone especially 4-chlorophenoxy acetic acid (4-CPA) on flower cluster effectively increase the fruit set as well as fruit production. 4-CPA has been found to be effective in improving tomato fruit set under higher temperature conditions (Kuo *et al.*, 1978). Now-a-days 4-CPA is used commercially in Korea, Japan and China to increase fruit set in tomatoes. The growth regulator has an important effect on the fruit retention of tomato as well as other horticultural crops and thus increasing the yield substantially (Younis and Tigani, 1977). 4-CPA is also used in reducing pre-harvest fruit drop and resulting in increased number of fruits and

yield in tomato crop. Therefore, an attempt was made to assess the effects of 4-CPA on fruit set and fruit size of tomato and ultimately yield.

As the fruit is important and comes in the off season, the farmer can get high profit due to higher price in market and can contribute to solve their financial problem. But the cultivation of summer tomato is not popular in Khulna region, as the farmers are not acquainted to it and there has been done a little work on summer tomato in the region. Most of the researcher applied the hormone two to three times in the life cycle of summer tomato. Some of them recommended to test the hormone by applying more times. Considering the above facts, the present research work was undertaken with the following objectives:

- i) To determine the adaptability and growing potentiality of summer tomato "BRAI hybrid tomato-4" in Khulna region; and
- ii) To assess the effect of 4-CPA on growth, morphological features and yield of summer tomato.

CHAPTER II

REVIEW OF LITERATURE

Tomato is one of the most important and widely used vegetables worldwide. The production level of summer tomato never meets the demand of Bangladesh. A large quantity was needed to import every year which may lead the process of losing foreign currency and reserve. Moreover, the country with high temperature and dry weather round the year lead the loss of production. Many researchers conducted their research to find out the effect of plant growth regulator on summer tomato and its profitability of cultivation. However, literatures available aspect in Bangladesh and abroad has been reviewed, here as follows

A field experiment was conducted by Karim *et al.* (2015) at the Horticulture Farm in the Department of Horticulture, Bangladesh Agricultural University, Mymensingh to evaluate the influence of different levels of 4-chlorophenoxy acetic acid on growth and yield potential of tomato during summer. The two-factor experiment *viz.*, Factor A: four different concentrations of 4-chlorophenoxy acetic acid (4-CPA) i.e., concentrations of 4-CPA were (i) 0 ppm (without 4-CPA), (ii) 20 ppm, (iii) 40 ppm and (iv) 60 ppm; and Factor B: two varieties of summer tomato namely, BARI Hybrid Tomato-4 and 8. The experiment was laid out in randomized complete block design with three replications. At harvest, the tallest plant (78.53cm), number of flowers and fruits (35.11 and 18.10, respectively) plant⁻¹, fruit yield plant⁻¹ and ha⁻¹ (1.12 kg and 21.98 tons, respectively) were found in BARI Hybrid Tomato-8. At harvest, the maximum plant height (85.57 cm), number of flowers and fruits (44.89 and 24.97, respectively) plant⁻¹, fruit yield and ha⁻¹ (1.32 kg and 27.78 tons, respectively) were found when 4-CPA applied at 60 ppm, whereas the minimum for these characters were recorded from control plants. In case of combined effect

of variety and plant growth regulator, the maximum plant height (88.90 cm), number of flowers and fruits (40.04 and 21.99, respectively), fruit yield plant⁻¹ and ha⁻¹ (1.34 kg and 28.28 tons, respectively) were observed in BARI Hybrid Tomato-8 when treated with 4-CPA at 60 ppm, and the minimum for all these characters were found in control plants. The results of the present study suggest that 4-CPA at 60 ppm can be practiced for increasing summer tomato production for both the varieties.

An experiment was carried out in pots at Bangladesh Institute of Nuclear Agriculture, Bangladesh by Rahman *et al.* (2015) to evaluate influence of different concentrations of GA₃ on biochemical parameters at different growth stages in order to maximize yield of summer tomato var. Binatomato-2. The concentrations of GA₃ were 0, 25, 50, 75 and 100 ppm. They were applied at three stages, namely root soaking of seedlings before transplanting, vegetative and flowering stages. The experiment was laid out in a randomized complete block design with four replications. Results indicated that the highest chlorophyll and soluble protein contents were recorded when GA₃ was applied through root soaking followed by vegetative stage and the lowest was found at the flowering stage. In contrast, the highest nitrate reductase activity was observed when GA₃ was applied at the vegetative stage and the lowest activity was recorded at the flowering stage. The applications of 50-75 ppm GA₃ had significantly encouraged the biochemical parameters studied at 50 DAT. The amount of GA₃ applied at different stages had significant influence on the yield and yield attributes of summer tomato. The highest plant height was recorded when 50 ppm of GA₃ was applied at the vegetative stage. While, the longest time to first fruit setting was required when the roots of the seedlings were soaked in 100 ppm GA₃ solution. The application of 50 ppm GA₃ by root soaking had significantly increased the number of flowers, fruits and fruit yield per plant but similar results were achieved when only 25 ppm



GA₃ was applied at the flowering stage. The fruit yield of tomato per plant increased linearly with the increased number of flowers and fruits per plant.

An experiment was conducted by Shemu *et al.* (2014) in the Horticulture farm of Sher-e-Bangla Agricultural University, Dhaka, during the period from April to October 2012 to quantify the effect of Tomatone on yield of summer tomato. The experiment consisted of four level of Tomatone, viz. H₀: no Tomatone (control), H₁: 1% Tomatone, H₂: 2% Tomatone and H₃: 3% Tomatone. The experiment was laid out in Randomized Complete Block Design with three replications. Results revealed that the significant variation was observed for the different growth contributing characters of summer tomato due to Tomatone. The longest plant (86.6cm), maximum number of leaves (50.2), maximum number of flowers per plant (63.4), highest number of fruits per plant (41.0), highest length of fruit (5.2 cm), highest weight of individual fruit (41.9 g), highest yield per plant (4.4 kg) and highest yield (22.7 t/ha) was found form H₂. On the other hand, lowest plant height, lowest yield, lowest number of leaves, flower and fruits was found form H₀ (control).

Baliyan *et al.* (2013) conducted an experiment to know the effects of different concentrations of 4-chlorophenoxyacetic acid (4-CPA) plant growth regulator hormone on fruit set, yield and economic benefit of tomato (*Lycopersicon esculentum* Mill) growing in high temperatures in Botswana (Southern Africa). In a field experiment laid under complete randomized block design, tomatoes flowers were treated with four different concentrations of 00 ppm (control), 15 ppm, 45 ppm and 75 ppm of 4-CPA growth regulator. Data collected involved number of fruit set, weight of small tomato, weight of cracked tomatoes, weight of cat face tomatoes, weight of rotten tomatoes, weight of pest damaged and marketable tomatoes. A two way analysis of variance (ANOVA) was performed using the SPSS software ver.19 to analyze the data. The application of

4-CPA hormone indicated a positive and significant effect on the fruit set and yields of tomato. A positive relationship between the hormone concentration and the fruit set as well as total yield of tomato was also established (higher the concentration, higher the fruit set and tomato yield). The 75 ppm concentration of 4-CPA resulted not only the highest increase in fruit set but also increased the tomato yield and hence economic benefit in tomato production increased. It was concluded that use of 4-CPA hormone increased the fruit set, yield and economic benefit of summer tomato production. Suggested future research can be conducted to observe the effect of higher concentration of the 4-CPA hormone on fruit set, yield and fruit quality of tomatoes.

Choudhury *et al.* (2013) carried out an investigation to assess the effect of different PGRs on tomato during summer season at Horticulture Farm of Sher-e-Bangla Agriculture University, Dhaka-1207. They have exposed the plant in plant growth regulators (PGR) viz. PGR_0 = Control, PGR_1 = 4-CPA (4-chloro-phenoxy acetic acid) @ 20 ppm, PGR_2 = GA_3 (gibberellic Acid) @ 20 ppm and PGR_3 = 4-CPA + GA_3 @20 ppm through foliar application. They have concluded that the growth and yield contributing characters of tomato plants were significantly differed due to different plant growth regulators. They have found the maximum plant height at 60 DAT, number of flowers cluster per plant, number of flowers per plant, number of fruits per plant, maximum individual fruit weight and maximum yield in the treatment PGR_3 , and the minimum for all parameters were found in control (PGR_0) treatment.

BINA (2009) applied sprunit (a growth hormone developed at Biological Science Department, Bangladesh Atomic Energy Agency) on tomato and observed increased flower production in sprunit applied plant than control.

Ahmed *et al.* (2008) conducted an experiment with a view to observing the performance of newly developed summer tomato hybrids during May 2008 to September 2008 at experimental field of Horticulture Research Centre, BARI, Gazipur. Number of fruits per plant, individual fruit weight, fruit size, etc. was significantly higher when the plants were treated with hormone. Fruit yield per plant was quite high in the hormone treated plant (1.57 kg) compared to untreated plants (0.90 kg). In general, all the hybrids were performed better when treated with hormone in respect of yield compared to their corresponding untreated plants. The hybrid WP7 × C-51 had the highest individual fruit weight (56.0 g). Among the hybrids, HT019 × WP10 had the highest fruit yield per plant (1.87 kg) closely followed by C-11 × WP10 (1.81 kg) when the plants were treated with hormone. The untreated plants of the hybrid lines C-41 × WP8, HT019 × WP10 and C-41 × WP10 produced more than 1.0 kg of fruits per plant. It was indicated bright scope of tomato production during summer through with and without hormone application, though application of hormone had positive effect on tomato yield.

Karim *et al.* (2008) conducted a study at Bagherpara thana under Jessore district to assess the profitability, contribution of factors to production and changes in socio-economic status of the farmers. About 42% and 21% of total variable cost was incurred for tunnel preparation and using human labour, respectively. The average yield of BARI hybrid tomato was found 32.78 t/ha. The average return per hectare over variable cost was observed to be Tk 11,44,387 on full cost basis and Tk 12,07,481 on cash cost basis. On an average benefit cost ratio was found to be 4.19 on full cost basis and 5.09 on cash cost basis. The cost per kilogram of hybrid tomato cultivation was Tk 10.94 and return from one kilogram of tomato production was Tk 45.83. The functional analysis shows that MP and TSP had positive significant contribution to yield while human labour, hormone, irrigation and seed had negative significant impact on yield of hybrid tomato.

The overall socio-economic status of the sample farmers was found increased by 20.33 percent. High price of tunnel materials, timely non availability of hormone, insect and diseases attack were reportedly the major problems for tomato production.

Zaman *et al.* (2006) was conducted a study to analyse the return of summer tomato cultivation by using the data collected from experimental plot in Regional Agricultural Research Station, Jamalpur. BARI released variety BARI Tomato-10 (Anupama) was performed best with a per hectare yield of 28240 kg. To cultivate summer tomato in one hectare of land, total variable cost incurred BDT 292936 and total cost of production was BDT 297936. Gross margin was BDT 695464, net return or profit was BDT 690464 and benefit cost ratio (BCR) was 3.32. It was observed that cultivation of summer tomato was profitable for Jamalpur region.

Sasaki *et al.* (2005) was conducted a field experiment on reduction of high temperature inhibition in tomato fruit set by plant growth regulators. They examined the effect of plant growth regulators on fruit set of tomato (*Lycopersicon esculentum* Mill.) under high temperature and in a controlled environment in the field under rain shelter. Tomato plants exposed to high temperature (34/20°C) had reduced fruit set. Treatments of plant growth regulators reduced the fruit set inhibition by high temperature to some extent, especially treatment with mixture of 4-chlorophenoxy acetic acid (4-CPA) and gibberellins (GAs). They have found, in the field experiment, tomato treated with a mixture of 4-CPA and Gas showed increased fruit set and the number of normal fruits (excluding abnormal types such as puffy fruit) were more than the plants treated with 4-CPA alone during summer.

Hossain (2003) investigated the effect of GA₃ on the production of tomato. He found that GA₃ applied at 50 and 100 ppm produced an increased fruit set. However, GA₃ treatment induced a

small size fruit. A gradual increase in the yield/plant was obtained with higher concentration of GA_3 .

Bhosle *et al.* (2002) carried out an investigation to know the effects of NAA (25, 50 and 75 ppm), gibberellic acid (15, 30 and 45 ppm) and 4-CPA (25, 50 and 75 ppm) on the growth and yield of tomato cultivars Dhanashree and Rajashree through the field experiment conducted in Rahuri, Maharashtra, India during the summer of 1997. They have concluded 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 gibberellic acid resulted in the highest number of primary branches of Dhanashree (4.16) and Rajashree (5.38), respectively. The highest marketable yield of Dhanashree and Rajashree resulted from treatment with 75 ppm 4-CPA.

Karakurt (2000) was studied on foliar application of 4-CPA in tomato hybrids under greenhouse conditions with pruning of some flowers in the inflorescence. He has concluded that foliar application of 4-CPA and pruning had positive effects on crop yield, development and maturation.

El-Habbasha *et al.* (1999) carried out a field experiment with tomato cv. castelrock over two growing seasons. The effects of GA_3 and 4-CPA on fruit yield and quality were investigated. Many of the treatments significantly increased fruit set percentage and total fruit yield and the percentages of puffy and parthenocarpic fruits compared to the controls.

Shittu and Adeleke (1999) investigated the effects of foliar application of GA_3 (0, 10, 250 or 500 ppm) on growth and development of tomatoes cv. 158-3 grown in pots. Plant height and

number of leaves were significantly enhanced by GA₃ treatment. Plants treated with GA₃ with 250 ppm were the tallest with the highest number of leaves.

Gupta *et al.* (1999) conducted a field experiment in Allahabad, Bangalore, Karnataka, India to investigate the effect of the plant growth regulators (PGRs) IAA and NAA (25 and 75 ppm), and of the 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 16.12% and iron content by 23.33%. The application of 75 ppm NAA+Humaur increased K content by 23.80% and Ca concentration by 52.38%. The Mg content increased by 43.84% due to the application of 25 ppm NAA+Humaur.

Tomar and Ramgiry (1997) studied that tomato plant treated with GA₃ showed significantly greater number of branches plant⁻¹ than untreated controls.

Cgsar *et al.* (1995) carried out a study in Antalya, Turkey, to determine the effect of vibration and 4-CPA (5, 10, 15, 20 and 40 ppm, applied 1-3 times to all clusters on fruit set of tomatoes in grown in an unheated greenhouse. Harvested fruits were screened for 4-CPA residues. Tomato cv. Dario was grown for autumn cropping and tomato cv. Argus was grown between December and March and in the spring. The highest yields were obtained in the 10-20 ppm 4-CPA treatments. Fruit deformation increased when increasing doses of 4-CPA were applied to Dario. Argus did not exhibit fruit deformation, but fruit diameter increased with increasing doses of 4-CPA. Fruits harvested from plants treated with 10, 20 and 40 ppm 4-CPA applied twice did not have 4-CPA residues. Vibration promoted fruit set during the autumn and spring seasons, but had

no effect on fruit set between December and March, necessitating the use of 4-CPA at this time to promote fruit set.

Sanyal *et al.* (1995) studied that the effects of plant growth regulators (IAA of NAA at 15, 25 or 50 ppm or GA₃ at 50, 75 or 100 ppm) and methods of plant growth regulator application on the quality of tomato fruits. Plant growth regulators had profound effects on fruit length, weight and sugar: acid ratio. The effects of presoaking seeds and foliar application of plant growth regulators were more profound than presoaking alone.

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

Randolph *et al.* (1989) conducted a field experiment on the effect of fruit-setting plant hormones and nitrogen level in relation to quality and storage life of tomatoes studied. The field plots were in commercial fields and consisted of replicated blocks in split-plot design. Plants were grown with two or more levels of nitrogen as ammonium sulphate applied usually in three side-dressed applications prior to, and during, the period when hormones were applied. Each nitrogen level was split into two plots, one untreated. The treated plot received hormone sprays, usually three replications of 50 ppm of 4-CPA spaced at 10-days to two week intervals. They have concluded that application of 4-CPA resulted in significant increase in both pointed and puffy fruit, as well as increase in early yield.



Chern *et al.* (1983) presented that one month old transplanted tomato plants were sprayed with 1, 10 or 100 ppm GA₃ and observed that GA₃ at 100 ppm increased leaf area, plant height and stem fresh and dry weight but 10 ppm inhibited the growth.

Lilov and Donchev (1984) observed that by the application of GA₃ at 20, 40 or 100 mg/L the yields were reduced compared with the non-treated control.

Leonard *et al.* (1983) reported that inflorescence development in tomato plants grown under low light regimes was promoted by GA₃ application directly on the inflorescence.

Wu *et al.* (1983) sprayed one-month old transplanted tomato plants with GA₃ at 1, 10 or 100 ppm and reported that GA₃ at 100 ppm increased plant height and leaf area.

Onofegharn (1981) carried out an experiment with tomato and sprayed GA₃ at 25- 1000 ppm. He observed that GA₃ promoted flower primordia production and the number of primordia produced or the pattern of primordia production over time.

Saleh und Abdul (1980) performed an experiment with GA₃ (25 or 50 ppm) applied 3 times in June or early July in summer tomato. They reported that GA₃ stimulated plant growth. The substance reduced the total number of flower plant⁻¹ but increased the total yield compared with the control. GA₃ also improved the fruit quality.

Mehra and Mathi (1975) reported that GA₃ treatment at 25 ppm improved the yield of tomato. The GA₃ resulted earlier setting and maturity.

Briant (1974) sprayed GA₃ on the growth of leaves of young tomato plants and observed that total leaf weight and area were increased by GA₃.

Hossain (1974) investigated the effect of GA₃ along with 4-CPA on the production of tomato. He found that GA₃ applied with 50,100 and 200 ppm produced an increased fruit set. However, GA₃

Gustafson (1960) sprayed tomato flower and flower buds of the first three clusters with GA₃ (35 and 70 ppm) and found that GA₃ improved fruit set but reduced fruit weight of tomato.

Rapport (1960) noted that GA₃ had no significant effect on fruit weight and size either at cool (11°C) or warm (23°C) night temperatures; but it strikingly reduced fruit size at an optimum temperature (17°C).

From the literature it has been observed that many researchers used PGRs (4-CPA) with different concentration which gave the higher yield. But there was a little research on number of application of 4-CPA hormone. For this reason the research has been based on number of application of 4-CPA hormone.

Chapter III

MATERIALS AND METHODS

This chapter includes the information regarding materials and methods that were used in carrying out the experiment. It consists a short description of location of the experimental site, characteristics of soil, climate, materials used for the experiment, raising of seedlings, treatments of the investigation, layout and design, land preparation, manuring and fertilizing, transplanting of seedlings, intercultural operations, harvesting, data collection procedure, economic and statistical analyses. The important topics of materials and methods that have been described under the following subheads:

3.1 Experimental site

The field experiment was conducted at Germplasm centre of Agrotechnology Discipline, Khulna University, Khulna during the period from May 2016 to September 2016 to study the production potentiality and profitability of summer tomato with hormone application in Khulna District of Bangladesh. Experimental field was located at 89°33' E Longitudes and 22°50' N Latitude at an altitude of 8 meters above the sea level (UNDP, 1988).

3.2. Climate of the experimental site

The climate of the experimental area was subtropical in nature, which was characterized by high temperature, heavy rainfall, high humidity and relatively long day during the months of April to September and low rainfall associated with moderately low temperature, low humidity and short day during the rest of the year. Information regarding monthly maximum, minimum and average temperature, relative humidity, and rainfall and average sunshine hours as recorded by Weather station of Khulna which is adjacent to Khulna University during the experimental period has been presented in Appendix II

3.3. Characteristics of soil

The experiment was carried out on a medium high land belonging to Agro-ecological Zone -13, (AEZ-13) i.e. Gangetic tidal floodplain. The texture of the soil was clay-loam with a pH of 7.4. Soil samples of the experimental plots were collected from a depth of 0 to 15 cm before conducting the experiment and analyzed in SRDI Laboratory, Daulatpur, Khulna and presented in Appendix I.

3.4. Plant material used

The tomato variety used in the experiment was BARI Tomato-4. The seeds were collected from Regional Agricultural Research Station (RARS), Jessore which is a branch of BARI.

BARI Tomato -4

It was a high yielding summer variety that was released by BARI. The fruits of this variety were bigger in size and fleshy portion of fruits were attractively red. The average weight of each fruit was 50 g and each plant contained average 30-35 fruits. Fruits came generally 50-60 days after transplanting. Life cycle of this variety is 80-90 days and yield and average yield was 20-24 t/ha.

3.5. Raising of seedlings

Tomato seedlings were raised in separate seedbeds of 3m × 1m size and the land was 15-20 cm high from the ground. The soil was well prepared and converted into loose friable and dried mass by spading. All weeds and stubbles were removed. Ten grams of seeds were sown in each seedbed on 20 May, 2016. After sowing, the seeds were covered with light soil. Heptachlor 40 WP was applied around each seedbed at the rate of 4 kg/ha as precautionary measure against ants and worms. The emergence of seedlings took place within 5 to 6 days after sowing. Weeding, mulching and irrigation were done as and when necessary. The seedlings were covered by transparent polythene sheet supported by bamboo structure to protect from heavy rainfall.

Shading was given by bamboo mat (chatai) to protect the seedlings from scorching sunlight. The seedlings were also covered by 40-60 mesh nylon net to protect from the white fly. Tomato seedlings were raised at the Germplasm centre of Agrotechnology Discipline, Khulna University, Khulna with special care.

3.6. Treatments of the experiment

A variety named BARI Tomato-4 and six different types of treatments were used in this experiment. The treatments were mainly number of application of hormone 4-chlorophenoxy acetic acid (4-CPA) at 1% concentration. Hormone was applied generally 7 days interval after first spray. It was applied generally in the morning between 9 am-10 am for better result.

The treatments enlisted below:

T₀: Control (No hormone application)

T₁: Application of 4-CPA one time on 21 DAT.

T₂: Application of 4-CPA two times on 21 and 28 DAT.

T₃: Application of 4-CPA three times on 21, 28 and 35 DAT.

T₄: Application of 4-CPA four times on 21, 28, 35 and 42 DAT.

T₅: Application of 4-CPA five times on 21, 28, 35, 42 and 49 DAT.

3.11. Transplanting of summer tomato seedlings

Seedlings were transplanted in the experimental plots on June 25, 2016. Healthy and uniform sized, 30 days old seedlings were used as transplanting materials. Seed beds were watered before uprooting of the seedlings to minimize damage to the roots of seedlings. Transplanting was done in the afternoon at a spacing of 60 cm x 40 cm accommodating 12 plants in each unit plot. After transplanting, the seedlings were watered immediately. Until the seedlings were established, watering were continued for 7 days when necessary. A number of seedlings were also planted around the experimental area for gap filling and to check the border effect.

3.12. Application of hormone

An artificial plant hormone named 4-chlorophenoxy acetic acid (4-CPA) was applied in the plants of the plots for achieving more flowers and fruits. The hormone was applied at 1 % concentration with foliar spray by small hand sprayer. At first it was applied in the experimental plots in July 15, 2016 which was 21 days after transplantation. Then it was applied another 4 times with 7 days intervals. Hormones were generally applied between 9 am-10 am.

3.13. Intercultural operations

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

3.13.1. Gap filling

When the tomato 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 seedlings failed to survive.

3.13.2. Weeding

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

3.13.3. Staking

When the tomato plants were well established, staking was done using bamboo sticks to keep the plants upright.

3.13.4. Irrigation

Light irrigation was given by a watering can at every morning and afternoon following transplanting and it was continued for a week for rapid and well establishment. Two irrigations were given throughout the growing period by a watering cane. The first irrigation was given at 30 day after planting followed by second irrigation at 15 day after the first irrigation. Light irrigation was done after each hormone application Mulching was also done by breaking the soil crust after each irrigation.

3.13.5. Plant protection

Insect pests control

Malathion 57EC was applied @ 2 ml/liter as preventive measure against insect pests like cut worms, leaf hoppers and fruit borers. The insecticides were applied fortnightly as a routine work from a week after transplanting to a week before first harvesting

Diseases control

Precautionary measure against diseases especially damping off of summer tomato was taken by spraying Dithane M-45 or Rovral @ 2 g/l fortnightly during the early vegetative stage. Ridomil MZ 75WP was also applied at the rate of 2 g/l against late blight disease of tomato. Leaf curl of tomato, a viral diseases was controlled by protecting seedbed from white fly by using 40-60 mesh nylon net around the seed bed.

3.14. Harvesting

Ripening of summer tomato was started 60 days after seedling transplanting when the fruit was turned into the attractive red colour. Fruits were harvested 5-6 times within 3-4 weeks. In the experiment first harvest was done at August 15, 2016. Fruits were harvested by hand picking.

3.15. Data collection

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

3.15.1. Plant height

Plant height was measured from the sample plants in centimetre from the ground level to the tip of the longest stem and mean value was calculated. Plant height was recorded from 15 days of planting up to 60 days at 15 days interval to observe the growth rate of plants.

3.15.2. Number of leaves per plant

Number of leaves per plant was counted on 15, 30, 45 and 60 DAT from randomly selected five plants from each plot.

3.15.3. Leaf length

Length of the leaf was measured from the base of the petiole to the tip of leaf with a scale and was recorded in centimeter at 15, 30, 35 and 60 DAT.

3.15.4. Leaf breadth

Breadth of the leaf was measured at the widest part of the leaf by a meter scale and was expressed in centimeter at 15, 30, 35 and 60 DAT.

3.15.5. Number of flowers per plant

The number of flowers was counted from the sample plants periodically, and average number of flower produced per plant was recorded at 30, 45 and 60 DAT.

3.15.6. Number of fruits per plant

The number of fruits was counted from the sample plants periodically, and average number of flower produced per plant was recorded at 30, 45 and 60 DAT.

3.15.7. Fruit length

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

3.15.8. Fruit breadth

Breadth of fruit was measured at the middle portion of 20 selected marketable fruits from each plot with a slide calipers, and their average was calculated in centimeter.

3.15.9. Weight of individual fruit

Among the harvests of marketable fruits during the period from first to final harvest, the first and the last harvests were omitted, and the remaining harvests were used for obtaining the individual fruit weight (g) by the following formula:

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

3.15.10. Fruit yield per plot

It is the total weight of fruits from all plants per plot. An electric balance was used to take the weight of fruits per plot. It was measured by totaling of fruit yield from each unit plot separately during the period from first to final harvest and was recorded in kilogram (kg).

3.15.11. Fruit yield per hectare

Fruit yield was calculated as t/ha by the following formula:

$$\text{Fruit yield (ton) per hectare} = \frac{\text{Fruit yield per plot (kg)} \times 10000 \text{ (m}^2\text{)}}{\text{Area of plot in square meter (m}^2\text{)} \times 1000}$$

3.16. Economic analysis

Economic analysis was done in order to find out the most profitable treatment.

3.16.1. Total cost of production of summer tomato

Total material input costs, non-material input costs, interests on fixed capital of land and miscellaneous costs were considered for calculation of total cost of production. Interest was calculated at the rate of 12% for six months and miscellaneous cost was considered as 5% of the total input cost.

3.16.2. Gross income

Gross income was calculated based on the sale price (BDT – 80 Tk/kg) of marketable fruit of summer tomato.

3.16.3. Net return

Net return was calculated by deducting the total production cost from the gross return for each treatment combination

3.16.4. Benefit cost ratio

The economic indicator BCR was calculated using following formula for each treatment.

$$\text{Benefit Cost Ratio} = \frac{\text{Gross income per hectare}}{\text{Total cost of production per hectare}}$$

3.17. Statistical analysis of data

The collected data on various parameters under study were statistically analyzed using MSTAT-C statistical program. Means for all the treatments were calculated and analyses of variances for all the characters under consideration were performed by F test. Significance of differences among the treatment means were evaluated by Duncan's New Multiple Range Test (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The results obtained from the effect of number of application of 4-chlorophenoxy acetic acid (4-CPA) hormone at same concentrations on various growth characters and yield of summer tomato have been presented and discussed under the following headings.

4.1 Plant height

The variation in plant height due to number of application of hormone 4-chlorophenoxy acetic acid (4-CPA) was statistically significant in summer tomato on 30, 45 and 60 days after transplanting (DAT) (Table 2). On 30 DAT the maximum plant height (86.34 cm) was found in the treatment T₁ (Application of 4-CPA one time on 21 DAT) and minimum plant height (58.14 cm) was observed in the treatment T₀ (Control). In case of 45 DAT the maximum plant height (106.28 cm) was recorded in the treatments T₄ (Application of 4-CPA four times on 21, 28, 35 and 42 DAT) and minimum plant height (68.47 cm) was observed in the treatment T₀ (Control). Finally on 60 DAT the maximum plant height (110.0 cm) was recorded in the treatment T₅ (Application of 4-CPA five times on 21, 28, 35, 42 and 49 DAT) and minimum plant height (77.02 cm) was recorded in the treatment T₀ (Control).

Baliyan *et al.* (2013) also reported that application of 4-CPA (4-chlorophenoxy acetic acid) had a positive effect on plant height.

The variation in plant height of summer tomato on different days after transplanting (DAT) has been represented in Table 2.

Table 2: Effect of hormone (4-CPA) application on plant height of summer tomato

Treatment	Plant height (cm)		
	30 DAT	45 DAT	60 DAT
T ₀	58.14 b	68.47 b	77.02 b
T ₁	86.34 a	99.03 a	103.8 a
T ₂	84.66 a	98.85 a	103.3 a
T ₃	81.72 a	100.2 a	104.7 a
T ₄	78.66 a	106.28 a	109.7 a
T ₅	82.62 a	106.21 a	110.0 a
Level of Significance	**	**	**
LSD _(0.05)	11.06	8.25	7.07
CV (%)	5.43	3.30	2.69

T₀: Control (No hormone application); T₁: Application of 4-CPA one time on 21 DAT; T₂: Application of 4-CPA two times on 21 and 28 DAT; T₃: Application of 4-CPA three times on 21, 28 and 35 DAT; T₄: Application of 4-CPA four times on 21, 28, 35 and 42 DAT; T₅: Application of 4-CPA five times on 21, 28, 35, 42 and 49 DAT.

** =Significant at 1% level.

4.2. Number of leaves per plant

The number of leaves produced per plant under different time of application of hormone was statistically significant on 30, 45 and 60 DAT (Table 3). On 30 DAT, the treatment T₄ (Application of 4-CPA at four times on 21, 28, 35 and 42 DAT) also produced maximum number of leaves (16.00) which was similar to T₁ (Application of 4-CPA one time on 21 DAT), T₂ (Application of 4-CPA two times on 21, and 28 DAT), T₃ (Application of 4-CPA three times on 21, 28, and 35 DAT) and minimum was found from the T₀ (control) treatment i.e., (10.00) leaves. On 45 DAT, the maximum number of leaves per plant (22.00) was recorded from the T₃ (Application of 4-CPA three times on 21, 28, and 35 DAT) and the minimum (13.00) was found from the T₀ (Control) treatment. Finally on 60 DAT, the maximum number of leaves per plant (26.67) was found from the T₃ (Application of 4-CPA three times on 21, 28, and 35 DAT) and the minimum (15.00) was found from the T₀ (Control) treatment.

The result obtained from the present study was consistent with result of Tomar and Ramgiriy (1997) in tomato who stated that leaf number increased in hormone applied plants than control plants.

The variation in number of leaves per plant of summer tomato on different days after transplanting (DAT) has been represented in Table 3.

Table 3: Effect of hormone (4-CPA) application on number of leaves per plant of summer tomato



Treatment	Number of leaves per plant		
	30 DAT	45 DAT	60 DAT
T ₀	10.00 b	13.00 c	15.00 c
T ₁	16.00 a	19.00 b	21.67 b
T ₂	16.00 a	21.33 ab	24.33 ab
T ₃	16.00 a	22.00 a	26.67 a
T ₄	16.00 a	21.33 ab	26.00 ab
T ₅	15.67 a	20.33 ab	25.00 ab
Level of Significance	**	**	**
LSD _(0.05)	3.05	2.71	4.55
CV (%)	7.89	5.38	7.60

T₀: Control (No hormone application); T₁: Application of 4-CPA one time on 21 DAT; T₂: Application of 4-CPA two times on 21 and 28 DAT; T₃: Application of 4-CPA three times on 21, 28 and 35 DAT; T₄: Application of 4-CPA four times on 21, 28, 35 and 42 DAT; T₅: Application of 4-CPA five times on 21, 28, 35, 42 and 49 DAT.

** =Significant at 1% level.

4.3. Leaf length

The variation in leaf length due to number of application of hormone 4-CPA (4-chlorophenoxy acetic acid) was statistically significant in summer tomato on 30, 45 and 60 days after transplanting (DAT) (Table 4). On 30 DAT the maximum leaf length (30.60 cm) was observed in the treatments T₅ (Application of 4-CPA five times on 21, 28, 35, 42 and 49 DAT) and minimum leaf length (16.82 cm) was observed in the treatment T₀ (Control). In case of 45 DAT the maximum leaf length (32.78 cm) was found in the treatments T₅ (Application of 4-CPA five times on 21, 28, 35, 42 and 49 DAT) and minimum leaf length (19.13 cm) was recorded in the treatment T₀ (Control). Finally on 60 DAT the maximum leaf length (33.93 cm) was observed in the treatments T₅ (Application of 4-CPA five times at 21, 28, 35, 42 and 49 DAT) and minimum leaf length (21.97) cm was recorded in the treatment T₀ (Control). In most of cases it was found that treatment T₅ (Application of 4-CPA five times on 21, 28, 35, 42 and 49 DAT) gave the higher leaf length and the treatment T₀ (control) gave the lower result.

Karakurt (2000) found that foliar application of 4-chlorophenoxy acetic acid (4-CPA) had increased the leaf length and breadth of summer hybrid tomato.

The variation in leaf length of summer tomato on different days after transplanting (DAT) has been represented in Table 4.

Table 4: Effect of hormone (4-CPA) application on leaf length of summer tomato

Treatment	Leaf length (cm)		
	30 DAT	45 DAT	60 DAT
T ₀	16.82 b	19.13 c	21.97 b
T ₁	30.52 a	31.62 ab	32.62 a
T ₂	29.71 a	31.82 ab	32.69 a
T ₃	28.52 a	30.95 b	33.11 a
T ₄	30.01 a	32.16 ab	33.30 a
T ₅	30.60 a	32.78 a	33.93 a
Level of Significance	**	**	**
LSD _(0.05)	2.03	1.42	1.27
CV (%)	2.84	1.84	1.57

T₀: Control (No hormone application); T₁: Application of 4-CPA one time on 21 DAT; T₂: Application of 4-CPA two times on 21 and 28 DAT; T₃: Application of 4-CPA three times on 21, 28 and 35 DAT; T₄: Application of 4-CPA four times on 21, 28, 35 and 42 DAT; T₅: Application of 4-CPA five times on 21, 28, 35, 42 and 49 DAT.

** =Significant at 1% level.

4.4. Leaf breadth

The leaf breadth under different number of application of hormone was statistically significant on 30, 45 and 60 DAT (Table 5). On 30 DAT the maximum leaf breadth (19.48 cm) was found in the treatments T_5 (Application of 4-CPA five times on 21, 28, 35, 42 and 49 DAT) and minimum leaf breadth (12.15 cm) was recorded in the treatment T_0 (Control). In case of 45 DAT the maximum leaf breadth (22.07 cm) was found in the treatments T_5 (Application of 4-CPA five times on 21, 28, 35, 42 and 49 DAT) and minimum leaf breadth (15.01 cm) was found in the treatment T_0 (Control). Finally on 60 DAT the maximum leaf breadth (23.85 cm) was observed in the treatments T_4 (Application of 4-CPA four times on 21, 28, 35, and 42 DAT) and minimum leaf breadth (18.03 cm) was recorded in the treatment T_0 (Control).

Karakurt (2000) found that foliar application of 4-CPA (4-chlorophenoxy acetic acid) had increased the leaf length and breadth of summer hybrid tomato.

The variation in leaf breadth of summer tomato on different days after transplanting (DAT) has been represented in Table 5.

Table 5: Effect of hormone (4-CPA) application on leaf breadth of summer tomato

Treatment	Leaf breadth (cm)		
	30 DAT	45 DAT	60 DAT
T ₀	12.15 b	15.01 d	18.03 c
T ₁	17.85 a	20.57 c	21.50 b
T ₂	18.36 a	21.21 abc	23.50 a
T ₃	18.01 a	21.02 bc	23.27 a
T ₄	18.90 a	21.61 ab	23.85 a
T ₅	19.48 a	22.07 a	23.62 a
Level of Significance	**	**	**
LSD _(0.05)	1.58	0.89	1.31
CV (%)	3.50	1.71	2.27

T₀: Control (No hormone application); T₁: Application of 4-CPA one time on 21 DAT; T₂: Application of 4-CPA two times on 21 and 28 DAT; T₃: Application of 4-CPA three times on 21, 28 and 35 DAT; T₄: Application of 4-CPA four times on 21, 28, 35 and 42 DAT; T₅: Application of 4-CPA five times on 21, 28, 35, 42 and 49 DAT.

** =Significant at 1% level.

4.5. Number of flowers per plant

The variation of number of flowers per plant was significant on 45 and 60 DAT due to application of treatment (Table 6). In case of 45 DAT the maximum number of flowers per plant (14.00) was recorded in the treatment T₄ (Application of 4-CPA four times on 21, 28, 35, and 42 DAT) and minimum number of flowers per plant (6.67) was found in the treatment T₀ (Control). Finally at 60 DAT the maximum number of flowers per plant (10.00) was found in the treatment T₄ (Application of 4-CPA four times on 21, 28, 35, and 42 DAT) and minimum number of flowers per plant (4.00) was recorded in the treatment T₀ (Control).

Karim *et al.* (2015) reported that the foliar application of 4-CPA (4-chlorophenoxy acetic acid) hormone increased the number of flower and fruit per plant of summer tomato.

The variation in number of flowers per plant of summer tomato on different days after transplanting (DAT) has been represented in Table 6.

Table 6: Effect of hormone (4-CPA) application on number of flowers per plant of summer tomato

Treatment	Number of flowers per plant		
	30 DAT	45 DAT	60 DAT
T ₀	10.00	6.67 d	4.00 c
T ₁	16.67	7.67 cd	5.00 bc
T ₂	15.34	12.00 ab	7.00 b
T ₃	17.67	13.67 a	9.67 a
T ₄	15.33	14.00 a	10.00 a
T ₅	16.33	10.00 bc	7.00 b
Level of Significance	NS	**	**
LSD _(0.05)		2.54	2.09
CV (%)	17.94	9.22	11.39

T₀: Control (No hormone application); T₁: Application of 4-CPA one time on 21 DAT; T₂: Application of 4-CPA two times on 21 and 28 DAT; T₃: Application of 4-CPA three times on 21, 28 and 35 DAT; T₄: Application of 4-CPA four times on 21, 28, 35 and 42 DAT; T₅: Application of 4-CPA five times on 21, 28, 35, 42 and 49 DAT.

** =Significant at 1% level, NS= Non Significant.

4.6. Number of fruits per plant

The variation of number of fruits per plant was significant on 60 DAT due to application of treatment (Table 7). In case of 60 DAT the maximum number of fruits per plant (10.00) was found in the treatment T₁ (Application of 4-CPA one time on 21 DAT) and minimum number of fruits per plant (6.00) was observed in the treatment T₀ (Control).

Kaim *et al.* (2015) reported that the foliar application of 4-CPA (4-chlorophenoxy acetic acid) hormone increased the number of flowers and fruits per plant of summer tomato.

The variation in number of fruits per plant of summer tomato on different days after transplanting (DAT) has been represented in Table 7.

Table 7: Effect of hormone (4-CPA) application on number of fruits per plant of summer tomato

Treatment	Number of fruits per plant		
	30 DAT	45 DAT	60 DAT
T ₀	3.00	7.00	6.00 c
T ₁	3.67	14.00	10.00 a
T ₂	4.00	11.67	6.67 bc
T ₃	5.00	13.00	9.00 ab
T ₄	3.67	11.00	8.67 abc
T ₅	5.67	12.67	8.67 abc
Level of Significance	NS	NS	*
LSD _(0.05)			2.57
CV (%)	27.01	23.52	17.32

T₀: Control (No hormone application); T₁: Application of 4-CPA one time on 21 DAT; T₂: Application of 4-CPA two times on 21 and 28 DAT; T₃: Application of 4-CPA three times on 21, 28 and 35 DAT; T₄: Application of 4-CPA four times on 21, 28, 35 and 42 DAT; T₅: Application of 4-CPA five times on 21, 28, 35, 42 and 49 DAT.

** =Significant at 1% level, NS= Non Significant.

4.7. Fruit length

The variation in fruit length of summer tomato was significant due to different treatments (Table 8). The maximum fruit length (4.08 cm) was found in the treatment T₄ (Application of 4-CPA four times on 21, 28, 35, and 42 DAT) and minimum fruit length (3.11 cm) was observed in the treatment T₀ (Control).

4.8. Fruit breadth

Difference among the fruit breadth of summer tomato was significant due to different treatments (Table 8). The maximum fruit breadth (4.85 cm) was observed in the treatment T₄ (Application of 4-CPA four times on 21, 28, 35, and 42 DAT) and minimum fruit breadth (3.71 cm) was found in the treatment T₀ (Control).

Shemu *et al.* (2014) reported that the foliar application of 4-CPA (4-chlorophenoxy acetic acid) hormone increased the length and breadth of summer tomato.

4.9. Weight of individual fruit

The variation in weight of individual fruit of summer tomato was significant due to different treatments (Table 8). The maximum individual fruit weight (47.45 g) was found in the treatment T₂ (Application of 4-CPA two times on 21 and 28 DAT) and minimum individual fruit weight (33.42 g) was in the treatment T₀ (Control).

4.10. Yield per plot

Difference among the yield per plot of summer tomato was significant due to different treatments. (Table 8) The maximum yield per plot (5.05 kg) was observed in the treatment T₃ (Application of 4-CPA three times on 21, 28 and 35 DAT) and minimum yield per plot (3.02 kg) was found in the treatment T₀ (Control).

4.11. Yield per hectare

The variation in the yield per hectare of summer tomato was significant due to different treatments. (Table 8) The maximum yield per hectare (15.58 t/ha) was found in the treatment T₃ (Application of 4-CPA three times on 21, 28 and 35 DAT) and minimum yield per hectare (9.32 t/ha) in the treatment T₀ (Control). The yield of summer tomato was moderate. It could be improved if better environmental condition and soil fertility exist.

Choudhury *et al.* (2013) reported that application of 4-CPA (4-chlorophenoxy acetic acid) hormone improved the individual fruit weight which increased the fruit yield per pot and hectare.

The variation in fruit length, fruit breadth, individual weight of fruit, fruit yield per plot and fruit yield per hectare has been represented in the Table 8.

Table 8: Effect of hormone (4-CPA) application on fruit length, fruit breadth, weight of individual fruit, fruit yield per plot and fruit yield per hectare of summer tomato

Treatment	Fruit length (cm)	Fruit breadth (cm)	Weight of individual fruit (g)	Yield per plot (kg)	Yield per hectare (ton)
T ₀	3.11 c	3.71 b	33.42 c	3.02 c	9.32 b
T ₁	3.56 b	4.37 a	36.42 bc	4.03 b	12.43 a
T ₂	3.78 ab	4.80 a	47.45 a	4.46 b	13.77 a
T ₃	3.86 ab	4.68 a	47.16 a	5.05 a	15.58 a
T ₄	4.08 a	4.85 a	42.39 ab	4.15 b	12.42 a
T ₅	3.96 ab	4.69 a	45.15 a	3.96 bc	12.23 a
Level of Significance	**	**	**	**	**
LSD _(0.05)	0.41	0.50	8.30	0.43	3.72
CV (%)	4.34	4.32	7.64	8.48	11.57

T₀: Control (No hormone application); T₁: Application of 4-CPA one time on 21 DAT; T₂: Application of 4-CPA two times on 21 and 28 DAT; T₃: Application of 4-CPA three times on 21, 28 and 35 DAT; T₄: Application of 4-CPA four times on 21, 28, 35 and 42 DAT; T₅: Application of 4-CPA five times on 21, 28, 35, 42 and 49 DAT.

** =Significant at 1% level.

CHAPTER-V

SUMMARY AND CONCLUSIONS

An experiment was conducted to find out the effect of growth regulator (4-CPA) on growth, yield and economic performance of summer tomato at Germplasm Centre, Agrotechnology Discipline, Khulna University, Khulna during the period from May 2016 to September 2016. The single factor experiment comprised of different number of hormone application viz., T₀ (Control), T₁ (Application of 4-CPA one time on 21 DAT), T₂ (Application of 4-CPA two times on 21 and 28 DAT), T₃ (Application of 4-CPA three times on 21, 28 and 35 DAT), T₄ (Application of 4-CPA four times on 21, 28, 35 and 42 DAT) and T₅ (Application of 4-CPA five times on 21, 28, 35, 42 and 49 DAT). Size of each unit plot was 1.8 m x 1.8 m i.e., 3.24 m². Thirty days old seedlings were transplanted on 25 June, 2016 and 12 plants were accommodated in each plot following a spacing of 60 cm x 40 cm and the crops were harvested from 15 August to mid September, 2016. From each plot, plants were randomly selected and tagged for collection of data. Observations were made on the height of plant, number of leaves per plant, leaf length, leaf breadth, number of flowers per plant, number of fruits per plant on (30, 45 and 60 DAT), fruit length, fruit breadth, weight of individual fruit, fruit yield per plot and fruit yield per hectare. An economic analysis was also done to evaluate the profitability of the crops. Collected data were statistically analyzed and the means were compared with the Duncan's New Multiple Range Test (DMRT).

Different treatments influenced the growth and yield characters of summer tomato significantly. On 60 DAT, maximum plant height (110.00 cm) was recorded for the treatment T₅ (Application of 4-CPA five times on 21, 28, 35, 42 and 49 DAT) and in the minimum plant height (77.02 cm) was recorded for the treatment T₀ (Control).

Maximum numbers of leaves per plant was recorded (26.67) for the treatment T₃ (Application of 4-CPA three times on 21, 28, and 35 DAT) whereas the minimum number of leaves (15.00) was obtained from the treatment T₀ (Control).

Length and breadth of the leaf per plant were significantly influenced by hormone application. On 60 DAT, maximum leaf length (33.93 cm) was recorded from the treatment T₅ (Application of 4-CPA five times on 21, 28, 35, 42 and 49 DAT) and minimum (21.97 cm) from the treatment T₀ (Control).

Breadth of the leaf on 60 DAT, maximum (23.62 cm) was observed from the treatment T₅ (Application of 4-CPA five times on 21, 28, 35, 42 and 49 DAT) and minimum (18.03 cm) was found from the treatment T₀ (Control).

Number of flowers and fruits per plant was significant under different treatment. Number of flowers per plant on 45 DAT maximum (14.00) and minimum (6.67) was found from the treatment T₄ (Application of 4-CPA four times on 21, 28, 35, 42 and 49 DAT) and control respectively. Number of fruits per plant on 60 DAT maximum (10.00) and minimum (6.00) was observed from T₁ (Application of 4-CPA one time on 21 DAT) and control respectively.

Fruit length and breadth was significant in different treatment. The maximum fruit length (4.08 cm) and minimum (3.11 cm) was observed from the treatment T₄ (Application of 4-CPA four times on 21, 28, 35, 42 and 49 DAT) and control respectively. The maximum fruit breadth (4.85 cm) and minimum (3.71) cm was also observed from the treatment T₄ and control respectively.

According to the result, the maximum weight of individual fruit (47.45 g) was found in the treatment T₂ (Application of 4-CPA two times on 21 and 28 DAT) and the lowest (33.42 g) was recorded from the treatment T₀ (Control).

Yield per plot and yield per hectare were significantly influenced by number of application of hormone. The highest yield per plot (5.05 kg) and yield per hectare (15.58 ton) was obtained from the treatment T₃ (Application of 4-CPA three times on 21, 28 and 35 DAT) and the lowest yield per plot (3.02 kg) and yield per hectare (9.32 ton) was obtained from the treatment T₀ (Control).

The treatment T₃ (Application of 4-CPA three times on 21, 28 and 35 DAT) yielded significantly highest benefit cost ratio (4.22) and the minimum benefit cost ratio (2.61) was obtained from the treatment control affect net return severely. So, it was observed that the treatment T₃ (Application of 4-CPA three times on 21, 28 and 35 DAT) was more profitable than other treatment.

From the present study the following conclusion could be made:

- ❑ It was observed that higher yield could be obtained by cultivating the variety BARI tomato-4 in Khulna of Bangladesh.
- ❑ The morphological and yield attributing characteristics was increased by 4-CPA hormone and the highest BCR and more return was obtained from the treatment T₃ (Application of 4-CPA at 1% concentration on 21, 28 and 35 DAT) than others.

However, the present study was carried out in Khulna University, Khulna in one season with 6 treatments only. Further trial of this study in different locations of the country with more treatment combinations is necessary before final recommendation at farmer's level.



CHAPTER VI

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Appendix I: Chemical properties of soil from the experimental field

Parameters	Soil pH		EC (dS/m)		Organic matter (%)		Potassium (mg/ 100 g soil)		Total nitrogen (%)		Phosphorus (μ g/ g soil)		Zinc (μ g/ g soil)		Boron (μ g/ g soil)	
	After applicati on	After harvest	After applicat ion	After harvest	After applicat ion	After harvest	After applicat ion	After harvest	After applicat ion	After harvest	After applicat ion	After harvest	After applicat ion	After harvest	After applicat ion	After harvest
T ₀	7.6	7.3	4.18	4.56	4.73	5.01	0.36	0.34	0.176	0.157	45.56	40.03	1.47	1.19	1.77	1.83
T ₁	7.4	7.2	5.32	5.07	3.69	4.70	0.46	0.48	0.178	0.158	60.90	55.13	1.69	1.27	1.78	1.73
T ₂	7.3	7.2	5.20	4.82	6.44	5.84	0.60	0.41	0.178	0.158	40.10	32.08	2.38	2.03	1.78	1.95
T ₃	7.3	7.0	5.32	5.20	6.29	5.41	0.49	0.48	0.178	0.159	48.41	37.65	2.73	1.73	2.14	1.74
T ₄	7.2	7.2	5.58	4.94	5.13	5.48	0.65	0.55	0.179	0.157	65.02	58.33	2.62	2.21	2.45	2.54
T ₅	7.5	7.3	3.80	3.93	5.44	5.43	0.39	0.34	0.172	0.154	54.00	47.54	1.55	1.33	1.61	1.95
Range (Min. to Max.)	7.2-7.6	7.0-7.3	3.80- 5.58	3.93- 5.20	3.69- 6.44	4.70- 5.84	0.36- 0.65	0.34- 0.55	0.172- 0.179	0.154 0.159	40.10 65.02	37.65 58.33	1.47- 2.73	1.19- 2.21	1.61- 2.45	1.73- 2.54
Mean	7.38	7.20	4.90	4.75	5.28	5.31	0.49	0.43	0.177	.157	52.33	45.13	2.07	1.63	1.96	1.92

Source: Soil Resource Development Institute (SRDI) Laboratory, Daulatpur, Khulna.

Appendix II: Monthly record of temperature, relative humidity, rainfall and sunshine during the period from May to September, 2016

Year	Months	*Air Temperature (°C)		*Relative Humidity (%)	**Rainfall (mm)	*Sunshine (hours)
		Maximum	Minimum			
2016	May	35.1	25.3	78	128	7.2
	June	33.8	26.5	85	318	6.1
	July	32.2	26.5	88	924	2.5
	August	33.0	26.5	86	371	4.1
	September	34.0	26.4	84	293	5.2

*Monthly Average

**Monthly total

Source: Weather Station, Zeropoint, Gollamari, Khulna (Adjacent to Khulna University, Khulna).

Appendix III: Production cost and benefit cost ratio of summer tomato per hectare

1. Input cost

Particulars	Quantity	Unit price(Tk)	Value (Tk)
Human Labour	120	300	36000
Power Tiller	5 Day	500	2500
Seed	200 gm	300	600
Bambo	175	200	35000
Polythene	3500 yard	30	105000
Nylon(Rope)	150 kg	120	18000
Sutlee	20 kg	100	2000
Cowdung	10 ton	500	5000
Urea	300 kg	16	4800
TSP	150 kg	22	3300
MoP	150 Kg	20	3000
Insecticide			5000
Intercultural operation			5000
Total input cost			225200

2. Overhead cost

Particular	Description	Value (Tk)
Cost of lease of land for 6 month	(12% of value of land Tk. 600000/year)	36000
Miscellaneous cost	(Tk. 5% of the input cost)	11260
Interest for running capital for 6 month	(10% of cost/year)	13625
Total overhead cost		60885