INFLUENCE OF PLANT GROWING STRUCTURES AND DIFFERENT COMBINATIONS OF GIBBERELLIC ACID AND SILICON ON SUMMER TOMATO IN ROOFTOP GARDEN

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*This is to certify that thesis entitled, "**INFLUENCE OF PLANT GROWING STRUCTURES AND DIFFERENT COMBINATIONS OF GIBBERELLIC ACID AND SILICON ON SUMMER TOMATO IN ROOFTOP GARDEN**" submitted to the Department of Agricultural Botany, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in Agricultural Botany**, embodies the result of a piece of bona fide research work carried out by **Titly Kaiyum Talukder**, Registration No.* **15-06980** *under my supervision and guidance. No part of the thesis has been submitted for any other degree.*

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

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Dated: June, 2016

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DEDICATED

TO MY BELOVED

PARENTS

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INFLUENCE OF PLANT GROWING STRUCTURES AND DIFFERENT COMBINATIONS OF GIBBERELLIC ACID AND SILICON ON SUMMER TOMATO IN ROOFTOP GARDEN

ABSTRACT

An experiment was conducted in the rooftop garden of Agricultural Botany Department, Sher-e-Bangla Agricultural University, Dhaka during June to October 2016 to assess the influence of different plant growing structures and different combinations of gibberellic acid (GA) and silicon (Si) on summer tomato cultivation for spreading the sustainable urban agriculture in the Dhaka city. GA3 and Silicic acid (SA) were used as source of GA and Si, respectively. Summer hybrid tomato Success, Bejo Sheetol Seed Company (BD) Limited was used in this study. The two factors experiment was laid out in Randomized Complete Block Design (RCBD) with four replications. Factor A was different kinds of plant growing structures which includes three types; earthen pot (E), concrete bed (C) and wooden bed (W) and Factor B was four different combinations of GA and Si; H_0= 0 ppm GA3 and 0 mM Si, G=20 ppm GA3 and 0 mM Si, Si=0 ppm GA3 and 0.4 mM Si, GSi= 20 ppm GA3 and 0.4 mM Si. The total treatment combinations were 12 (3 x 4). The experimental results showed that plant growing structures significantly influenced to change morpho-physiology, yield contributing characters and fruit yield of summer tomato. The morpho-physiological characters including plant height, number of leaves and branches plant^{-1}, stem diameter, SPAD value and yield contributing characters such as number of flower clusters, flowers and fruits plant^{-1}, fruit weight and fruit yield plant^{-1} were significantly increased with wooden bed (W) whereas earthen pot showed poor performance. In contrast, the leaf water loss as measured in percent of fresh weight was minimum at earthen pot whereas it was maximum at concrete bed. It was found that plant growing structures, different combinations of GA and Si showed significant variation on changes in morpho-physiology, yield contributing characters and fruit yield of summer tomato. Different combinations of GA and Si showed significant effect on morpho-physiological and yield contributing characters of the tomato plants. The experiment exhibited that exogenous application of 20 ppm GA and 0.4 mM Si significantly increased plant height, leaf Number plant^{-1}, number of branches plant^{-1}, stem diameter, SPAD value and yield contributing characters like number of flower clusters plant^{-1},number of flowers plant^{-1}, number of fruits plant^{-1}, individual fruit weight and total yield plant^{-1}. However application of Si has reduced the leaf water loss percentage. The interaction between plant growing structure and sole or combined application of GA and Si influenced all the morpho-physiological and yield contributing characters and yield of tomato. The highest yield plant^{-1} (190.9g) was obtained in wooden bed with 20 ppm GA along with 0.4 mM Si (WGSi) treatment combination whereas the lowest yield (52.11g) was recorded from EH_0, earthen pot and 0 ppm GA and 0 mM Si treatment combination. Therefore, this experimental results suggest that wooden bed in combination with 20 ppm GA and 0.4 mM Si can increase the production of summer tomato in the rooftop garden.

LIST OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ACRONYMS

AEZ	Agro- Ecological Zone
Anon.	Anonymous
BARI	Bangladesh Agricultural Research Institute
BAU	Bangladesh Agricultural University
BBS	Bangladesh Bureau of Statistics
BINA	Bangladesh Institute of Nuclear Agriculture
cm	Centi-meter
CV	Coefficient of Variance
cv.	Cultivar (s)
DAS	Days after sowing
DAT	Days After Transplanting
^{0}C	Degree Centigrade
df	Degree of freedom
dSm^{-1}	Dessisimen per meter
DW	Dry Weight
EC	Electrical conductivity
et al.	And others
FAO	Food and Agricultural Organization
FAOSTAT	Food and Agricultural Organization Statistics
GA	Gibberellic Acid
gm	Gram (s)
hr	Hour(s)
IAA	Indole Acidic Acid
Kg	Kilogram (s)
LSD	Least Significant Difference
m	Meter
m^{2}	Meter squares
mg	Milligram
ml	Milliliter
mm	Millimeter
mM	Millimolar
No.	Number
NS	Non significant
OM	Organic matter
%	Percentage
pH	Negative Logarithm of hydrogen ion concentration
ppm	Parts per million
RCBD	Randomized complete block design
ROS	Reactive Oxygen Species
SA	Silicic Acid

SAU	Sher-e- Bangla Agricultural University
Si	Silicon
t ha^{-1}	Ton per hectare
TDM	Total Dry mass
var.	Variety
Wt.	Weight

CHAPTER I

Introduction

The global population expansion increases the resource consumption, ultimately threatens the ecosystem, changes the environment and strains the humanity's ability to feed itself. It is well known that the following reasons are involved in changing environment *viz:* over population, rising temperature, excess CO_2, CH_4, N_2O emission etc. In the urban area, the atmospheric temperature is high compared to the surrounding rural areas creating an urban heat island (UHI) effect (Wong *et al.* 2011; Arabi *et al*. 2015 and Sharma *et al*. 2016). The augmentation of urban vegetation is an outstanding mitigation strategy to keep the sound environment in the city. The concrete structure including building roofs occupies almost 60% area of the total area along with decreased vegetation which increases urban temperature and create UHI in the Dhaka city (Ahmed *et al*. 2013). As a part of urban vegetation, rooftop garden systems improve air quality and decrease the UHI, extend roof life, reduce energy use, increase property value, pleasing work environment, increased biodiversity and source of crop production, etc (Hui, 2006; Tomalty and Komorowski, 2010). It is well known that rooftop garden is an old practice in abroad but recently it is gaining popularity in Bangladesh. There are numerous fruit, vegetables including, brinjal, chili, capsicum and tomato are easy to grow in the rooftop garden with suitable plant growing structures.

Tomato (*Solanum lycopersicum L.*) is a herbaceous annually cultivated crop under Solanaceae family that originated from central and south America and widely grown throughout the world both in the field and home or kitchen garden. It is one of the most popular vegetables and grouped as fruit. It easy to grow and produce a lot of fruits. The requirement of tomato is increasing gradually due to its nutritional quality. Tomato is a key component in the so-called “Mediterranean diet”, which is strongly associated with a reduced risk of chronic degenerative diseases. (Agarwa and Aai, 2000; Rao and Agarwal, 1998). It has been reported that it is a major source of antioxidants, carotenoids such as β-carotene, a precursor of vitamin A, and mainly lycopene which prevents cancer, vitamins such as ascorbic acid and tocopherols, and phenolic compounds such as flavonoids and

hydroxycinnamic acid derivatives (Borguini and Torres, 2009; Clinton, 1998; Kotkov *et al.* 2009; Kotkov *et al.* 2011; Moco *et al.* 2006 and Vallverdú-Queralt *et al.* 2011). Therefore, it can contribute to supply nutrients to the urban dwellers by growing both seasons of an agricultural year namely known as *rabi* and *kharif* in the rooftop garden.
It is well known that tomato is one among the foremost vital and widespread vegetable crops in Bangladesh and usually is grown from November to March (Rahman *et al.* 1998). It has been reported that, although tomato plants can grow under a wide range of climatic conditions, they are extremely sensitive to hot and wet growing conditions, the weather which prevails in the summer season in Bangladesh (Ahmed, 2002). Also the fruit setting in tomato is reportedly interrupted at temperature above 26/20°C day/night, respectively and is often completely arrested above 38/27°C (Stevens and Rudich, 1978; El-Ahmadi and Stevens, 1979 and Kuo *et al.* 1979). According to Yearbook of Agricultural Statistics, in Bangladesh in the year 2014-15 tomato was cultivated in 76 thousand acre in *rabi* season with 5471 kg $acre^{-1}$ yield which was approximately 414 thousand tons in total. However, in summer production of tomato is much lower due to the adverse environmental conditions. Recently, the farmers of the north-west part of Bangladesh have been producing summer tomato using summer varieties which are developed by BARI, BINA and other institutions. However, to my knowledge no study has conducted about the response of hybrid summer tomato in the rooftop garden.

The knowledge and skill about plant growing structures, fertilization, irrigation, mulching, pest management, shoot and root pruning are essential to ensure long term success of the rooftop garden. In the rooftop garden, plant growing structures such as earthen and plastic pot, wooden and concrete bed, half drums and their sizes are major concern to grow different crops including, pepper, tomato, chili etc. (Nesmith and Duval, 1998 and Metwally, 2016). Morphological, physiological and yield responses of tomato, cauliflower and cabbage were uneven to container sizes (Bouzo and Favaro, 2016, NeSmith and Duval, 1998). In addition, the previous observer of our laboratory found that the water requirement also unequal to both *rabi* and *kharif* season in different types of pots however those data are not published yet. However, to my knowledge limited study have been conducted on the selection of plant growing structures including concrete and wooden bed, earthen and plastic pot for growing tomato as *kharif* season crops in the rooftop garden in the Dhaka city.

As plant growing structures, plant nutrients along with plant bio-regulators are also important factors which contributes to establish a sustainable rooftop garden under various adverse environmental conditions including heat, deficiency of water etc. Many authors reported that plant growth regulators (PGRs) played essential functions on growth, flowering, fruit setting, ripening and quality of tomato (Kumar *et al.* 2014; Naeem *et al*. 2001 and Davies, 1995). The PGRs are used extensively in tomato to enhance yield and quality by improving germination, stem and internode elongation, enzyme production, fruit set, size and number (Davies, 1995, Gemici *et al.* 2006 and Batlang, 2008). Rafeekher *et al.* (2002) reported that the application of certain PGRs like auxin and GA_3 carry the possibility of tomato production under adverse environmental conditions. Gibberellic acid (also called Gibberellin A3, GA, and GA_3) is a hormone found in plants having chemical formula $C_{19}H_{22}O_6$. In summer, tomato fruit set can be increased by applying plant growth regulators (Hossain *et al.* 1999; Sasaki *et al*. 2005; Khan *et al*. 2006; Gemici *et al*. 2006; Serrani *et al*. 2007; Batlang, 2008 and Rahman *et al.* 2015). However, to my knowledge no study has yet been conducted on the role of GA to mitigate the adverse effect of heat injury in summer tomato in the rooftop garden.

Although silicon (Si) is not considered an essential element for plant nutrition, many authors reported that it enhanced growth of various cultivated plants. The Si on crop plants deposited to the cell walls in form of amorphous silica ($SiO_2.nH_2O$) (Inanaga and Okasaka, 1995; Epstein, 1999). It was also reported that the usage of Si alleviates abiotic stress including heat during flowering and fruit setting in agricultural crops. The yield and quality of tomato increased with Si reported by Jarosz (2014). The Si reduced both the fungal and bacterial disease infection in tomato and thus increased the fruit yield of tomato and muskmelon (Dannon and Wydra 2004, Dallagnol *et al.* 2012; Yanar *et al.* 2011). However, so far no study has conducted about the use of Si to mitigate the adverse effect of heat injury in summer tomato in the rooftop garden.

In spite of proven benefits arising from the application of GA and Si in crop plants no information was found about the use of GA and Si in tomato during *kharif* season for the rooftop garden in Bangladesh. However, to my knowledge no study has conducted about the suitability of plant growing structures including earthen pot, wooden and concrete bed; and the role of exogenous GA and Si on changing the morpho-physiology and yield of summer tomato in rooftop garden.

Therefore this research was undertaken to achieve the following objectives:

- To identify the suitable plant growing structures for summer tomato production in *kharif* season for the rooftop garden.

- To investigate the sole or together effects of GA and Si on changes of morpho-physiology and yield summer tomato during *kharif* season for the rooftop garden.

- To find the best combination/combinations between different plant growing structures and GA and/or Si on changes of morphophysiology, yield and quality of summer tomato during *kharif* for the rooftop garden.

CHAPTER II

REVIEW OF LITERATURE

Over half the world's population now lives in urban as opposed to rural environments with this increasing rate of urbanization over time; it is a crucial need to increase food production sites near main consumption centers. New strategies should be devised to ensure the food security and rooftop gardens has already shown its potential as a source of Urban food production site as well as preventing environmental pollution. Cultivation of summer tomato on rooftop garden can be a great source of nutrition also a unique procedure to improve urban environment especially in Bangladesh. However researches on rooftop garden in Bangladesh is still very limited.

This research was conducted to identify the effects of different plant growing structures on summer tomato in rooftop garden as well as to analyze the effect of gibberellins and silicon application on them with their best possible interaction. Different research work in this respect has been reviewed below.

2.1 Effect of different plant growing structures on morpho-physiological parameters and yield of various plants including tomato

Sharma *et al.* (2016) green roof reduced the daytime roof temperature which varied linearly with increasing green roof fractions. Green roofs also reduced the horizontal and vertical wind speeds. The lowered wind speeds during daytime led to stagnation of air near the surface, potentially causing air quality issues. The selection of green and cool roofs for UHI mitigation should be considered.

Bouzo and Favaro (2016) conducted trials to examine the effects of container size during spring-summer on tomato. The first experiment was conducted in a greenhouse to measure the effect on the initial yield. A second experiment was performed outdoors to incorporate the effect of plant age on the development and yield. Commercial hybrid tomato seeds of the cv. 'Tauro' were dry sown in containers of different volumes (20, 40, 70 and 350 mL) and with variable transplant times (14, 21, 28 and 35 days). The authors found that an increase in the container size results in plants of higher size and yield.

Arabi *et al*. (2015) stated that green roofs are alleviating urban heat island (UHI). Rooftop garden as green roof mitigate the air pollution, improving management of run-off water, improving public health and enhancing the aesthetic value of the urban environment. They recommend that the using green roofs as a main strategy for decreasing the harmful impacts of UHI especially the high air temperatures as well as their ability to add to the greening of cities.

Ahmed *et al.* (2013) reported that the amount of built-up area of Dhaka city built-up area increased by 88.78% in the past 20 years (from 1989 to 2009) and is expected to increase three-fold and four-fold by 2019 and 2029, respectively. In 1989, a larger part of the Dhaka Metropolitan (DMP) area (74%) fell within the lower temperature zones (<18°C to < 21 °C). But in 1999, a majority of the area (91.40%) was found to fall into the mid-temperature zones (21 °C to < 27 °C). This trend continues, and a larger portion of the DMP area (44%) moved into the higher temperature zones (27 °C to <30 °C) in 2009. Therefore, it is suggesting that the temperature of Dhaka city is gradually increasing day by day with changing environment.

Carter and Rasmussen (2006) reported that rooftop garden reduces ambient air temperatures, extends the roof life, energy savings, increases bird and insect habitat, increase the beauty of the building or city, improve ecosystem, source of food and nutrition.

Hui (2006) stated that green roof system showed a positive effect on mitigation of urban heat island and enhance the building thermal and environmental performance.

Celik (2010) performed a theoretical analysis of air-conditioning energy savings with different green roof applications. Thermal data was collected from a typical non-reflective (EPDM) roof membrane and model greenroof systems with three types of growth media (lava, arkalyte and hadite) matched with three sedum types (*Sedum kamtchaticum, S. spurium,* and *S. sexangulare*). Temperature readings underneath the growth media and from the non-reflective roof membrane were recorded for 32 months continuously. Results demonstrated that the right combination of growth media and vegetation can yield significant energy savings for air-conditioning.

Liu (2002) identified rooftop garden as an important component of any strategy to reduce greenhouse gas (GHG) emissions. He stated that Rooftop garden reduce energy demand on space conditioning, and hence GHG emissions, through direct shading of the roof, evapo-transpiration and improved insulation values. From his experiment, he indicated that rooftop gardens could reduce the airborne pollutants, UHI, heat stress, energy consumption and improve storm water management.

Keller (1985) stated that rooftop gardening can be an effective method in ensuring food supply and satisfying nutritional needs of the inhabitants. Rooftop gardening, although is being practiced in the city in many forms for years in the past, there have been hardly any concerted effort on part of the Government, community organizations and as well the general citizens to integrate it to urban agriculture. Proper understanding of the problems and prospects associated with the adoption of policies will contribute, to a great extent, to increased food supply in the city.

Eumorfopoulou and Aravantinos (1998) conducted an experiment and stated that in the summer, the heat flow through the reference roof created an average daily energy demand for space conditioning of 6.5–7.0 $kWhday^{-1}$. However, this energy demand was reduced to less than 1.0 $kWhday^{-1}$ in the garden roof—a reduction of over 75%, which can be attributed to the presence of the growing medium and the plants.

Metwally (2016) carried out an experiment with different substrate culture systems in relation to growth and production of hot pepper; beds system (100 liter of substrate/m^2, depth 10 cm), big pots system (60 liters of substrate/m^2, depth 15 cm), small pots system (30 liters of substrate/m^2, depth 13 cm) and horizontal bags system (90 liter of substrate/m^2, depth 10 cm). The author found that hot pepper plants grown in big pots system has the highest values regarding: plant height, number of leaves, aerial parts fresh and dry weights, root fresh and dry weights, yield per m^2 and highest nitrogen and phosphorus percentages in leaves and suggest that the big pots system could be recorded as the most suitable substrate culture system for producing hot pepper in rooftops gardens.

An investigation aimed to fertility management for tomato production on an extensive green roof by Ouellette (2013). This research project evaluated four fertilizer treatments on ‘Bush Champion II’ tomato (*Solanum lycopersicum*) growth and yield in a 7.62 cm green roof production system: (1) vermicompost tea, 2) Miracle-Gro fertilizer, 3) Organic Miracle-Gro fertilizer, 4) no fertilizer. Results indicated that Miracle-Gro® provided the highest total tomato fruit yield, which was 30% and 50% more in 2011 and 2012, respectively, compared to the next highest treatment - Organic Miracle-Gro®. Therefore, these results suggested that tomato can be successfully grown in a 7.62 cm green roof medium when given adequate fertilizer applications.

Kostopoulou *et al.* (2011) reported that container depth is considered an important variable influencing plant and root morphology as it is directly related to water holding capacity, humidity and air availability.

2.2 Influence of growing season (summer) on morpho-physiological parameters and yield:

An investigation was carried out at Joydebpur, Gazipur to determine the optimum time of planting for BARI developed hybrid tomatoes, during summer (BARI, 1998). There were four dates of planting, namely, 15 May, 15 June, 15 July and 15 August, and three tomato varieties, namely, TM 0836, TM 0831 and TM 0832. It was observed that, planting time did not result any significant variation on the plant characters, except TSS. However, the maximum yield was found, when the crop was planted on 15 August. On the contrary, TM 0832 was the highest yielding hybrid (59 t ha^{-1}), which was significantly different from other hybrids. All the parameters showed negative response to the delay in planting.

The optimum sowing time for producing off-season tomatoes (cv. House Momodaro) in highland areas of Korea Republic was investigated by Jang *et al*. (1997). Seeds were sown on 25 June, 15 July and 15 August. Time from sowing to anthesis was 25, 13 and 12 days for the June, July and August plantings, respectively. Fruit weight for the June and July plantings was 182 and 194 g, respectively. Marketable fruits were produced primarily between September and October for June plantings and between October to November for

July and August plantings. Marketable yield during the off-season (October-November) was highest (42.74 t ha^{-1}) for plants sown in July.

Sharna and Tiwari (1996) carried out an experiment in India during 1989-90 to study the effect of planting time on yield and yield contributing characters of tomato. They reported that transplanting on 13 February resulted in greater percentage of fruit set (82.23%) and number of fruits $plant^{-1}$ (48.70) than transplanting on 5 or 25 March. But individual fruit weight, diameter and total and marketable yields were greater with transplanting on 5 March.

The effect of planting time and spacing on the growth and yield of three tomato cultivars (Solan Gola, Money Maker and Naveen) was studied in Himachal Prodesh of India. Result found that, close spacing and early planting increased harvest duration. The yield was not significantly affected by planting time and spacing. Naveen had the largest fruits (83.2 g) and produced the highest yield (44.1 t ha^{-1}) than others (Bhardwaj *et al.*, 1995).

Drost and Price (1991) while investigating the effect of planting date and tillage system on the growth and yield of tomato (cv. VC 82) at Michigan State USA, and reported that, planting date had no lasting effect on plant height, but late planting (2 June) led to fewer flower trusses than early planting (7 May). Late planting reduced the number of fruit and yields, but increased the weight of fruit compared to early (7 or 19 May).

When tomatoes are grown under unfavorable conditions, such as during summer in tropical countries, the usual problem is low fruit set. The problem is due to high night temperature (above 22°C) and high humidity, which result in poor pollination and flower fertilization. Although the problem is solved with the use of heat tolerant verities, these are inadequate under extreme conditions. Application of plant growth regulators has been shown to improve fruit setting particularly in verities that have low level of heat tolerance (AVRDC, 1990).

Tomato *(Lycopersicon esculentum* Mill.) is seldom grown in summer season in Bangladesh, because of high temperatures, high humidity and heavy rainfall. An attempt was made in 1991 to grow a summer tomato crop by growing tomatoes on raised beds, using heat-tolerant lines, chemical application for improving fruit set and wild species as root stock to control diseases. Tomatoes transplanted in June on raised beds gave an excellent crop stand and growth compared to transplanting into flat plots. Two lines, TM 0111 and TM 0367, from the Asian Vegetable Research and Development Center (AVRDC) set some fruits in summer, but further increase fruit set were obtained by use of the plant growth regulator "Tomatotone." Plants sprayed at flowering stage with 2% tomatotone resulted in an average 760 – 940 g parthenocarpic fruits plant^{-1} (AVRDC, 1990).

Iwahori (1967) stated that high temperature increased the probability of floral abscission after anthesis in tomato. High temperature reduced the size of tomato flower with small anthesis and abortive pollens, as well as auxin content (Saito and Ito, 1967).

Abdullah and Verkerk (1968) reported that high temperature (both day and night); rainfall, humidity and intensity are the basic limiting factors of tomato production.

Kuo *et al.* (1978) stated that high light intensity affects the internal temperature of the reproductive organ of tomato. High temperature is known to limit fruit-set of tomato due to simultaneously and/or sequentially impaired series of reproductive processes i.e. pollen production and development, ovule development, pollination, germination of pollen grains, pollen tube growth, fertilization and fruit initiation (Rudich *et al.*, 1977 and Stevens, 1979).

Shelby *et al.* (1978) compared two heat tolerant tomato *(Lycopersicon esculentum* Mill.) breeding lines AVI65 and Nagcarlang, with the heat sensitive "Floradel" in fruit set, pollen abortion and embryo sac abortion. They found that two heat tolerant cultivars had a significantly higher percentage of fruit set under both moderate and high temperature in spring and summer than "Floradel" but fruit set of all three cultivars was significantly lower at high temperature. The poor fruit-set at high temperature in the tomato, principally, might be a result of a reduction of carbon export from the leaf (Dinar *et al.*, 1982 and Ho, 1979).

In 1983, Dinar *et al.* stated that poor fruit set at high temperature in tomato due to callose formation in the leaf petiole and an inability of reproductive organs to import assimilates in the early stages of flower development.

High day (above 32°C) and night (above 21°C) temperature were reported as limiting fruit-set due to an impaired complex of physiological process in the pistil, which results in floral or fruit abscission (Pickern, 1984).

Difference existed among the cultivars in their ability to transmit their fruit setting ability under high temperature to their hybrid progenies. Hybrid progenies appeared to have better consistency of performance especially under less than optimal growing conditions (Yordanov, 1983).

Cheema *et al.* (1993) worked to extend the growing period and availability of tomato in northwest India. A study was carried out in the field during 1989-90 to identify genotypes having extended fruit setting ability at high temperature (40°C day/25°C nights). Nine genotypes were rated as heat tolerant, having an average of 60-83% fruit set. Individual fruit weighed 20-40g. Marketable yield was low (110 - 140 g $plant^{-1}$) due to disease pressures.

Scott *et al.* (1995) reported that Equinox, a determinate, heat-tolerant, fresh-market tomato hybrid that sets a high percentage of marketable fruit in spring and autumn in Florida. Under 30-33°C/21-25°C day/night temperatures, fruit set is superior to that of the most large-fruited cultivars, but flowers abort in the early trusses.

Henna *et al.* (1994) conducted an experiment in 1992 and 1993 under optimal and sub-optimal field temperatures fruit set with some heat-tolerant and less heat-tolerant tomato cultivars. Sub-optimal temperatures during fruit set reduced the yield of all tomato cultivars, but yield reduction was less in heat-tolerant cultivars. At minimum/maximum temperatures above 73/95°F, the heat-tolerant and less heat-tolerant cultivars produced very little yield.

Rahman *et al.* (1998) conducted an experiment to evaluate the effects of temperature and water stress on agronomic and physiological characteristics in heat tolerant tomato cultivar TM 0126. Plants were grown in a “Phytotron” at day/night temperatures of 23/18°C (moderate temperature regime, MT) or 30°/25°C (high temperature regime, HT). HT significantly reduced yield, pollen germination percentage, shoot and weight.

Khalid (1999) conducted an experiment with two winter (Ratan and Bahar) and three summer (BINA Tomato-2, BINA Tomato-3 and E-6) varieties of tomato during the winter season of 1998-99 at the Horticulture Farm, BAU, Mymensingh. He observed that the highest yield plant^{-1} was obtained from BINA Tomato-2 (1.77 kg), followed by BINA Tomato-3 (1.67 kg). But the yields of these varieties were statistically similar to reach other.

In Nepal, an experiment was conducted by Lohar and Peat (1998) to study the floral characteristics of heat-tolerant and sensitive tomato cultivars at high temperature. They observed that flowering was the earliest in Pusa Ruby at 28/23°C (day/night) and the latest in CL-1131 at 15/10°C. They also indicated that cv. CL-1131 was suitable for cultivating at high temperature and as an earlier crop. Cultivar Pusa Ruby produced fewer flowers and high temperature than CL-1131, but not in 15°/10°C.

Flower buds at five to nine days before anthesis and one to three days after anthesis were highly sensitive to high temperature (Iwahori *et al*., 1963). Both macro and micro spore mother cells at meiosis and nine to eight days before anthesis were especially sensitive to high temperature (Iwahori, 1965). El-Ahmadi and Stevens (1979) also observed reduction in pollen viability and anther dehiscence when flower exposed to 40°C for 4 hours. Optimum temperature for pollen germination was found to be near 27°C (Abdullah and Verkerk, 1968). At high temperatures, pollen germination and pollen tube growth were retarded (Abdullah and Verkerk, 1968; Charles and Harris, 1972).

2.3 Effect of Gibberellic acid on morpho-physiological parameters and yield of tomato

Shittu and Adeleke (1999) investigated the effects of foliar application of GA3 (0, 10, 250 or 500 ppm) on growth and development of tomatoes cv, 158-3 grown on pots. Plant height and number of leaves were significantly enhanced by GA3 treatment. Plants treated with GA3 with 250 ppm were the tallest plant the highest number of leaves.

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

Gabal *et al.* (1990) found that 100 ppm of GA3 was more effective treatment in increasing leaf number plant^{-1} compared to control.

Sanyal *et al.*(1995) studied that the effects of plant growth regulators (IAA or 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.

EI- Habbasha *et al.* (1999) carried out a field experiment with tomato cv. castel rock over two growing seasons (1993-94). The effects of GA3 and 4-CPA 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 compared to the controls.

Total dry matter of a crop is the output of net photosynthesis. Patel and Saxena (1994) reported that presoaking of seed of gram in varying concentrations of GA3 showed the best results on dry weights. Application of GA3 at 50 and 100 ppm in french bean increased leaf number over control (Gabal *et al.,* 1990). The increased leaf number could intercept most of the incident radiation and result in higher dry matter production in faba bean (Takano *et al.,* 1995).

Lilov and Donchev (1984) observed that by the application of GA3 at 20,40 or 100 mgL^{-1} 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.

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 panern of primordia production over time.

Saleh and Abdul (1980) performed an experiment with GA3 *(*25 or 50 ppm) applied 3 times in June or early July. They reported that GA3 stimulated plant growth. The substance reduced the total number of flowers plant^{-1} but increased the total yield compared with the control. GA3 also improved fruit quality.

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 growth.

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

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.

Bora and Selman (1969) working with tomato demonstrated that four foliar sprays of GA3 (0, 5, 50 or 500 ppm) applied at 7, 17, 22, 27 or 37 increased the leaf area, weight and height of tomato plants. The best treatment was 5 ppm GA3 at 22^{0}C.

Jansen (1970) reported that tomato plants treated with GA3 neither increased the yield nor accelerated fruit ripening. He also mentioned that increasing concentration of GA3 reduced both the number and size of fruits.

Mehta and Malhi (1970) reported that GA3 application at 25 ppm improved the yield of tomato. GA3 produced earlier fruit setting and maturity.

Hossain (1974) investigated the effect of GA_3 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, GA_3 treatment induced small size fruit production. A gradual increase in the yield plant^{-1} was obtained with higher concentration of GA3.

Sawhney and Greyson (1972) reported that application of GA3 in non flowering plants of tomato induced multilocular, multicarpellary ovaries which were larger at anthesis than control upon pollination produced fruits which were significantly larger with higher fresh weight.

Adlakha and Verma (1964) observed that when the first four clusters of tomato plants were sprayed three times at unspecified intervals with GA3 at 50 and 100 ppm, the fruit setting increased by 5% with higher concentration.

Kaushik *et al.* (1974) in an experiment applied GA3 at 1, 10 or 100 mgL^{-1} on tomato plants at two leaf stage and then at weekly interval until 5 leaf stage. They reported that GA3 increased the number and weight of fruits plant^{-1} at the highest concentration.

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^{0}C) or warm (23°C) night temperatures; but it strikingly reduced fruit size at an optimum temperature (17^{0}C).

2.4 Effects of Silicic acid on morpho-physiological parameters and yield of various crops including tomato:

Silicon is a naturally occurring element in the soil and the second most abundant element in the earth’s crust. It is not an essential nutrient for all plants but it is considered a beneficial nutrient for many species (Epstein, 1994).

According to Raven (1983) while it is prevalent in the soil, Si primarily exists as silica (SiO_2) which is not available for plant uptake. Silicon must be in the form of mono-silicic acid (H_2SiO_4) to be taken up by plants and the natural dissolution of SiO_2 to H_2SiO_4 in the soil is slow.

Once Si is taken up by plant roots it is deposited as amorphous silica ($SiO_2.nH_2O$) or opal phytoliths in cell lumens, cell walls and intercellular spaces (Raven, 1983; Marschner, 1990). Once it is deposited to respective sites within plant tissue, SiO_2 is not redistributed (Epstein, 1994).

The structural integrity and rigidity from the deposited SiO_2 is the basis for many of the benefits associated with Si uptake. Several good reviews (Jones and Handreck, 1967; Raven, 1983; Epstein, 1999) on Si and its benefits are available.

Epstein (1994) reported that increased tissue SiO_2 has been shown to alleviate lodging effects. Leaves become more erect which decreases shading in the lower canopy and allows for greater surface area for sunlight contact, resulting in higher rates of photosynthesis.

Upon uptake by plant roots, Si is deposited as amorphous silica ($SiO_2 \cdot nH_2O$) or opal phytoliths in cell lumens, cell walls and intercellular spaces (Raven, 1983; Marschner, 1990). Strengthening these protective layers and the increase in overall structural integrity is what provides the basis for many of the benefits associated with Si uptake in plants. Silicon has been shown to increase resistance to multiple biotic and abiotic stresses such as lodging, disease and pest damage (Fallah, 2012; Ma *et al*., 2001; Meyer and Keeping, 2005)

Positive responses of plant growth parameters to Si fertilization have been observed. Ma *et al*. (1989) reported increases in the number of panicles, spikelets panicle^{-1}, and decreases in the number of blank spikelets when Si was applied. Increases in grain weight were also observed, as well as plant height and longer spikes in wheat (Balasta *et al*., 1989; Abro *et al*., 2009). These and other benefits of Si fertilization can all contribute to yield increases.

Epstein (1994) reported that Silicon fertilization has become a common practice contributing to higher yields in crops such as rice and sugarcane.

Ma and Takahashi (2002) reported that the use of slags is widespread in Japan for degraded paddy soils in rice production. Yoshida (1981) reported that yield increases of 10% are common in these and similar areas, and when leaf blast is severe, yield increases up to 30% were observed. Using silicate slags, Korndorfer *et al*. (2001) reported yield increases in 19 out of 28 field experiments in rice production in the Everglades Agricultural Area in Florida.

According to Jones and Handreck (1967) perhaps one of the most studied and greatest benefits of Si is its role in reducing effects of abiotic and biotic stresses in plants. Harder plant surfaces make it more difficult for fungal hyphae and insects to penetrate and spread disease.

There has been a wealth of research showing that Si can increase growth parameters and grain yield. Ma *et al*. (1989) reported increases in the number of panicles, spikelets panicle^{-1}, and a remarkable decrease in the number of blank spikelets when Si was applied to rice plants. They did not observe any differences in the weight of 1,000 grains but increases in grain weight were observed by others (Balasta *et al*., 1989).

Abro *et al*. (2009) conducted a study where silicic acid was applied directly to the soil in a pot experiment in wheat. They reported increases in height of wheat treated with low and moderate Si levels (2.5 and 5.0 g kg^{-1}, respectively) as well as longer spikes and higher number of grains spike^{-1} than untreated wheat plants. Conversely, the application rate of 7.5 g kg^{-1} of silicic acid decreased growth parameters and yield demonstrating the negative effect of over-application of Si.

Rice productivity has been reported to be higher in temperate regions as compared to the tropics (Savant *et al.*, 1997; Rodrigues and Datnoff, 2005) because the amount of Si in the tropical soils is about 5 to 10 times lower than its amount in the temperate region soils (Foy, 1992; Rodrigues and Datnoff, 2005). Hence, improved Si management appears to be necessary to increase yield and sustain crop productivity in temperate and tropical regions (Meena *et al.*, 2014).

Savant *et al. (*1997) reported that Silicon nutrition improves the light receiving posture of the plants, there by stimulating photosynthate production in plants.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at a rooftop during the period from June 2016 to October 2016. A brief description of materials used, treatments, location of the experiment, characteristics of soil, weather and climate, process of experimentations etc have been mentioned in this chapter.

3.1 Experimental site

This experiment was carried out at the rooftop garden of the Department of Agricultural Botany, Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh. Location of the experimental site was 23°74′N latitude and 90°35′E longitude at an altitude of 8.6 meter above the sea level (Anon., 2004), which have been shown in the Appendix I.

3.2 Experimental period

The experiment was carried out during the *kharif* season from June 2016 to October 2016. Seedlings were sown on 5 June 2016 and were harvested up to 15 October 2016.

3.3 Climatic condition of the experimental site

The experimental site is situated in the subtropical monsoon climatic zone. Generally this zone is characterized by heavy rainfall during the months from April to September in *kharif* season. The overall weather condition at the experimental site during the cropping season June to October 2016 have been presented in Appendix II including minimum and maximum temperature, rainfall, relative humidity and sunshine hours etc.

3.4 Soil type

The soil for experiment was collected from an area that belongs to Modhupur Tract under AEZ No. 28 (Anon., 1988). The soil characteristics of experiment have been presented in Appendix IX.

3.5 Planting materials

Summer hybrid tomato variety Success used in the study which collected from Bejo Sheetol Seed Company Bangladesh Limited.

3.6 Treatments of the experiment

The experiment consisted of two factors:

Factor A: Different kinds of plant growing structures

i. Concrete bed marked as C
ii. Wooden bed marked as W
iii. Earthen Pot marked as E

Factor B: Different concentration of Gibberellic acid (GA) and Silicic acid (Si)

i. Controlled marked as H_o
ii. GA (20 ppm) marked as G
iii. Silicon (0.4 mM) marked as Si
iv. GA (20 ppm) and silicon (0.4 mM) marked as GSi

The following total 12 treatment combinations were considered:

CH_o : Concrete bed (Without GA + Without Si)

CG : Concrete bed (20 ppm GA + Without Si)

CSi : Concrete bed (Without GA + 0.4 mM Si)

CGSi : Concrete bed (20 ppm GA + 0.4 mM Si)

WH_o : Wooden bed (Without GA + Without Si)

WG : Wooden bed (20 ppm GA + Without Si)

WSi : Wooden bed (Without GA + 0.4 mM Si)

WGSi : Wooden bed (20 ppm GA + 0.4 mM Si)

EH_o : Earthen Pot (Without GA + Without Si)

EG : Earthen Pot (20 ppm GA + Without Si)

ESi : Earthen Pot (Without GA + 0.4 mM Si)

EGSi : Earthen Pot (20 ppm GA + 0.4 mM Si)

3.7 Design and layout of the experiment

The factorial experiment was laid out in a Randomized Complete Block Design (RCBD) with four replications. The 48 plants were planted in the earthen pot, wooden bed and concrete bed. The earthen pot size was 40 cm in diameter and 30 cm in height. Both the wooden and concrete bed height or depth was 30 cm and plant to plant distance was 40 cm.

3.8 Raising of the Seedling

In raising of seedlings, a common procedure was followed in the seedbed. Seedlings were raised in one seedbed on a relatively high land. The size of the seedbed was 3 m × 1 m. The soil was well prepared with spade and made into loose friable and dried mass to obtain fine tilth. All weeds and stubbles were removed. During seedbed preparation 5 kg well rotten cowdung was applied. After 3 days sowing of seeds, germination was visible. Seeds were covered with light soil to a depth of about 0.6 cm. Heptachlor 40 WP was applied @ 4 kg ha^{-1} around each seedbed as precautionary measure against ants and worm. Emergence of the seedlings took place within 5 to 6 days after sowing. Shading was provided by banana leaves over the seedbed to protect the young seedlings from scorching sun or heavy rain. Weeding, mulching and irrigation were done as and when required.

3.9 Pot and bed preparation

Before transplanting the growing structures were prepared with silt loam soils. Well rotten cow dung and soil were mixed using the ratio of 1:3. Earthen pots as well as the wooden and concrete beds were filled 10 days before transplanting. Soils were made completely stubbles and weed free.

3.10 Manure and fertilizer application

Urea, TSP and MP were applied as a source of N, P_2O_5 and K_2O. At the time of final preparation the entire amounts of TSP and MP were applied and Urea was applied in three equal installments. During bed preparation well-rotten cow dung was also applied.

3.11 Uprooting and Transplanting of seedlings

Seedlings of 30 days old were uprooted separately from the seedbed and were transplanted in the beds in the afternoon of 5 July, 2016 maintaining one seedling in each pot.

Before uprooting the seedlings, seedbed was watered to minimize damage to roots. After transplanting, seedlings were watered and also shading was provided for three days to protect the seedlings from the hot sun. Shading was kept after till the establishment of seedlings.

3.12 Application of GA, Silicic Acid and combination of GA + Si

According to the treatment plants were treated with 20 ppm GA and 0.4 mM Si. The stock solution of 1000 ppm of GA_3 with small amount of ethanol to dilute and then mixed in 1 litre of water which turn as per requirement of 20 ppm. The silicic acid was used as a source of Si. 0 .4 mM Silicic acid from stock solution were mixed with 1 litre of water. Both GA and Si at 20 days interval were applied at 20 and 40 days after transplanting independently.

3.13 Gap filling

Gap filling was done as and when needed.

3.14 Intercultural operations

Intercultural operations were done whenever needed for better growth and development. Intercultural operations followed in the experiment were irrigation, weeding, staking and top dressing etc.

3.14.1 Irrigation

Irrigation was provided once in a day either at morning or at evening at early stage of seedling. After that irrigation was provided to the plants twice a day except the rainy days.

3.14.2 Shading

To protect the plants from excess rainfall of monsoon a transparent polythene shade was provided. The shade was made just after the establishment of seedlings and was maintained up to final harvest.

3.14.3 Stalking

Staking was given to each plant by bamboo sticks for support, when the plants were well established.

3.14.4 Weeding

Weeding was done whenever it was necessary, mostly in vegetative stage for better growth and development.

3.14.5 Top dressing

After basal dose, the remaining doses of urea were used as top-dressed in 3 equal installments at 15, 30 and 45 DAT. The fertilizers were applied on both sides of plant rows and mixed well with the soil. Earthening up operation was done immediately after top-dressing with nitrogen fertilizer.

3.15 Plant Protection Measures

Melathion 57 EC was applied @ 2 ml L^{-1} of water against the insect pests like cutworm, leaf hopper, fruit borer and others. The insecticide application was made fortnightly after transplanting and was stopped before second week of first harvest. Furadan 10G was also applied during pot preparation as soil insecticide. Emitaf 20 SL @ 0.25 ml L^{-1} of water at 7 days interval for three weeks was also applied.

3.16 Harvesting

Harvesting was started during early ripe stage when the fruits attained slightly red color. Harvesting was done at 3 days interval starting from 15 September 2016 and was continued up to 15 October 2016.

3.17 Recording of Data

Experimental data were recorded from 20 days after transplanting and continued until last harvest. The following data were recorded during the experimental period.

A. Morphological characters

1. Plant height (at different days after transplanting)
2. Leaf number $plant^{-1}$ (at different days after transplanting)
3. No. of branches $plant^{-1}$ (at different days after transplanting)
4. Stem diameter

B. Physiological characters

5. SPAD value of leaf

6. Water loss %

C. Yield contributing and yield characters

7. No. of flower clusters plant^{-1}

8. No. of flowers plant^{-1}

9. No. of fruits per plant^{-1}

10. Individual fruit weight

11. Total yield plant^{-1}

3.18 Procedure of Recording Data

3.18.1 Plant height

Plant height was measured from the sample plants in centimeter from the ground level to the tip of the highest leaf and means value was calculated. To observe the growth rate plant height was recorded at 20, 40 and 60 days after planting.

3.18.2 Leaf plant^{-1}

Leaf number was counted from each plant at 20, 40 and 60 DAT.

3.18.3 Branches plant^{-1}

The total number of branches plant^{-1} was counted from each plant at 20 DAT, 40 DAT and 60 DAT.

3.18.4 Stem diameter

Stem diameter was measured in cm with slide caliper at the base of each plant.

3.18.5 Chlorophyll content- SPAD reading

Leaf chlorophyll content was measured using a hand-held chlorophyll content SPAD meter (CCM-200, Opti-Science, USA). At each evaluation the content was measure 5 times from five leaves at different positions plant^{-1} and the average was used for analysis.

3.18.6 Water loss percentage of leaf

Tomato leaves were collected from each plant in an icebox for measuring the transpiration rate. Fresh leaves were weighed and weight of leaves was recorded at 120 minutes. Rate of water loss was calculated from these data.

3.18.7 Flower clusters plant^{-1}

The number of flower clusters produced plant^{-1} was counted and recorded.

3.18.8 Flowers plant^{-1}

The number of flower plant^{-1} was counted and recorded.

3.18.9 Fruits per plant^{-1}

The number of fruits plant^{-1} was counted and recorded.

3.18.10 Individual fruit weight

Among the total number of fruits during the period from first to final harvest, fruit was considered for determining the individual fruit weight by the following formula:

$$\text{Weight of individual fruit (gm)} = \frac{\text{Total weight of fruits}}{\text{Total number of fruits}}$$

3.18.11 Fruit yield per plant^{-1}

Fruit yield plant^{-1} was calculated by totaling fruit yield from first to final harvest and was recorded in gram (g).

3.19 Statistical Analysis

The data were statistically analyzed following the analysis of variance (ANOVA) technique using MSTAT-C computer package program and the mean differences were adjudged by least significant difference (LSD) test at 5% level of significance (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The response of summer tomato to different plant growing structures and different combinations of gibberellic acid and silicic acid have been presented and discussed in this chapter under separate heading.

4.1 Effect of different plant growing structures, Gibberellic acid and silicic acid on plant morphological characters

4.1.1 Plant height

Plant height is considered as the most important morphological parameter of plant. The plant height varied significantly due to different growing structures, gibberellic acid and silicon. Plant growing structures showed significant variation in plant height (Fig.1 and appendix III) at different days after transplanting (DAT). At 20 DAT, highest plant height was found from W (50.81 cm) and the lowest (33.44 cm) was observed from E. At 40 DAT, highest plant height was observed from W (98.81 cm) and lowest was recorded from E (89.13 cm). At 60 DAT, highest plant height was found from W (125.6 cm) and the lowest (116.4 cm) was observed from E. These results were partially supported by Bouzo and Favaro (2016) who stated that an increase in the container size results in plants of higher size and yield. These findings were also partially supported by Metwally (2016) who reported that plants grown in big pots system has the highest values regarding plant height. Altogether these results suggest that wooden bed is more suitable to increase plant height of tomato than earthen and concrete bed.

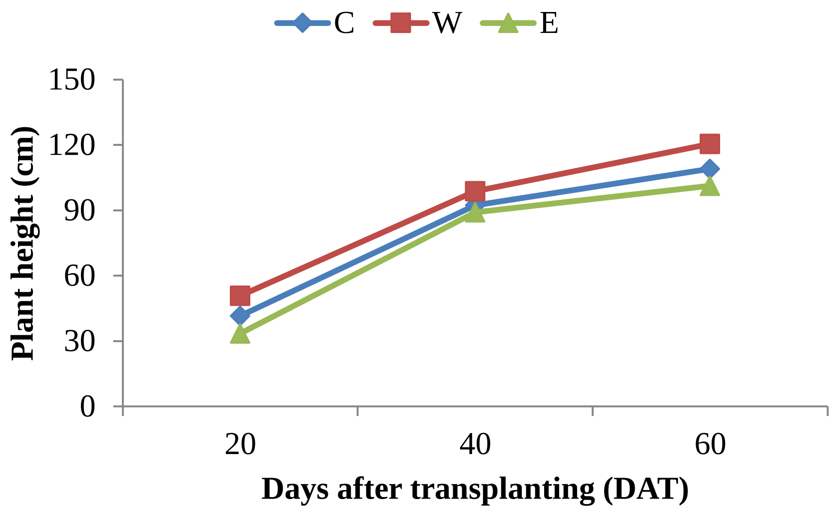


Figure 1. Effect of different plant growing structures on the plant height of tomato at different days after transplanting (LSD $_{(0.05)}$ = 2.27, 4.73 and 7.03 at 20, 40 and 60 DAT, respectively); Here, C= Concrete bed, W=Wooden bed, E=Earthen pot.

Previous numerous authors stated that GA increased the plant height by increasing the cell division and volume of cell. Different combinations of GA and Si to examine the sole or combined effect of GA and Si on changes in plant height of summer tomato in the rooftop garden as GA and Si enhanced plant axis or plant height. In this study GA_3 as GA and Silicic acid as a source of Si was used.

Different combinations of GA and Si showed a significant impact to promote plant height (Fig. 2 and Appendix III) at 20, 40 and 60 DAT. At 20 DAT, the highest plant height was observed from GSi (44.83 cm) which was statistically similar to G (42.92 cm). Lowest plant height at 20 DAT was found from H_o (39.00 cm) which was statistically similar to Si (40.92 cm). At 40 DAT, highest value (97.67 cm) was found from GSi which was statistically similar to G (94.17 cm) and lowest value (89.58 cm) was found from Ho which was statistically similar to Si (92.17 cm). At 60 DAT, highest plant height was found from GSi (119.1 cm) which was statistically similar to G (111.7 cm). From this study it was observed that GA and Si increased plant height as compared with the control whereas the best result was found from the combined application of GA and Si. These results are partially supported by the findings of Wu *et al.* (1983) who reported increased plant height with application of GA. These results are also supported by Balasta *et al*. (1989) and Abro *et al*. (2009) who reported that application of Si increases plant height. Altogether these results suggested that combined application of GA and Si increased plant height than the other combinations.

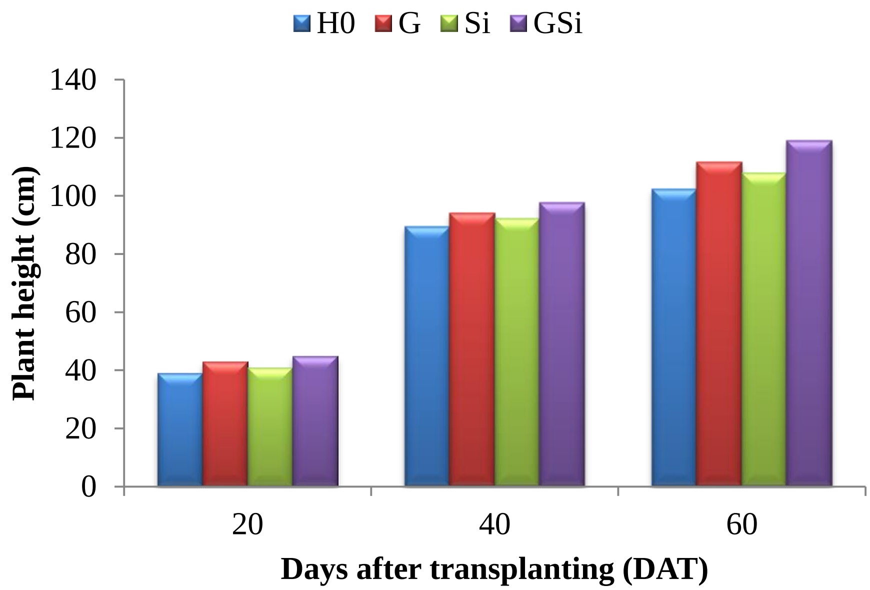


Figure 2. Effect of different combinations of GA and Si on the plant height of tomato at different days after transplanting (LSD $_{(0.05)}$ = 2.62, 5.46 and 8.11 at 20, 40 and 60 DAT, respectively); Here, H_o=Controlled, G=20 ppm GA + 0 mM Si, Si=0 ppm GA +0.4 mM Si, GSi=20 ppm GA+0.4 mM Si.

The results of the present study showed that the interaction effect between growing structures and different combinations of GA and Si on plant height was significant at 20, 40 and 60 DAT (Table 1 and appendix III). At 20 DAT, the highest plant height (53.75 cm) was found from WGSi which was statistically similar to WG (51.50 cm) & WSi (50.25 cm) and the lowest value (31.25 cm) was recorded in case of EH_o which was statistically similar to EG (34.50 cm), ESi (32.50 cm) & EGSi (35.50 cm). At 40 DAT, the highest plant height (104.0 cm) was found from WGSi which was statistically similar to CGSi (97.00 cm), WH_o (95.00 cm), WG (99.50 cm) and WSi (96.75 cm) where the lowest value (85.75 cm) was recorded from EH_o which was statistically similar to EG (90.00 cm), ESi (88.75 cm), EGSi (92.00 cm), CG (93.00 cm), CSi (91.00 cm) and WH_o (95.00 cm). At 60 DAT, the highest plant height (129.5 cm) was recorded from WGSi which was statistically similar to WSi (118.3 cm), WG (121.0 cm) and CGSi (118.3 cm). The lowest value (118.3 cm) at 60 DAT was found at EH_0 which was statistically similar to EG (103.5 cm), ESi (98.00 cm) and CSi (107.5 cm).

Altogether it has been observed that wooden bed along with combined effect of GA and Si was more suitable to increase plant height.

Table 1. Interaction effect of different plant growing structures and different combinations of GA and Si on the plant height of tomato at different days after transplanting

Treatment combinations	Plant height (cm) at different days after transplanting (DAT)		
	20	40	60
CH_0	38.00 fg	88.00 cd	100.3 c-e
CG	42.75 de	93.00 b-d	110.5 b-d
CSi	40.00 ef	91.00 b-d	107.5 b-e
CGSi	45.25 cd	97.00 a-c	118.3 ab
WH_0	47.75 bc	95.00 a-d	113.3 bc
WG	51.50 ab	99.50 ab	121.0 ab
WSi	50.25 ab	96.75 a-c	118.3 ab
WGSi	53.75 a	104.0 a	129.5 a
EH_0	31.25 h	85.75 d	93.75 e
EG	34.50 gh	90.00 cd	103.5 c-e
ESi	32.50 h	88.75 cd	98.00 de
EGSi	35.50 f-h	92.00 b-d	109.5 b-d
LSD $_{(0.05)}$	**4.53**	**9.45**	**14.05**
Significant level	*	*	*
CV (%)	**7.51**	**7.03**	**8.86**

C=Concrete bed
W=Wooden bed
E=Earthen pot

Ho=0 ppm GA+0 mM Si
G=20 ppm GA+0 mM Si
Si=0 ppm GA+0.4 mM Si
GSi=20 ppm GA+0.4 mM Si

CV=Co-efficient of Variance
LSD=Least Significant Difference
* = Significant at 5% level

4.1.2 Number of leaves plant^{-1}

As being the main photosynthetic organ leaf is a very crucial part of plant, thus leaf number is very important character for plant growth and development. Leaf number was counted at 20, 40 and 60 DAT to find out the effect of growing structure and combination of GA and Si.

Different growing structures have shown a significant influence on number of leaves plant^{-1} (Fig. 3 and Appendix IV). At 20 DAT, maximum number of leaves were observed in W (10.25) and lowest number were found from E (7.75). At 40 DAT, maximum numbers of leaves plant^{-1} (33.19) was found in W and the lowest (23.44) from E. At 60 DAT, the highest number of leaves (98.81) was recorded from W which was statistically similar to C (95.88). These results showed that wooden bed has given highest number of leaves plant^{-1} whereas from earthen pot lowest number of leaves plant^{-1} was found. These results are partially supported by Metwally (2016) who found that plants grown in big pots system has the highest values regarding number of leaves. Altogether these results suggest that wooden bed was more suitable to increase number of leaves per plant other than earthen pot and concrete bed.

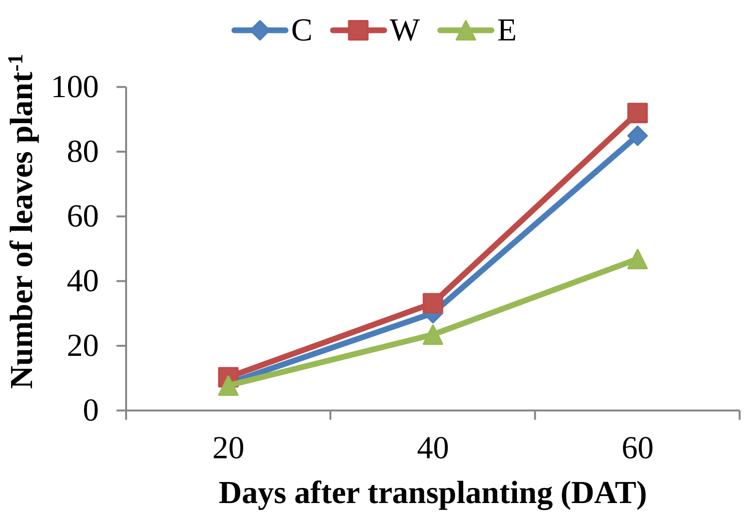


Figure 3. Effect of different plant growing structures on the number of leaves plant^{-1} of tomato at different days after transplanting (LSD $_{(0.05)}$ = 0.47, 1.75 and 4.40 at 20, 40 and 60 DAT, respectively); Here, C= Concrete bed, W=Wooden bed, E=Earthen pot.

Significant influence of different combinations of GA and Si was found on number of leaves plant^{-1} at 20, 40 and 60 DAT (Fig. 4 and Appendix IV). At 20 DAT, highest number of leaves was found from GSi (10.42) and lowest number of leaves was found from H_o (7.33). At 40 DAT, maximum number of leaves was found from GSi (31.58) which was statistically similar to G (29.75) and lowest number (25.67) was at H_o. At 60 DAT, highest number of leaves plant^{-1} was observed in GSi (85.58) and the lowest number number of leaves plant^{-1} was found at H_o (63.25).

From this study it was observed that GA and Si increased number of leaves plant^{-1} as compared with the controlled condition whereas the best result was found from the combined application of GA and Si. These results are consistent with Shittu and Adeleke (1999) who reported that number of leaves were significantly enhanced by GA3 treatment. These results are also in agreement with findings of Gabal *et al.* (1990) that GA3 was more effective treatment in increasing leaf number plant^{-1} compared to control.

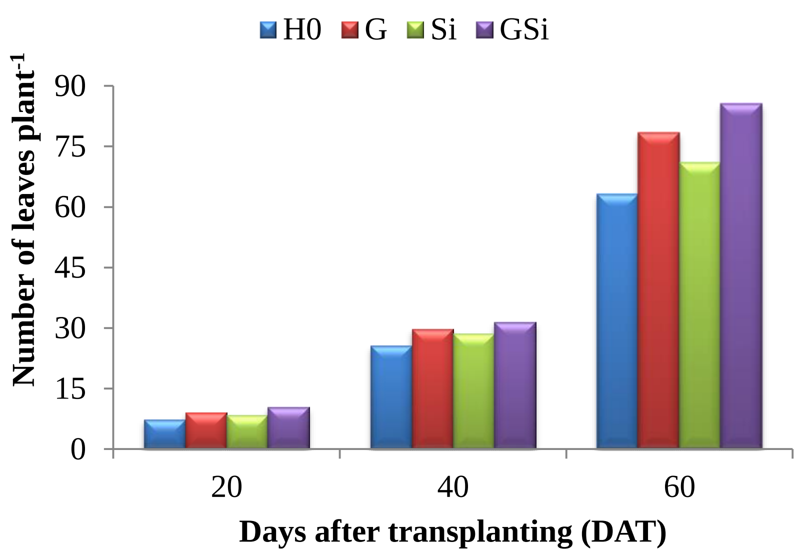


Figure 4. Effect of different combinations of GA and Si on the number of leaves plant^{-1} of tomato at different days after transplanting (LSD $_{(0.05)}$ = 0.54, 2.02 and 5.08 at 20, 40 and 60 DAT, respectively); Here, H_o=Controlled, G=20 ppm GA + 0 mM Si, Si=0 ppm GA + 0.4 mM Si, GSi=20 ppm GA+ 0.4 mM Si.

Significant interaction effect has been observed between growing structures and different combinations of GA and Si at 20, 40 and 60 DAT (Table 2, Appendix IV). At 20 DAT, highest number of leaves was found from WGSi (13.00) and lowest (7.00) was found from EH_0 which was statistically similar to CH_0 (7.25), ESi (7.25) and WH_0 (7.75). At 40 DAT, maximum number of leaves was found from WGSi 36.00 which was statistically similar to WSi (32.75), WG (33.25) and CGSi (33.00). Lowest value (20.25) at 40 DAT was found from EH_0 which was statistically similar to ESi (23.50). At 60 DAT, maximum number of leaves was found from WGSi (100.3) which was statistically similar to WG (97.75). Lowest value (33.00) was found from EH_0. Altogether it can be said that number of leaves $plant^{-1}$ was found highest in case of wooden bed with combination of GA and Si and lowest was found from earthen pot in controlled condition.

Table 2. Interaction effect of different plant growing structures and different combinations of GA and Si on the number of leaves plant^{-1} of tomato at different days after transplanting

Treatment combinations	Number of leaves plant^{-1} (no.) at different days after transplanting (DAT)		
	20	40	60
CH_0	7.25 de	26.00 d	74.25 d
CG	8.50 c	31.75 bc	88.00 bc
CSi	8.00 cd	29.75 c	82.00 cd
CGSi	10.00 b	33.00 a-c	95.50 ab
WH_0	7.75 c-e	30.75 bc	82.50 cd
WG	10.25 b	33.25 ab	97.75 a
WSi	10.00 b	32.75 a-c	87.25 bc
WGSi	13.00 a	36.00 a	100.3 a
EH_0	7.00 e	20.25 e	33.00 g
EG	8.50 c	24.25 d	49.50 f
ESi	7.25 de	23.50 de	43.75 f
EGSi	8.25 c	25.75 d	61.00 e
LSD $_{(0.05)}$	**0.94**	**3.50**	**8.79**
Significant level	*	*	*
CV (%)	**7.4**	**8.4**	**8.19**

C=Concrete bed
W=Wooden bed
E=Earthen pot

Ho=0 ppm GA+0 mM Si
G=20 ppm GA+0 mM Si
Si=0 ppm GA+0.4 mM Si
GSi=20 ppm GA+0.4 mM Si

CV=Co-efficient of Variance
LSD=Least Significant Difference
* = Significant at 5% level

4.1.3 Number of branches plant^{-1}

Number of branches plant^{-1} was significantly influenced by growing structure and different combinations of GA and Si at 20, 40 and 60 DAT.

In case of growing structures there was significant effect (Fig. 5 and Appendix V). At 20 DAT, the highest number of branches plant^{-1} were found from C (3.88) which was statistically similar to W (3.75) and lowest (3.13) was found from E. At 40 DAT, maximum number of branches plant^{-1} were found from W (11.56) and the lowest value was found from E (8.813). Highest number of braches at 60 DAT was observed from W (15.63) and lowest from E (12.44). Altogether it can be said that wooden structure has significantly increased number of branches plant^{-1}.

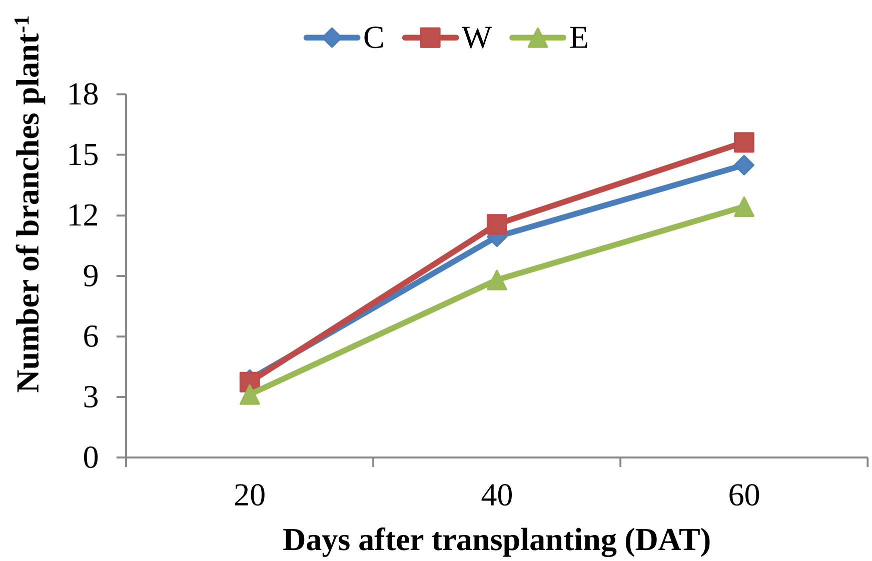


Figure 5. Effect of different plant growing structures on the number of branches plant^{-1} of tomato at different days after transplanting (LSD $_{(0.05)}$ = 0.33, 0.62 and 0.77 at 20, 40 and 60 DAT, respectively); Here, C= Concrete bed, W=Wooden bed, E=Earthen pot.

Different combinations of GA and Si showed significant variations in number of branches per plant at 20, 40 and 60 DAT (Fig.6 and Appendix V). At 20 DAT, highest number of branches were found from GSi (4.58) which was statistically similar to G (4.25) and lowest number of branches were observed from H_o (2.58) which was statistically similar to Si (2.92). At 40 DAT, maximum number of branches was observed in GSi (12.17) and lowest number was observed in H_o (8.92). At 60 DAT, highest number of branches was found from GSi (15.75) and lowest was found from H_o (12.50).

Combined application of GA and Si has been found more effective than the other combinations and gibberellic acid has been found given more branches than Si. These results are partially supported by Tomar and Ramgiry (1997) who reported that tomato plant treated with GA3 showed significantly greater number of branches plant^{-1} than untreated controls.

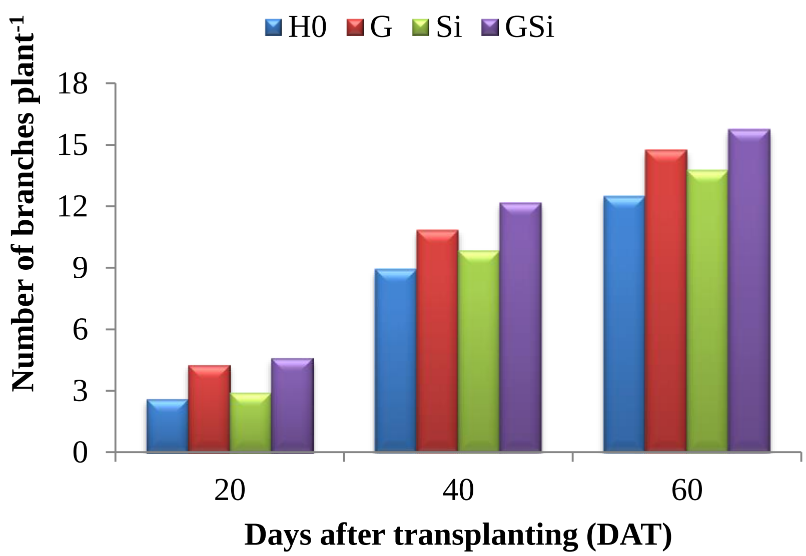


Figure 6. Effect of different combinations of GA and Si on the number of branches plant^{-1} of tomato at different days after transplanting (LSD $_{(0.05)}$ = 0.38, 0.72 and 0.89 at 20, 40 and 60 DAT, respectively); Here, H_o=Controlled, G=20 ppm GA + 0 mM Si, Si=0 ppm GA +0.4 mM Si, GSi=20 ppm GA+0.4 mM Si.

A significant effect has been found on number of branches plant^{-1} in case of interaction between growing structure and different combinations of GA and Si (Table 3 and Appendix V). At 20 DAT, maximum number of branches were found in CGSi (5.00) which was statistically similar to CG (4.75) and WGSi (4.50). Lowest value was found in EH_o (2.00) which was statistically identical to ESi (2.50). At 40 DAT, maximum number of branches were found in WGSi (13.25) which was statistically similar to CGSi (12.75). Lowest value was found in EH_0 (7.25) which was statistically similar to ESi (8.00). At 60 DAT, highest value was found from WGSi (17.25) which was statistically identical to CGSi (16.25) and WG (16.00) and lowest value **(**10.75) was found from EH_0 which was statistically similar to ESi (12.00). Altogether it can be said that wooden bed along with combined application of GA and Si has given the best result in case of number of branches plant^{-1} whereas controlled condition in earthen pot has given the lowest number of branches.

Table 3. Interaction effect of different plant growing structures and different combinations of GA and Si on the number of branches plant^{-1} of tomato at different days after transplanting

Treatment combinations	Number of branches plant^{-1} at different days after transplanting (DAT)		
	20	40	60
CH_0	2.75 ef	9.50 e	12.75 de
CG	4.75 ab	11.00 cd	15.00 bc
CSi	3.00 ef	10.50 de	14.25 cd
CGSi	5.00 a	12.75 ab	16.00 ab
WH_0	3.00 ef	10.00 de	14.00 cd
WG	4.25 bc	12.00 bc	16.25 ab
WSi	3.25 de	11.00 cd	15.00 bc
WGSi	4.50 ab	13.25 a	17.25 a
EH_0	2.00 g	7.25 f	10.75 f
EG	3.75 cd	9.50 e	13.00 de
ESi	2.50 fg	8.00 f	12.00 ef
EGSi	4.25 bc	10.50 de	14.00 cd
$LSD_{(0.05)}$	**0.66**	**1.24**	**1.53**
Significant level	*	*	*
CV (%)	**12.89**	**8.29**	**7.52**

C=Concrete bed
W=Wooden bed
E=Earthen pot

Ho=0 ppm GA+0 mM Si
G=20 ppm GA+0 mM Si
Si=0 ppm GA+0.4 mM Si
GSi=20 ppm GA+0.4 mM Si

CV=Co-efficient of Variance
LSD=Least Significant Difference
* = Significant at 5% level

4.1.4 Stem diameter:

Stem diameter of the plants have shown significant results in response to growing structures and different combinations of GA and Si at 50 DAT.

Growing structures have shown significant effect on stem diameter (Fig. 9 and Appendix VI). Highest value was found in W (1.01) which was statistically similar to C (0.99) and the lowest was found in E (0.77).

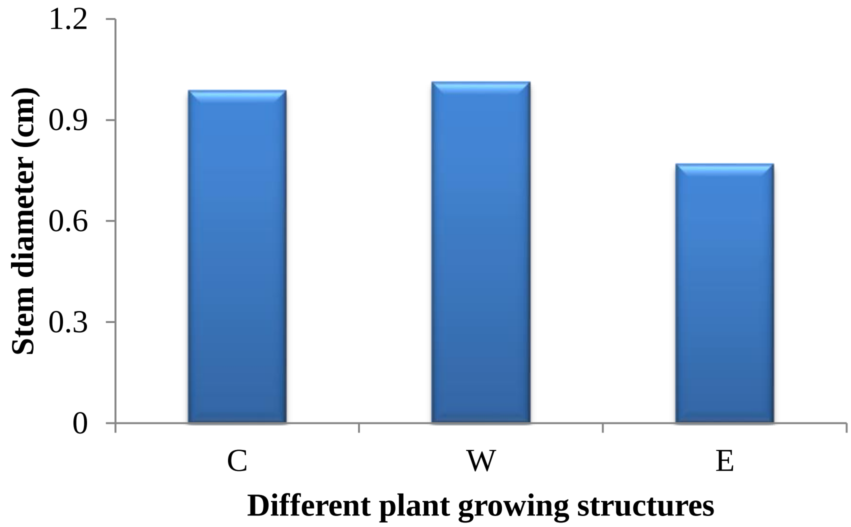


Figure 7. Effect of different plant growing structures on the stem diameter of tomato (LSD $_{(0.05)}$ = 0.06); Here, C= Concrete bed, W=Wooden bed, E=Earthen pot.

Different combinations of GA and Si has exhibited significant effect on stem diameter of tomato plants (Fig. 10 and Appendix VI). Highest value was found from GSi (1.03) and lowest value was found from H_o (0.83). Stem diameter was more in case of combined application of GA and Si.

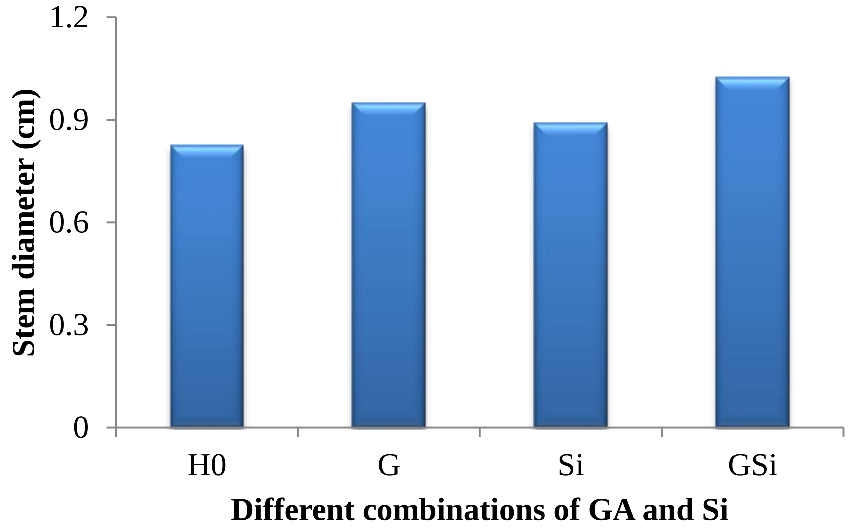


Figure 8. Effect of different combinations of GA and Si on the stem diameter of tomato (LSD $_{(0.05)}$ = 0.07); Here, H_o= Controlled, G=20 ppm GA + 0 mM Si, Si=0 ppm GA +0.4 mM Si, GSi=20 ppm GA+0.4 mM Si.

Interaction of growing structures and different combinations of GA and Si exhibited significant effect on stem diameter of tomato plant (Table 4 and Appendix VI).

The highest value was observed in WGSi **(**1.18) which was statistically identical to CGSi (1.10) and the lowest (0.73) was observed in EH_0 which was statistically similar to EG **(**0.78), ESi (0.78) and EGSi (0.80). Altogether it can be said that growing tomato on wooden bed with a combined application of GA and Si has given the best stem diameter.

Table 4. Interaction effect of different plant growing structures and different combinations of GA and Si on the stem diameter of tomato

Treatment combinations	Stem diameter (cm)
CH_0	0.88 ef
CG	1.05 bc
CSi	0.93 de
CGSi	1.10 ab
WH_0	0.88 ef
WG	1.03 b-d
WSi	0.98 c-e
WGSi	1.18 a
EH_0	0.73 g
EG	0.78 fg
ESi	0.78 fg
EGSi	0.80 fg
$LSD_{(0.05)}$	**0.12**
CV (%)	**9.15**

C=Concrete bed
W=Wooden bed
E=Earthen pot

Ho=0 ppm GA+0 mM Si
G=20 ppm GA+0 mM Si
Si=0 ppm GA+0.4 mM Si
GSi=20 ppm GA+0.4 mM Si

CV=Co-efficient of Variance
LSD=Least Significant Difference
* = Significant at 5% level

4.2 Effect of growing structure and different combinations of GA and Si on Physiological characteristics of tomato plants

4.2.1 Leaf chlorophyll content as measured in SPAD value:

Growing structures have shown a significant effect on chlorophyll content of tomato leaves on 40, 50 and 60 DAT (Fig. 11 and Appendix VIII). At 40 DAT, highest chlorophyll content (51.32 SPAD units) was found from W which was statistically similar to C (50.73 SPAD units) lowest (45.33 SPAD units) was observed from E. At 50 DAT, maximum chlorophyll content was recorded from W (57.49 SPAD units) and the lowest (47.28 SPAD units) was observed in E. At 60 DAT, highest chlorophyll content was observed in W (52.14 SPAD units) which was statistically similar to C (50.76 SPAD units) and lowest value was recorded from E (44.78 SPAD units). Wooden bed has given highest chlorophyll content and in earthen pot it was lowest however in concrete bed the SPAD value was in between the other two.

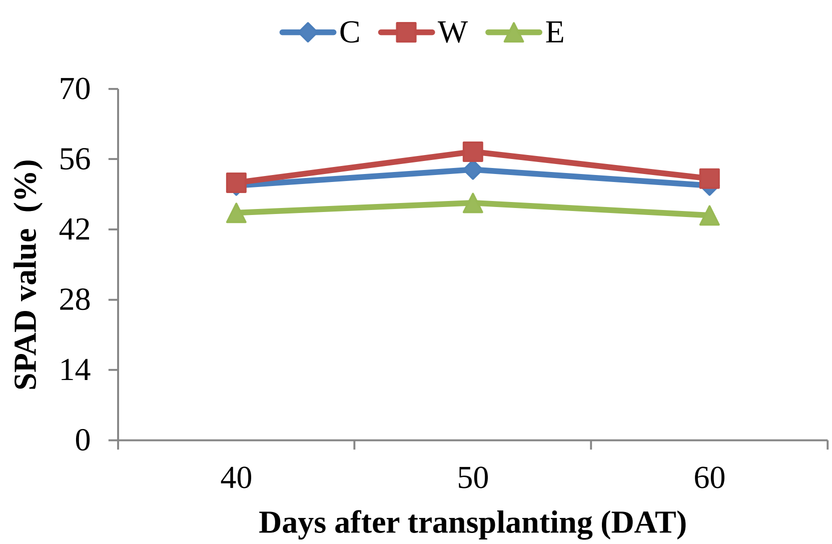


Figure 9. Effect of different plant growing structures on SPAD value of leaf of tomato at different days after transplanting (LSD $_{(0.05)}$ = 2.02, 3.38 and 2.92 at 40, 50 and 60 DAT, respectively); Here, C= Concrete bed, W=Wooden bed, E=Earthen pot.

Different combinations of GA and Si significantly affected the chlorophyll content of the leaves at 40, 50 and 60 DAT (Fig. 12 and Appendix VIII). At 40 DAT, the maximum chlorophyll content was recorded from GSi (51.74) which was statistically similar to G (50.13) and lowest value (46.04) was found from H_o. At 50 DAT, highest chlorophyll content was observed in GSi (55.66) which was statistically similar to G (53.62) and lowest value was found from H_o (50.73) which was statistically similar to Si (51.60). At 60 DAT, maximum chlorophyll content was found from GSi (51.63) which was statistically identical to G (49.87) and Si (48.92) and lowest chlorophyll content was found in H_o (46.51) which was statistically identical to G (49.87) and Si (48.92). Altogether it can be said that combined application of GA and Si has shown highest chlorophyll content of leaves.

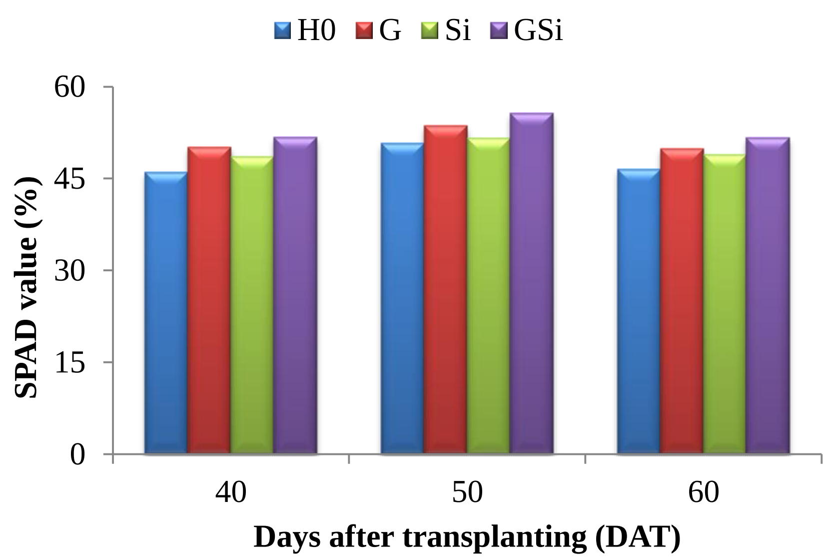


Figure 10. Effect of different combinations of GA and Si on SPAD value of leaf of tomato at different days after transplanting (LSD $_{(0.05)}$ = 2.33, 3.91 and 3.37 at 40, 50 and 60 DAT, respectively); Here, H_o=Controlled, G=20 ppm GA + 0 mM Si, Si=0 ppm GA +0.4 mM Si, GSi=20 ppm GA+0.4 mM Si.

Interaction between growing structures and different combinations of GA and Si has shown significant effect on chlorophyll content of leave (Table 5 and Appendix VIII) at 40, 50 and 60 DAT. At 40 DAT, maximum chlorophyll content was recorded from WGSi (53.60) which was statistically identical to CGSi (53.36), CG (52.09), CSi (50.01), WG (52.40) and WSi (51.44). Lowest value was found from EH_0 (42.81) which was statistically similar to EG (45.90) and ESi (44.35). At 50 DAT maximum chlorophyll was observed from WGSi (61.00) which was statistically identical to WG (58.49), WH_0 (54.78), WSi (55.69), CGSi (56.61) and CG (54.90). Lowest chlorophyll content was found from EH_0 (45.35) which was statistically similar to EG (47.46), ESi (46.92), EGSi (49.3) and CH_0 (52.06). At 60 DAT, highest chlorophyll content was found from WGSi (55.29) which was statistically similar to WSi (50.99), WG (51.53), WH_0 (50.78), CGSi (52.50), CSi (50.17) and CG (51.53). Lowest value (39.91) was observed in EH_0 which was statistically similar to ESi (45.59). Altogether it can be said that leaves from wooden bed which were treated with GA and Si have shown highest chlorophyll content

Table 5. Interaction effect of different plant growing structures and different combinations of GA and Si on the SPAD Value of leaf of tomato at different days after transplanting

Treatment combinations	SPAD Value at different days after transplanting (DAT)		
	40	50	60
CH_0	47.47 cd	52.06 b-e	48.85 b-d
CG	52.09 ab	54.90 a-c	51.53 a-c
CSi	50.01 a-c	52.20 b-d	50.17 a-d
CGSi	53.36 a	56.61 ab	52.50 ab
WH_0	47.83 cd	54.78 a-c	50.78 a-d
WG	52.40 a	58.49 ab	51.53 a-c
WSi	51.44 a-c	55.69 a-c	50.99 a-d
WGSi	53.60 a	61.00 a	55.29 a
EH_0	42.81 e	45.35 e	39.91 e
EG	45.90 de	47.46 de	46.55 cd
ESi	44.35 de	46.92 de	45.59 de
EGSi	48.25 b-d	49.38 c-e	47.09 b-d
$LSD_{(0.05)}$	**4.04**	**6.76**	**5.83**
Significant level	*	*	*
CV (%)	**5.71**	**8.89**	**8.23**

C=Concrete bed
W=Wooden bed
E=Earthen pot

Ho=0 ppm GA+0 mM Si
G=20 ppm GA+0 mM Si
Si=0 ppm GA+0.4 mM Si
GSi=20 ppm GA+0.4 mM Si

CV=Co-efficient of Variance
LSD=Least Significant Difference
* = Significant at 5% level

4.2.2 Leaf Water loss (%)

Growing structures significantly affected the leaf water loss (%) of tomato plant (Fig. 13 and Appendix VI). Highest transpiration was observed in C (9.15) and the lowest leaf water loss (%) was observed in E (8.32).

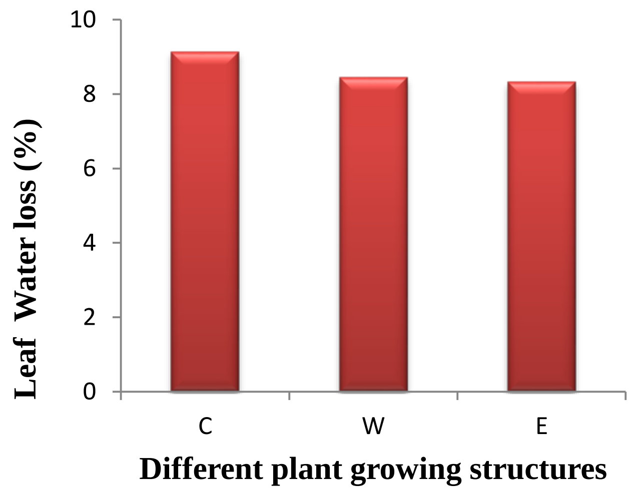


Figure 11. Effect of different plant growing structures on the leaf water loss (%) of tomato (LSD $_{(0.05)}$ = 0.52); Here, C= Concrete bed, W=Wooden bed, E=Earthen pot.

Different combinations of GA and Si showed significant effect on transpiration rate (Fig. 14 and Appendix VI). Maximum leaf water loss (%) was found from G (9.28) which was statistically identical to H_o (8.94) and lowest value was found from Si (8.03) which was statistically identical to GSi (8.31). Application of silicon has reduced leaf water loss (%) whereas GA has increased the leaf water loss (%).

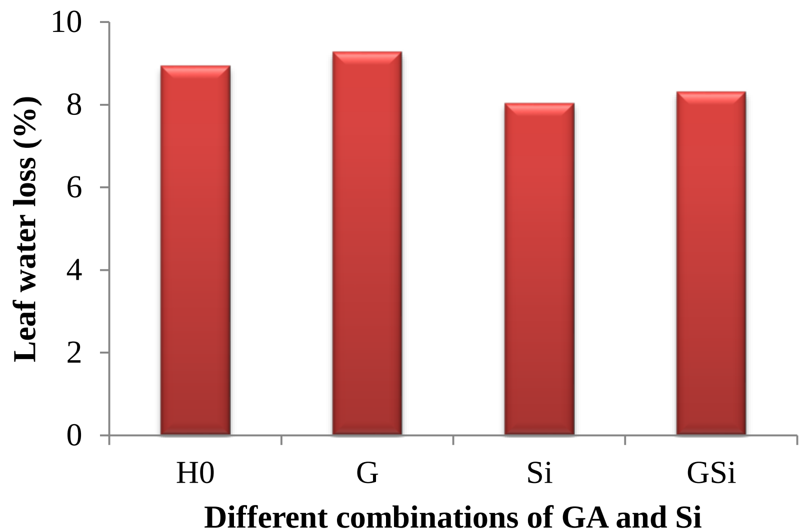


Figure 12. Effect of different combinations of GA and Si on the leaf water loss (%) of tomato (LSD $_{(0.05)}$ = 0.60); Here, H_o=Controlled, G=20 ppm GA + 0 mM Si, Si=0 ppm GA +0.4 mM Si, GSi=20 ppm GA+0.4 mM Si.

Interaction of growing structures and different combinations of GA and Si showed significant effect on leaf water loss (%) of tomato plants (Table 6 and Appendix VI).

In case of interaction of both the factors maximum leaf water loss (%) was found from CG (9.97) which was statistically similar to WG (8.96) and EH_0 (9.43). Lowest value was observed in ESi (7.67) which was statistically similar to CGSi (7.97), WSi (7.97) and WGSi (8.21). Altogether it can be said that tomato plants which were grown in concrete bed with gibberellic acid had shown highest leaf water loss (%) whereas silicon application has reduced leaf water loss (%) also plants from earthen pot had shown to reduce leaf water loss (%).

Table 6. Interaction effect of plant growing structures and different combinations of GA and Si on the Leaf Water loss (%) of tomato

Treatment combinations	Leaf Water loss (%)
CH_0	9.43 ab
CG	9.97 a
CSi	8.47 b-d
CGSi	8.74 bc
WH_0	8.62 bcd
WG	8.96 abc
WSi	7.97 cd
WGSi	8.21 cd
EH_0	8.76 bc
EG	8.91 bc
ESi	7.67 d
EGSi	7.97 cd
LSD $_{(0.05)}$	**1.04**
Significant level	*
CV (%)	**8.34**

C=Concrete bed
W=Wooden bed
E=Earthen pot

Ho=0 ppm GA+0 mM Si
G=20 ppm GA+0 mM Si
Si=0 ppm GA+0.4 mM Si
GSi=20 ppm GA+0.4 mM Si

CV=Co-efficient of Variance
LSD=Least Significant Difference
* = Significant at 5% level

4.3 Effect of different growing structures and different combinations of GA and Si on yield contributing and yield characters:

4.3.1 Number of flower cluster plant^{-1}

Significant effects of growing structures were found in number of flower cluster plant^{-1} (Fig 15 and Appendix VII). Maximum number of flower cluster plant^{-1} was found in W (13.56) and lowest number of flower cluster was found in E (7.063). Plants from wooden bed has given more flower cluster than the plants from earthen bed however plants from concrete bed has given more flower cluster than the earthen pot but less than wooden bed.

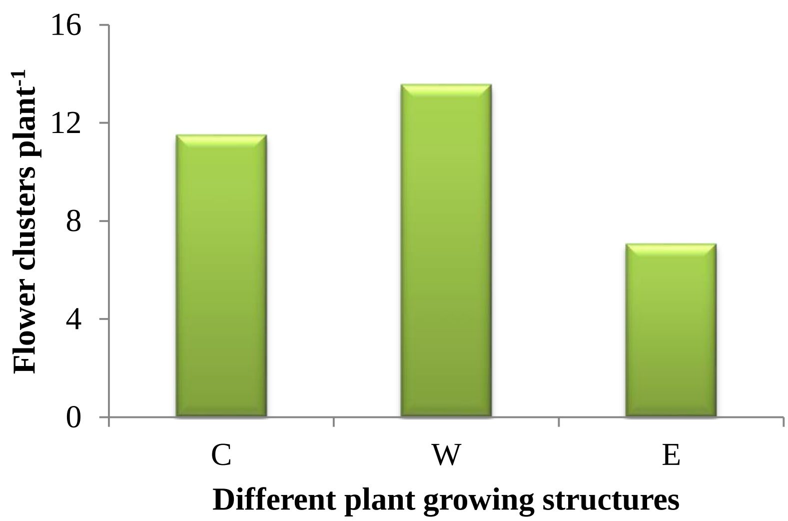


Figure 13. Effect of different plant growing structures on the flower clusters plant^{-1} of tomato (LSD $_{(0.05)}$ = 0.60) ; Here, C= Concrete bed, W=Wooden bed, E=Earthen pot.

Different combinations of GA and Si exhibited significant effect on number of flower cluster plant^{-1} (Fig 16 and Appendix VII). Highest value (12.83) was observed in GSi and lowest (9.17) was found from H_o which was statistically similar to Si (9.75). So, the combined effect of GA and Si has exhibited the best result for flower cluster plant^{-1}. These findings are partially supported by those of Leonard *et al.* (1983) and Onofegharn (1981) who reported that inflorescence development and flower primordia production in tomato was promoted by GA3 application.

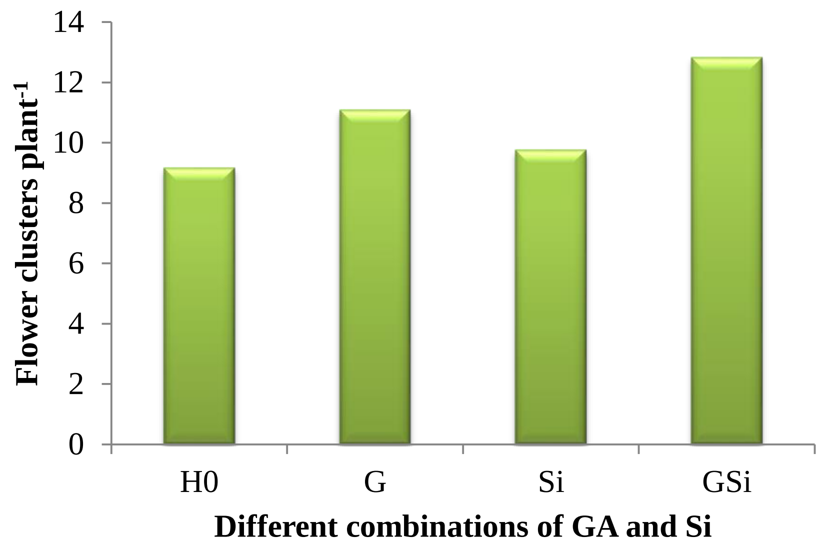


Figure 14. Effect of different combinations of GA and Si on the flower clusters plant^{-1} of tomato (LSD $_{(0.05)}$ = 0.69); Here, H_o= Controlled, G=20 ppm GA + 0 mM Si, Si=0 ppm GA +0.4 mM Si, GSi=20 ppm GA+0.4 mM Si.

Interaction of different growing structures and different combinations of GA and Si exhibited significant effect on number of flower cluster plant^{-1} (Table 7 and Appendix VII). Maximum number of flower cluster plant^{-1} was found from WGSi (15.50) which was statistically similar to CGSi (14.50). Lowest value was observed from EH_0 (6.00) which was statistically similar to ESi (6.25). Altogether it can be said that the wooden beds in combination with GA and Si has given the best result in case of number of flower cluster plant^{-1}.

4.3.3 Number of Flowers plant^{-1}

There was significant difference between numbers of flowers plant^{-1} in respect of different growing structures (Fig.17 and Appendix VII). The maximum number of flowers were observed in W (43.38) and lowest value was observed from E (27.00).

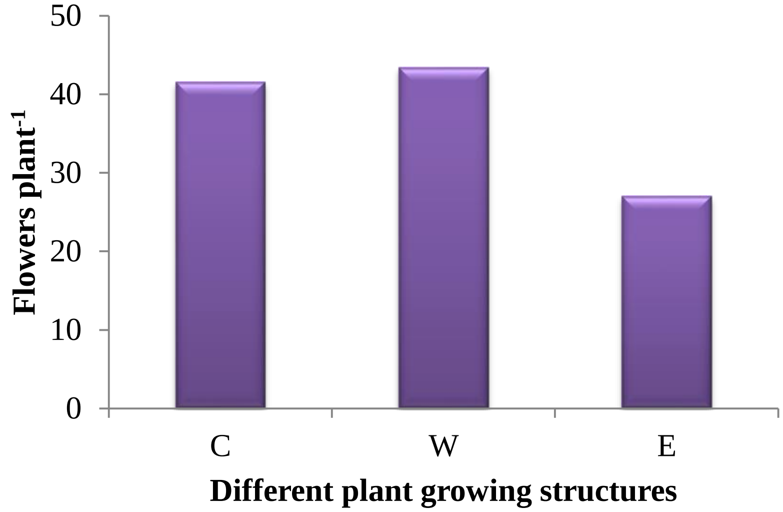


Figure 15. Effect of different plant growing structures on the flowers plant^{-1} of tomato (LSD $_{(0.05)}$ = 1.40); Here, C= Concrete bed, W=Wooden bed, E=Earthen pot.

In case of different combinations of GA and Si number of flowers plant^{-1} was found to be significantly affected (Fig. 18 and Appendix VII).

Maximum number of flowers was found in GSi (40.42) and lowest (34.58) was found from H_o which was statistically similar to Si (35.92). However single application of Gibberellin has shown more flowers than single application of Silicon.

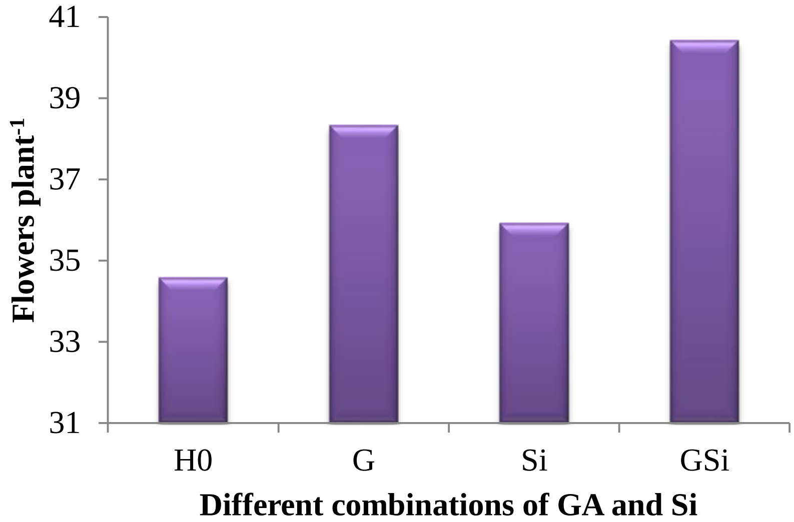


Figure 16. Effect of different combinations of GA and Si on the flowers plant^{-1} of tomato (LSD $_{(0.05)}$ = 1.61); Here, H_o=Controlled, G=20 ppm GA + 0 mM Si, Si=0 ppm GA +0.4 mM Si, GSi=20 ppm GA+0.4 mM Si.

Interaction between different growing structures and different combination of GA and Si showed significant affect in total number of flowers plant^{-1} (Table 7 and Appendix VII). Maximum numbers of flowers plant^{-1} was observed in WGSi (46.75) which was statistically similar to CGSi (44.25) and WG (44.00) and the lowest number of flowers was found from EHo (24.25) which was statistically similar to ESi (25.00). Altogether it was observed that wooden bed in a combination of both GA and Si application gave maximum number of flowers plant^{-1}.

4.3.4 Fruits plant^{-1}

Number of fruits plant^{-1} exhibited significant variation in number with different growing structures (Fig.19 and Appendix VII). The Highest number of fruits was found from W (8.75) which was statistically similar to C (8.38) and lowest number of fruits was found from E (5.81). Plants from wooden bed gave more fruits plant^{-1} than the other two. However plants from concrete bed gave a number in between wooden and earthen.

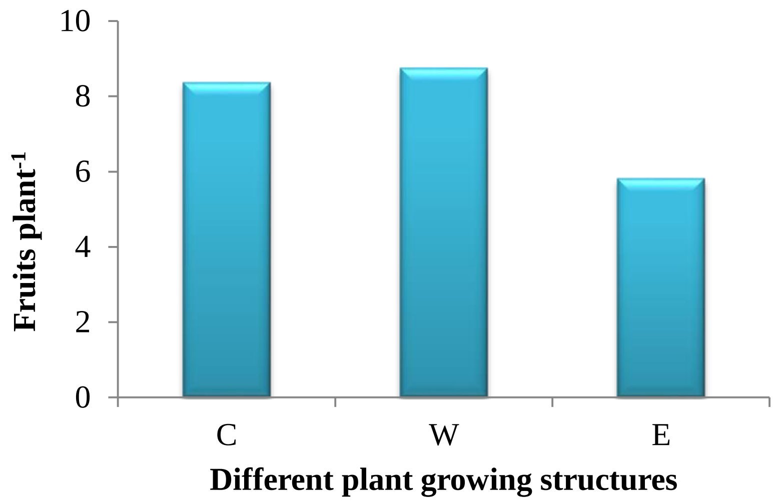


Figure 17. Effect of different plant growing structures on the fruits plant^{-1} of tomato (LSD $_{(0.05)}$ = 0.48); Here, C= Concrete bed, W=Wooden bed, E=Earthen pot.

Different combinations of GA and Si significantly affected the fruit number plant^{-1}. Maximum number of fruits was found from GSi (9.00) and lowest number of fruits was found from H_o (6.33). However single application GA gave more fruits than Si. These results are partially supported by Adlakha and Verma (1964) and Kaushik *et al.* (1974) who reported that the fruit setting increased by 5% with higher concentration of GA.

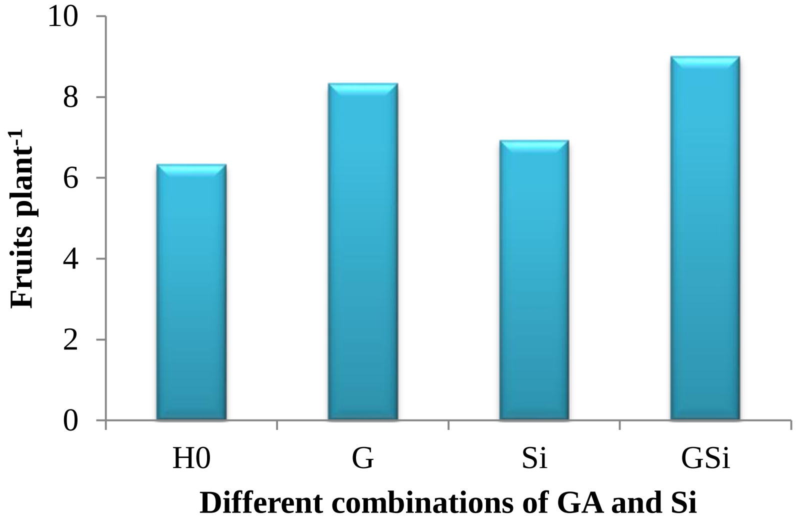


Figure 18. Effect of different combinations of GA and Si on the fruits plant^{-1} of tomato (LSD $_{(0.05)}$ = 0.55); Here, H_o= Controlled, G=20 ppm GA + 0 mM Si, Si=0 ppm GA +0.4 mM Si, GSi=20 ppm GA+0.4 mM Si.

Number of fruits plant^{-1} was significantly affected by the interaction of different growing structures and different combinations of GA and Si (Table 7 and Appendix VII). Maximum number of fruits was found from WGSi (10.00) which was statistically similar to CGSi (9.75) and WG (9.50). Lowest value (4.50) was found from EH_0 which was statistically similar to ESi (5.00). Altogether it can be said that plants grown in wooden bed and treated with both GA and Si gave maximum fruit.

Table 7. Interaction effect of different plant growing structures and different combinations of GA and Si on the flower clusters plant^{-1}, flowers plant^{-1} and fruits plant^{-1} of tomato

Treatment combinations	Flower clusters plant^{-1}	Flowers plant^{-1}	Fruits plant^{-1}
CH_0	9.25 ef	38.75 d	7.00 de
CG	12.00 d	42.50 bc	9.00 b
CSi	10.25 e	40.75 cd	7.75 cd
CGSi	14.50 ab	44.25 ab	9.75 ab
WH_0	12.25 d	40.75 cd	7.50 cd
WG	13.75 bc	44.00 ab	9.50 ab
WSi	12.75 cd	42.00 bc	8.00 c
WGSi	15.50 a	46.75 a	10.00 a
EH_0	6.00 h	24.25 f	4.50 f
EG	7.50 g	28.50 e	6.50 e
ESi	6.25 h	25.00 f	5.00 f
EGSi	8.50 fg	30.25 e	7.25 c-e
LSD $_{(0.05)}$	**1.20**	**2.80**	**0.95**
Significant level	*	*	*
CV (%)	**7.79**	**5.21**	**8.66**

C=Concrete bed
W=Wooden bed
E=Earthen pot

Ho=0 ppm GA+0 mM Si
G=20 ppm GA+0 mM Si
Si=0 ppm GA+0.4 mM Si
GSi=20 ppm GA+0.4 mM Si

CV=Co-efficient of Variance
LSD=Least Significant Difference
* = Significant at 5% level

4.3.5 Individual fruit weight

Individual fruit weight significantly varied with different plant growing structures (Fig. 21 and Appendix VII). Maximum fruit was observed from W (16.54) which was statistically similar to G (15.92). Lowest individual fruit weight was found from E (13.09). Individual fruit weight of concrete bed was in between them.

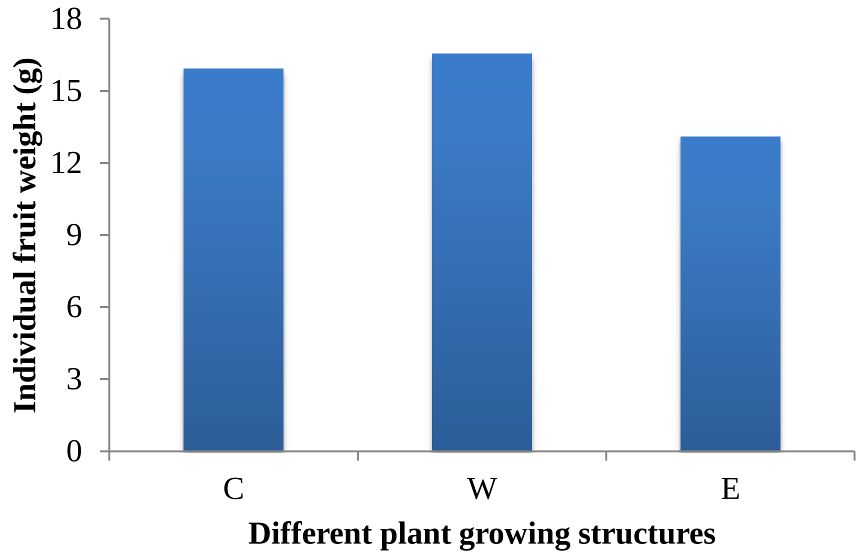


Figure 19. Effect of plant growing structures on the individual fruit weight of tomato (LSD $_{(0.05)}$ = 0.91); Here, C= Concrete bed, W=Wooden bed, E=Earthen pot.

Effect of different combinations of GA and Si was significant on individual fruit weight (Fig. 22 and Appendix VII). Maximum fruit weight was recorded from GSi (17.43) and lowest value was observed from Ho (13.18). It was obvious from the results that combined application of GA and Si has privileged more weight gain than the other treatment combinations. These results are partially supported by Kaushik *et al.* (1974) GA3 increased the number and weight of fruits plant $^{-1}$.

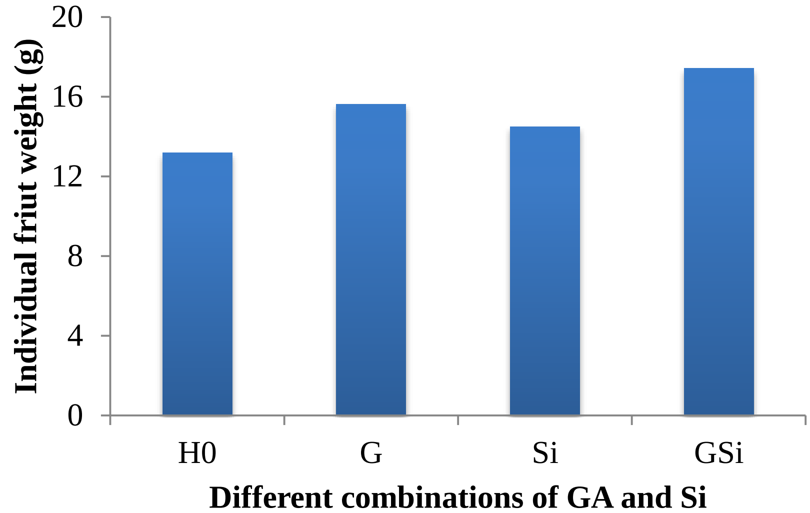


Figure 20. Effect of different combinations of GA and Si on the individual fruit weight of tomato (LSD $_{(0.05)}$ = 1.05); Here, H_o=Controlled, G=20 ppm GA + 0 mM Si, Si=0 ppm GA +0.4 mM Si, GSi=20 ppm GA+0.4 mM Si.

Interaction between different plant growing structures and different combinations of GA and Si exhibited significant variation in individual fruit weight individual fruit weight (Table 8 and Appendix VII). The highest value (19.15) was reported from WGSi which was statistically similar to CGSi **(**18.20). Lowest value (11.65) was found from EH_0 which was statistically similar to ESi (12.60), EG (13.18) and CH_0 (13.43). Plants from wooden bed those were treated with GA and Si showed highest individual weight.

4.3.5 Fruit yield plant^{-1}

Different growing structures showed significant effect on fruit yield plant^{-1} (Fig. 23 and Appendix VII). Maximum yield plant^{-1} was reported from W (146.6 g) and the lowest value was found from E (135.1 g). In wooden bed fruit yield was highest whereas concrete bed has shown yield less than the wooden bed but more than the earthen pot. This is partially supported by Bouzo and Favaro (2016) who reported an increase in the container size results in plants of higher size and yield. These findings were also partially supported byb Metwally (2016) who found that plants grown in big pots system has the highest values regarding yield.

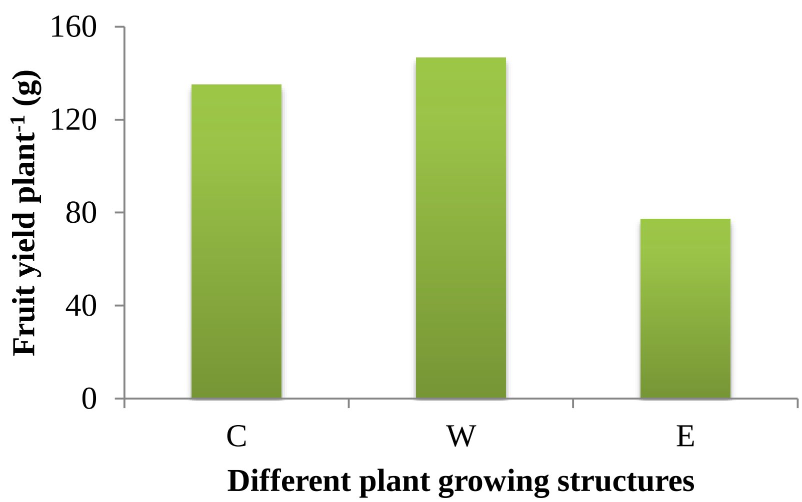


Figure 21. Effect of different plant growing structures on the fruit yield plant^{-1} of tomato (LSD $_{(0.05)}$ = 9.67) ; Here, C= Concrete bed, W=Wooden bed, E=Earthen pot.

Fruit yield plant^{-1} was significantly affected by different combinations of GA and Si (Fig. 24 and Appendix VII). Maximum fruit yield plant^{-1} was observed in GSi (159.0) and lowest value was found from H_o (84.93). However the plants those were treated with GA showed more yield plant^{-1} than those treated with Si and in controlled condition yield of fruits were lowest. These results are partially supported by Saleh and Abdul (1980) who performed an experiment with GA3 and found increase in the total yield compared with the control.

These results are also supported by Yoshida (1981) who reported that yield increases with application of Si.

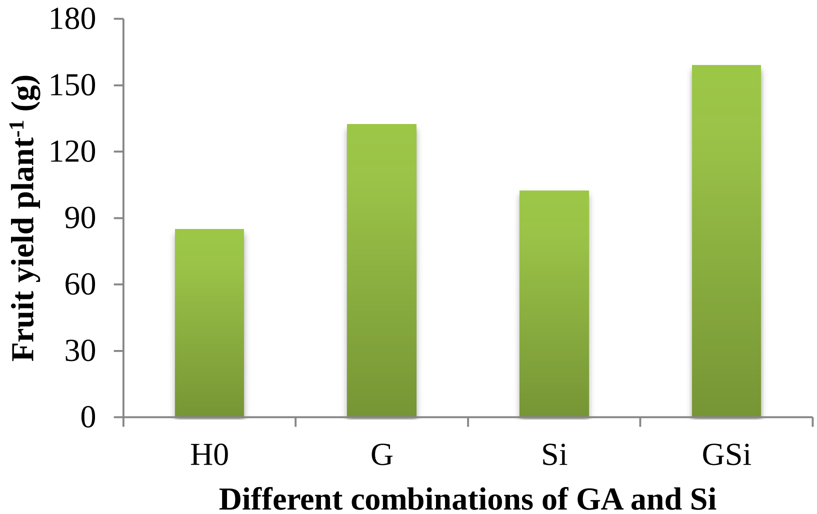


Figure 22. Effect of different combinations of GA and Si on the fruit yield plant^{-1} of tomato (LSD $_{(0.05)}$ = 11.16) ; Here, H_o=Controlled, G=20 ppm GA + 0 mM Si, Si=0ppm GA +0.4 mM Si, GSi=20 ppm GA+0.4 mM Si.

Yield plant^{-1} varied significantly with interactions between different growing structures and different combinations of GA and Si (Table 8 and Appendix VII). The highest yield was observed from WGSi (190.9) which was statistically similar to CGSi (177.6). The lowest value (52.11) was reported from EH_0 which was statistically similar to ESi (63.14). Altogether it was observed that the plants grown in wooden bed and treated with both GA and Si exhibited highest yield plant^{-1}.

Table 8. Interaction effect of different plant growing structures and different combinations of GA and Si on the individual fruit weight and fruit yield plant^{-1} of tomato

Treatment combinations	Individual fruit weight (g)	Fruit yield plant^{-1} (g)
CH_0	13.43 d-f	94.49 ef
CG	16.15 bc	144.8 c
CSi	15.90 bc	123.7 d
CGSi	18.20 a	177.6 ab
WH_0	14.45 c-e	108.2 de
WG	17.58 ab	166.6 b
WSi	15.00 cd	120.5 d
WGSi	19.15 a	190.9 a
EH_0	11.65 f	52.11 g
EG	13.18 ef	85.50 f
ESi	12.60 f	63.14 g
EGSi	14.93 c-e	108.4 de
LSD $_{(0.05)}$	**1.82**	**19.33**
Significant level	*	*
CV (%)	**8.34**	**11.23**

C=Concrete bed
W=Wooden bed
E=Earthen pot

Ho=0 ppm GA+0 mM Si
G=20 ppm GA+0 mM Si
Si=0 ppm GA+0.4 mM Si
GSi=20 ppm GA+0.4 mM Si

CV=Co-efficient of Variance
LSD=Least Significant Difference
* = Significant at 5% level

CHAPTER V

SUMMARY AND CONCLUSION

This study was conducted in the rooftop garden of Department of Agricultural Botany of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from June to October 2016. The purpose of the experiment was to investigate the influence of different kinds of growing structures and different combinations of Gibberellic acid (GA) and Silicon (Si) on summer tomato cultivation in the rooftop garden. In this research, the treatments consisted of three different kinds of growing structures, Wooden bed marked as W, Concrete bed marked as C, Earthen pot marked as E and four different combinations of GA and Si viz. Ho=0 ppm GA and 0 mM Si, G=20 ppm GA and 0 mM Si, Si=0 ppm GA and 0.4 mM Si and GSi= 20 ppm GA and 0.4 mM Si. Silicic acid was used as a source of Si and GA_3 was used as GA. The research was laid out in two factors Randomized complete Block Design (RCBD) with four replications. Different morpho-physiological parameters and yield with yield contributing characters of tomato were recorded and statistically analyzed to investigate the treatment effect. Different growing structures and different combinations of GA and Si exhibited a significant variation among the treatments.

Significant difference was found among different growing structures in respect of most of the parameters. Plant grown in wooden bed showed maximum height whereas the lowest height was found from the plants of earthen pot. At 20, 40 and 60 DAT, the highest plant height was 50.81 cm, 98.81 cm and 125.6 cm with wooden bed (W) whereas lowest was 33.44 cm, 89.13 cm and 116.4 cm with earthen pot (E). Maximum number of leaves plant^{-1} were 10.25, 33.19 and 98.81 at 20, 40 and 60 DAT with wooden bed (W) and lowest number of leaves plant^{-1} were 7.75, 23.44 and 36.63 was with earthen pot (E). The highest number of branches plant^{-1} at 40 and 60 DAT were 11.56, 15.63 with wooden bed (W) and lowest number were 8.813 and 12.44 with earthen pot (E). The highest stem diameter (1.01 cm) was found from W (wooden bed) and lowest (0.77 cm) found from E (earthen pot). Leaf SPAD value was recorded highest from W (wooden beds) at 40, 50 and 60 DAT and values were 51.32, 57.49 and 52.14, respectively. The lowest values were 45.33, 47.28 and 44.78 recorded from (E) earthen pot plants at 40, 50 and 60 DAT. Maximum leaf water loss percent (9.15) was found in C (Concrete bed) and lowest (8.32) in E (Earthen pot).

The maximum number of flower cluster plant^{-1} (13.56), flowers plant^{-1} (43.38) and fruit plant^{-1} (8.75) was recorded from W (wooden bed) whereas lowest number of flower cluster plant^{-1} (7.063), flowers plant^{-1} (27.00) and fruit plant^{-1} (5.81) was recorded from plants of E (earthen pot). The highest individual fruit weight (16.94g) and fruit yield plant^{-1} (146.6 g) was recorded from W (wooden bed) whereas individual lowest fruit weight (13.09 g) and fruit yield plant^{-1} (77.29 g) was recorded from plants of E (earthen pot).

Different combinations of Gibberellic acid (GA) and Silicon (Si) significantly influenced most of the parameters of the research. At 20, 40 and 60 DAT the maximum height (44.83, 97.67 and 119.1) of plant was observed from GSi (20 ppm GA and 0.4 mM Si) whereas lowest value (33.44, 89.13 and 116.4) was found from EH_0. The maximum number of leaves plant^{-1} were 10.42, 31.58 and 85.58 at 20, 40 and 60 DAT observed from GSi (20 ppm GA and 0.4 mM Si) and lowest number of leaves plant^{-1} were 7.33, 25.67 and 63.25 which were found from H_0 (0 ppm GA and 0.4 mM Si). The highest number of branches plant^{-1} at 20 DAT, 40 and 60 DAT were 4.58, 12.17 and 15.75 observed from GSi (20 ppm GA and 0.4 mM Si) and lowest number were 2.58, 8.92 and 12.50 which were found from H_0 (0 ppm GA and 0.4mM Si). Highest stem diameter (1.03cm) was observed from GSi (20 ppm GA and 0.4 mM Si) and lowest (0.83cm) was found from H_0 (0 ppm GA and 0.4 mM Si). Leaf Chlorophyll content was recorded highest from GSi (20 ppm GA and 0.4 mM Si) at 40, 50 and 60DAT and values were 51.74, 55.66 and 51.63, respectively. The lowest values were 46.04, 50.73 and 46.51 recorded from plants under H_0 (0 ppm GA and 0.4 mM Si) at 40, 50 and 60 DAT. The maximum leaf water loss (%) (9.28) was observed from G (20 ppm GA) and lowest (8.03) with application of Si. The maximum number of flower cluster plant^{-1} (12.83), flowers plant^{-1} (40.42) and fruit plant^{-1} (9.00) was recorded from GSi (20 ppm GA and 0.4 mM Si) whereas lowest number of flower cluster plant^{-1} (9.17), flowers plant^{-1} (34.58) and fruit plant^{-1} (6.33) was recorded from H_0 (0 ppm GA and 0.4 mM Si). The highest individual fruit weight (17.43g) and fruit yield plant^{-1} (159 g) was recorded from observed from GSi (20ppm GA and 0.4mM Si) whereas individual lowest fruit weight (13.18g) and fruit yield plant^{-1} (84.93g) was recorded from H_0 (0 ppm GA and 0.4 mM Si).

The interaction effect between plant growing structures and Gibberellic acid with silicic acid had significant effect on all parameters. The highest plant height was (53.75, 104.0 and 129.5 at 20, 40 and 60 DAT) observed from WGSi (Wooden bed with 20 ppm GA and 0.4 mM Si) treatment combination whereas lowest value (31.25, 85.75 and 113.0) was observed from EHo (Earthen pot with 0 ppm GA and 0.4 mM Si). The maximum number of leaves plant^{-1} was (13, 36 and 101.3 at 20, 40 and 60 DAT) observed from WGSi (Wooden bed with 20 ppm GA and 0.4 mM Si) treatment combination whereas lowest value (7, 20.25 and 33) was observed from EHo (Earthen pot 0 ppm GA and 0.4 mM Si). The highest number of branches plant^{-1} was (5, 13.25 and 17.25 at 20, 40 and 60 DAT) observed from CGSi (Concrete bed with 20 ppm GA and 0.4 mM Si) at 20 DAT and at 40 and 60 DAT from WGSi (Wooden bed with 20ppm GA and 0.4mM Si) treatment combination whereas lowest value (2, 7.25 and 10.75) was observed from EHo (Earthen pot under controlled condition). Highest stem diameter (1.18cm) was observed from WGSi (Wooden bed with 20 ppm GA and 0.4 mM Si) treatment combination whereas lowest value (0.73 cm) was observed from EHo (Earthen pot 0 ppm GA and 0.4 mM Si). At 40, 50 and 60 DAT, highest leaf SPAD value was (53.60, 61 and 55.29) observed from WGSi (Wooden bed with 20 ppm GA and 0.4 mM Si) and lowest value (42.81, 45.35 and 39.91) was observed from EHo (Earthen pot 0 ppm GA and 0.4 mM Si). Maximum leaf water loss percent (9.97) was observed from CG (Concrete bed with 20 ppm GA) and lowest (7.67) from ESi (Earthen pot with 0.4 mM Si). The maximum number of flower cluster plant^{-1} (15.50), flowers plant^{-1} (46.75) and fruit plant^{-1} (10) was recorded from WGSi (Wooden bed with 20ppm GA and 0.4mM Si) treatment combination whereas lowest number of flower cluster plant^{-1} (6.00), flowers plant^{-1} (24.25) and fruit plant^{-1} (4.50) was observed from EHo (Earthen pot 0 ppm GA and 0.4 mM Si). The highest individual fruit weight (19.15g) and fruit yield plant^{-1} (190.9g) was recorded from WGSi(Wooden bed with 20 ppm GA and 0.4 mM Si) treatment combination whereas individual lowest fruit weight (11.65 g) and fruit yield plant^{-1} (52.11g) was recorded from EHo (Earthen pot 0ppm GA and 0.4 mM Si).

On the basis of the findings of the investigation, it can be concluded that the yield of summer tomato on rooftop garden was increased while using wooden bed with exogenous application of 20 ppm GA and 0.4 mM Si.

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

1. Repeated trial is needed in the rooftop garden for analogy the accuracy of the experiment.
2. It needs to conduct related experiment with other summer varieties.
3. Scope to conduct similar experiment for *Rabi* season in the rooftop.
4. Scope to conduct advance experiments how, plant growing structures and GA3 with Silicon physiologically increase yield of tomato.

REFERENCES

Abdalla, A. A. and Verkerk, K. 1968. Growth flowering and fruit-set of the tomato at high temperature. *Neth. J. Agric. Sci*. **16**: 71-76.

Abro, S.A., R. Qureshi, F.M. Soomro, A.A. Mirbahar, and G.S. Jakhar. 2009. Effects of silicon levels on growth and yield of wheat in silty loam soil. Pakistan Journal of Botany. 41:1985-1390.

Adlakha, P.A. and Verma, S.K. 1995. Effect of gibbellic acid on fruiting and yield of tomatoes *Sci. and Cult.* 31: 301-303.

Adlakha. P.A. and Verma, S.K. 1964. Effect of gibbellic acid on the quality of tomato fruit. *The Punjab Hort. J*. **4** (3-4): 148-151.

Agarwa, A., Rao, A.V. 2000. Tomato lycopene and its role in human health and chronic diseases. Can. Med. Assoc. J. 163: 739-744.

Ahmad, S. 2002. Genetics of fruit set and related traits in tomato under hot-humid conditions. Ph.D. Thesis. BSMRAU. pp. 44 - 180.

Ahmed, B., Kamruzzaman, M., Zhu, X., Rahman, M., Shahinoor and Choi, K. 2013. Simulating land cover changes and their impacts on land surface temperature in Dhaka, Bangladesh. Remote Sensing, 5(11), pp. 5969-5998.

Anonymous. 2004. Annual Internal Review for 2000-2001. Effect of seedling throwing on the grain yield of wart land rice compared to other planting methods. Crop Soil Water Management Program Agronomy Division, BRRI, Gazipur-1710.

Arabi, R., Shahidan, M. F., Kamal, M. S. M., Ja'afar, M. F. Z. B. and Rakhshandehroo, M. 2015. Mitigating urban heat island through green roofs, *Current World Environ.* Vol. 10 (1): 918-927.

AVRDC. 1982. Progress Report. Asian Vegetables Research and Development Center, Shanhua, Tainan, Taiwan, pp. 19 - 54.

AVRDC. 1988. Progress Report. Asian Vegetables Research and Development Center, Shanhua, Tainan, Taiwan, p. 541.

AVRDC. 1990. Progress Report. Asian Vegetables Research and Development Center, Shanhua, Tainan, Taiwan, pp. 352 - 358.

AVRDC. 1988. Progress Report. Asian Vegetables Research and Development Center, Shanhua, Tainan, Taiwan, p. 541.

AVRDC. 1990. Progress Report. Asian Vegetables Research and Development Center, Shanhua, Tainan, Taiwan, p. 447.

Balastra, M.L.F.C., Perez, C.M., Villareal, C.P.,Lott, J.N.A. and Roxas, D.B. 1989. Effects of silica level on some properties of *Oryza sativa* straw and hull. *Canadian Journal of Botany*. **67**:2356-2363.

BARI, 1998. Annual Report (1997-98). BARI. Joydebpur, Gazipur. p. 116.

BARI. 1983. Annual Report (1979-82). Bangladesh Agricultural Research Institute, joydebpur. Gazipur. pp.1-2.

Batlang, U. 2008. Benzyladenine plus gibberellins (GA4+7) increase fruit size and yield in greenhouse- grown hot pepper (Capsicum annuumL.). J. Biol Sci., 8(3): 659-662.

BBS (Bangladesh Bureau of Statistics). 2003. Statistical Yearbook of Bangladesh Bur.Stat.,Div., Mini.Plan.Govt. People's Repub. Bangladesh.

Bhardwaj, R.K., Mehta, B.S. and Kohli, U.K. 1995. Effect of planting time and spacing on some indeterminate tomato cultivars in mid hills. *Ann, Agril. Res*. **16** (3): 396-398.

Bora, P.C. and Selman, J.W. 1969. Growth and nitrogen accumulation in young tomato plants treated with gibberellic acid, *J. Exp. Bot.* 288-301.

Borguini, R. and Torres, E. 2009. Tomatoes and tomato products as dietary sources of antioxidants.Food Rev. Intern. 25: 313–325.

Bouzo, C. A. and Favaro, J. C. 2016. Container size effect on the plant production and precocity in tomato (*Solanum lycopersicum* L.) *Bulgarian Journal of Agri. Science, 21 (No 2) 2015, 325–332*

Briant. R E. 1974. An analysis of the effect of gibberellic acid on tomato leaf growth .*J. Exp. Bot.* **25**: 764-771.

Carter, T. L. and Rasmussen, T. 2006. Hydrologic Behavior of Vegetated Roofs. *In* Journal of the American Water Resources Association Paper #05090. Middleburg, VA: American Water Resources Association.

Celik, S., William A. Retzlaff, W. A. and Morgan, M. 2010. Evaluation of energy savings for buildings with green roofs having different vegetation. International High Performance Buildings Conference. Paper 24.

Charlels, W. B. and Harris, R. E. 1972. Tomato fruit set at high and low temperatures. *Can. J. Plant Sci.* 52: 497 - 506.

Chang, C.-H., Lin, H.-Y., Chang, C.-Y., Liu Y.-C. 2006. Comparisons on the antioxidant properties of fresh, freeze-dried and hot-air-dried tomatoes. *J. Food Eng.* 77: 478–485.

Chern, J. K; Wu, C. W; Lin, J K. and Tarng, S. F. 1983. Effect of plant growth regulators on the growth and development of tomato. *J. Agnc. Assoc. China.* **124**: 31-42.

Cheema, D. S.; Surjan, S. and Kuo, C. G. 1993. Variability in heat-tolerant tomato germplasm. Adaptation of food crops to temperature and water stress: proceedings of an international symposium, Taiwan, 13-18 August 1992. Department of Vegetable Crops, Landscaping and Floriculture, Punjab Agricultural University, Ludhiana 141004, India. 12: 316 - 320.

Clinton, S.K. 1998. Lycopene; chemistry, biology and implications for human health and diseases. Nutr. Rev. 56: 35–51.

Crozier, A., Jaganath, I.B., Clifford, M.N. 2009. Dietary phenolics: chemistry,bioavailability and effects on health. Nat. Prod. Rep. 26, 1001–1043.

Dallagnol L.J, Rodrigues F.A, Tanaka O, Amorim L, Camargo L.E.A. 2012. Effect of potassium silicate on epidemic components of powdery mildew on melon. Plant Pathology 61:323-330.

Dannon E and Wydra K. 2004. Interaction between silicon amendment, bacterial wilt development and phenotype of *Ralstonia solanacearum* in tomato genotypes. Physiological and Molecular Plant Pathology. 64:233-243.

Davies P.J. 1995. Plant Hormones, Physiology,Biochemistry and Molecular Biology. Kluwer Academic Publishers, Dordrecht

Dinar, M. J.; Rudich, J. and Zamski, E. 1983. Effect of heat stress cr. carbon transport from tomato levels. Annals of Botany. 50: 97- 103.

Dinar, M. J.; Rudich, J. and Zamski, E. 1982. Effect of heat stress on carbon transport from tomato levels. Annals of Botany. 78: 90-100.

Dorst, D.T. and Price, H.C. 1991. Effect of tiliage system and planting date on the growth and yield of transplanted tomato. *Hort. Sci*. **26.** (11):1478.

El-Ahmadi, A. B. and Stevens, M. A. 1979a. Reproductive responses of heat tolerant tomatoes to high temperatures. J. Amer. Soc. *Hort. Sci*. 104 : 689-691.

El-Ahmadi, A. B. and Stevens, M. A. 1979b. Genetics of high temperature fruit set in the tomato. *J. Amer. Soc. Hort. Sci.* 104: 691-696.

EI-Habbasha. K.M.; Gomaa, H.M, EI-Gizawy, A.M and Mohamed, S S. 1999. Response of tomato plants to foliar spray with some growth regulators under later summer conditions. *Egyptian J. Hort*. 26: 3546.

Epstein, E. 1994. The anomaly of silicon in plant biology. Proceedings of the National Academy of Sciences. 91:11-17.

Epstein, E. 1999. Silicon. Annual Review of Plant Physiology and Plant Molecular Biology. 50:641-664.

Eumorfopoulou, E. and Aravantinos, D. 1998. The Contribution of a Planted Roof to the Thermal Protection of Buildings in Greece, *Energy and Buildings*. 27:29-36

Fallah, A., Osko, T., Khosravi, V., Mohammadian, M. and Rosttami, M. 2011. Reduction of chemical pesticides by using of silicate fertilizer in paddy fields. (In): *Proceedings of the 5th International Conference on Silicon in Agriculture,* 13-18 September, Beijing, China. pp. 46.

Foy, C.D. 1992. Soil chemical factors limiting plant root growth. *Advances in Soil Sci,* **19**:97-149.

FAO. 2013. Food and Agriculture Organization of the United Nations(2013).“Production Crops: tomato”, Rome, Italy.

Gabal, G.M.; Oben. G. and Marcell, R. 1990. Effect of GA3 on morpho-physiological characters and yield of kidney beans *(Phasetolus valgaris). J. Agron. Crop Sci.* **160** (2): 91.101.

Gemici, M., Türkyilmaz, B. and Tan, K. 2006. Effect of 2,4-D and 4-CPA on yield and quality of the tomato, Lycopersicon esculentum Mill. JFS, 29, 24-32.

Giovannucci, E., Rimm, E.B., Liu, Y., Stampfer, M.J. and Willett, W.C. 2002. A prospective study of tomato products, lycopene, and prostate cancer risk. J. Natl.Cancer Inst. 94, 391–398.

Gillaspy, G., Ben-David, H., and Gruissem, W. 1993. Fruits: a developmental perspective. The Plant Cell, 5, 1439–1451.

Gomez, K. A. and Gomez, A. A. 1984. Statistical procedure for agricultural research. Second Edn. Intl. Rice Res. Inst., John Wiley and Sons. New York. pp. 1-340.

Gustafson, F. G. 1936. Induconcrete of fruit development by growth promoting chemicals. Proceedings of the National Academy of Sciences, USA, 22, 628-636.

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

Henna, H. Y.; McBride, J. M. and Romaine, D. J. 1994. Feasibility of extending tomato harvest season by planting heat tolerant cultivars. Proceedings of the Florida State Horticultural Society. USA. 107: 111-113.

Henna, H. Y. and Hernandez, T. P. 1979. Heat tolerance in tomato. Hort. Sci. 14(2): 121.

Henna, H.Y. and Hernandez, T. P. 1980. A study of several characters related to heat tolerance in tomato. Hort. Sci. 15 (3): 45-56.

Hossain, M.A.E. 1974. Studies on the effect of parachlorophenoxy acetic acid and gibberellic acid on the production of tomato. M.Sc. Ag, Thesis, Dep. Hort. Bangladesh Agril. Univ. Mymensingh.

Hossain, M. A., Gaffer, M. A., Chowdhury, J. C. S., Rahman, M. S. and Hossain, M. I. 1999. A study on postharvest practices and loss of tomato in some selected areas of Bangladesh. Bangladesh J. Agril. Res. 24(2), 299.

Hossain, M. A., Gaffer, M. A., Chowdhury, J. C. S., Rahman, M. S. & Hossain, M. I. (1999). A study on postharvest practices and loss of tomato in some selected areas of Bangladesh. Bangladesh J. Agril. Res., 24(2), 299.

Hui, S. C. M. 2006. Benefits and potential applications of green roof systems in Hong Kong, In Proceedings of the 2nd Megacities International Conference, Guangzhou, China, pp. 351-360.

Inanaga, S. and Okasaka, A. 1995. Calcium and silicon binding compounds in cell walls of rice shoots. *Soil Sci. Plant Nutr.* 41:103-110

Iwahori, S. (1967). Auxin of tomato fruit-set at different stages of its development with a special reference to high temperature injuries. Plant and Cell Physiology. 8: 15-22.

Jarosz Z., 2013. The effect of silicon application and type of substrate on yield and chemical composition of leaves of cucumber. J. Elem., 18(3): 403–414, DOI: 10.5601/jelem.2013.18.3.05

Jansen, H. 1970. The effect of gibberellic acid and CCC on the yield of tomatoes. Garteribauwissen-Chaft. **35**: 303-306.

Jones, L.H.P. and Handreck, K.A. 1967. Silica in soils, plants, and animals. Advances in Agronomy. 19:107-149.

Jones, J.B., B. Wolf, and H.A. Mills. 1991. Plant Analysis Handbook. Micro- Macro Publishing.pp. 23-26.

Kaushik, M. P.; Shanna, J.K and Singh, I. 1974. Effect of alpha naphthalene acetic acid, gibberellic acid, kinetin and morphactin on yield of tomato *PI. Sci.* **6**: 51-53.

Keller, H. 1985. International and Institute of Public Health Nutrition. Bangladesh Nutritional Blindness Study 1982-83, Dhaka.

Khan, M. M. A., Gautam, A. C., Mohammad, F., Siddiqui, M. H., Naeem, M. and Khan, M. N. 2006. Effect of gibberellic acid spray on performance of tomato. *Turk. J. Biol.* 30:11-16.

Kotkov, Z., Hejtmnkov, A. and Lachman, J. 2009. Determination of the influence of variety and level of maturity of the content and development of carotenoids in tomatoes.*Czech J. Food Sci.* 27, S200-S203.

Korndörfer, G. H., G.H. Snyder, M. Ulloa, G. Powell, and L.E. Datnoff. 2001. Calibration of soil and plant silicon analysis for rice production. J. of Plant Nutrition. 24(7): 1071–1084.

Kostopoulou, P., Radoglou, K.,Papanastasi, O. and Adamidou, C.(2011). Effect of mini-plug container depth on root and shoot growth of four forest tree species during early developmental stages. *Turk. J. Agric. For.* 35: 379-390.

Kotkov, Z., Lachman, J., Hejtmnkov, A. and Hejtmnkov, K. 2011. Determination of antioxidant activity and antioxidant content in tomato varieties and evaluation of mutual interactions between antioxidants. LWT - Food Sci. and Technol. 44: 1703-1710.

Kumar, A., Biswas, T.K., Singh and A. Lal, E.P. 2014. Effect of gibberelic acid on growth quality and yield of tomato. Journal of Agri. and vet. sci. (7)7:28-30

Kuo, C. G., Chen, B. W. and Chou, M. H. 1978. Tomato fruit set at high temperature, lst Intl. Sym. on Trop. Tomato, AVRDC, Taiwan. pp. 94-109.

Lohas, D. P. and Peat, W. E. 1998. Floral characteristics of heat tolerant and heat sensitive tomato *(Lycopersicon esculentum* Mill.) cultivars at high temperature. Scientia Hort. 73 (1): 53-60.

Lilov, D. and Donchev, T. 1984. Effect of a Bulgarian gibberellin preparation on tomato fruiting Gradinarska, Lozarska Nauka, **21** (1): 49-55.

Liu, K. 2002. Energy Efficiency and Environmental Benefits of Rooftop Gardens. Construction Canada, 44(2):17, 20-23.

Lenucci, M.S., Cadinu, D., Taurino, M., Piro, G. and Dalessandro, G. 2006. Antioxidant composition in cherry and high-pigment tomato cultivars. *J. Agric. Food Chem. 54*, 2606-2613.

Ma, J.F., and E. Takahashi. 2002. Soil, fertilizer, and plant silicon research in Japan. Elsevier, Amsterdam.

Marschner, H., H. Oberle, I. Cakmak, and V. Romheld. 1990. Growth enhanconcrete by Silcon in cucumber (*Cucumis sativus*) plants depends on imbalance in phosphorus and zinc supply. *Plant and Soil.* 124:211–219

Meena, V. D., Dotaniya, M. L., Vassanda, C.R.S., Kundu, A.S. and Subba, R.A. 2014. A case for silicon fertilization to improve crop yields in tropical soils. (In): *Proceedings of the National Academy of Sciences, India Section B: Biological Sciences.* **84**(3): 505-518.

Mehta, A.K. and Mathi P.J. 1975. Effect of growth regulators on summer tomato *(Lycopercicon esculentum* Mill.) *Haryana Hort. Sci.* **4** (34):167-176.

Metwally, N. E. 2016. Effect of using different substrate culture systems on growth and production of hot pepper grown in rooftops gardens. *Int. J. Environ*. 5(2):25-35.

Meyer, J.H. and Keeping, M.G. 2000. Review of research into the role of silicon for sugarcane production. (In): *Proceedings of South African Sugar Technologists Association,* **74**:29-40.

Moco, S., Bino, R.J., Vorst, O., Verhoeven, H.A., de Groot, J., van Beek, T.A.,Vervoort, J. and de Vos, J.H.R. 2006. A liquid chromatography-mass spectrometrybased metabolome database for tomato. Plant Phys. 141: 1205-1218.

Monteiro A.A. 1998. Tomato fruit growth in relation to methods of improving fruit- setting. ISHS Acta Horticulturae 137: Growth Regulators, XXIIHC.

Naeem, N., Ishtitiaq, M., Khan, P. and Mohammad, N. 2001. Effect of Gibberellic acid on growth and yield of tomato Cv. Roma. J.Biol.Sci.1(6):480-450

NeSmith, D. S. and Duval, J. R. (1984). The effect of container size. *HortTech.*,8(4): 495–498.

Oberndorfer, E. 2007. Green Roofs as Urban Ecosystems: Ecological Structures, Functions, and Services. BioScience. 57(10):823-833.

Onofeghara, F.A. 1981. The effects of growth substances on flowering and fruiting of *Lycopersicon esculentum* and *Vigna unguiculata.* Phytol. Argentina. **40**(1):107-116.

Ouellette, N., Walters, S.A. and Midden, K.S. 2013. Fertility management for tomato production on an extensive green roof. Journal of Living Architecture. 1(1):1-14.

Picken., A. J. F. 1984. A review of pollination and fruit-set in tomato *{Lycopersicon esculentum* Mill.). Hort. Sci. 59: 1-13.

Rafeeker M., Nair S.A., Sorte P.N., Hatwal G.P., and Chandhan P.N. 2002. Effect of growth regulators on growth and yield of summer cucumber. J. Soils Crops. 12(1):108-110

Rahman, A. K. M. S., Hossain, S. M. M. and Islam, M. S. 1998. New hybrid tomato for summer season in Bangladesh. HortScience. 33(3), 527p

Rahman, S. M. L.; Nawata, E. and Sakuratani, T. 1998. Effect of temperature and water stress on growth, yield and physiological characteristics of hceat-tolerant tomato. Japanese Journal of Tropical Agriculture. 42(1): 46-53.

Rahman, M., Nahar, M. A., Sahariar, M. S. and Karim, M. R. 2015. Plant growth regulators promote growth and yield of summer tomato (Lycopersicon esculentum Mill.). Progress. Agric., (accepted).

Rapport, L. 1960. Effect of temperature and gibberellin on the growth of tomato frurts. Naturewissenchaften. **17**:285.

Rao, A.V. and Agarwal, S. 1998. Bioavailability and in vivo antioxidant properties of lycopene from tomato products and their possible role in the prevention of cancer. Nutr. Cancer *31*. 199–203.

Raven, J. A. 1983. The transport and function of silicon in plants. Biol. Rev. 58: 179-207

Rodrigues, F.A. and Datnoff, L.E. 2005. Silicon and rice disease management. *Fitopatologia Brasileira*, **30**(5):457-469.

Shalaby, G. I.; Imam, M. K.; Naeear, A; Wali, E. A. and Mohamed, M. F. 1983. Studies on combining ability of some tomato cultivars under high temperature conditions. Assiut. J. Agric. Sci. 14: 35-56.

Saleh, M.M.S. and Abdul, K.S. 1980. Effect of gibberellic acid and cycocel on growth, flowering and fruiting of tomato *(Lycopersicen esculentum* Mill.) *Plants Mesopotarma J. Agric.*,**15** (1):137-166.

Sanyal, D.; Kar, P.L. and Longkumar, M. 1995. Effect of growth regulators on the physicochemical composition of tomato *(Lycopersicon esculetum* Mill.). *Advances in Hort. And Forestry.* **4**:67-71.

Sasaki, H., Yano, T. and Yamasaki, A. 2005. Reduction of high temperature inhibition in tomato fruit set by plant growth regulators. JARQ. 39:135-138.

Saito, T. and Ito, H. 1967. Studies on the growth and fruiting in the tomato. IX. Effects of the early environmental conditions and cultural Genotypes on the morphological and physiological development of flowers and the flower drop. J. Japan. Sci. 36:195-205.

Savant, N.K., Snyder. G.H. and Datnoff, L.E. 1997. Silicon management and sustainable rice production. *Advances in Agronomy.* **58**:151-199.

Sawhney, V.K. and Greyson, R.I. 1972. Fruit size increase in tomato following application on gebberellic acid. *J. Amer. Soc. Hort.* Sci. **97** (5): 589-590.

Scott, J. W.; Olson, S. M.; Howe, T. K.; Stoffela, P. J.; Bartz, J. A. and Bryan, H. H. 1995. Equinox heat-tolerant hybrid tomato. HortScience. Gulf Coast Research and Education Center, University of Florida, 5007. 60"1 Street East, Bradenton, FI 34203, USA. 30(3): 647 - 648.

Serrani, J. C., Sanjua´n, R., Ruiz, R. O., Fos, M. and Garcı´a-Martı´nez, J. L. 2007. Gibberellin regulation of fruit set and growth in tomato. *Plant Physiology*, 145: 246-257.

Sharma, N. K. and Tiwari, R. S. 1996. Effect of time of planting on yield and yield contributing characters of tomato (*Lycopersicon esculentum* Mill). *Recent Hort*. **3**(1): 82-85. (Cited from Host. Abstr. 67 (1): 53, 1997).

Shittu, G.A. and Adeleke, l.A. 1999. Effect of gibberellic acid on the growth and development of tomato *(Lycopersicon esculetum* Mill.) cultivar. 158-163 *Global J. Pure Apply Sci.* **5** (1): 27-30.

Sharma, A., Conry, p., Fernando, H. J. S., Hamlet, A. F., Hellmann, J. J. and Chen, F. 2016. Green and cool roofs to mitigate urban heat island effects in the Chicago metropolitan area: evaluation with a regional climate model, *Environ. Res. Lett.* 1: 1-15.

Shelby, R. A.; Greenleaf, W. H. and Peterson, C. M. 1978. Comparative floral fertility in heat tolerant and heat sensitive tomatoes. *J. Amer. Sco. Hort. Sci.* 103: 778-780.

Stevens, M. A. and Rudich, J. 1978. Genetics potential for overcoming physiological limitations on adaptability, yield and quality in the tomato. *Hort. Sci.* 13: 673-678.

Stevens, M. A. 1979. Breeding tomatoes for processing. In: Tropical tomato. R. Cowell (ed.). Asian Vegetable Research and Development Center, Shanhua, Tainan, Taiwan, 290. p.

Takano, K.P.; Bialek, K. and Cohen, J.D. 1995. The effect of growth regulators on two spring legumes, protein peas and french beans Mekedelingen Jan de facutied landbouwwetensch apen Rijksunver siffeit Gent. **52**:1259-1266.

Talukder, N.K. 2017. Status of rooftop gardening in dhaka city:A case study of Dhanmondi residential area(Master’s Thesis). Stamford University Bangladesh, Dhaka, Bangladesh.

Tomalty, R. and Komorowski, B. 2010. The Monetary Value of the Soft Benefits of Green Roofs. Canada Mortgage and Housing Corporation, (CMHC)

Tomar, J.S. and Ramgiry, S. R. 1997. Effect of growth regulator on yield and yield attributes 10 tomato *(Lycopersicon esculetum* Mill.) *Advan. Plant Sci.* **10** (2) 29-31.

Vallverdú-Queralt, A., Medina-Remón, A., Martínez-Huélamo, M., Jáuregui O.,Andres-Lacueva, C., Lamuela-Raventos, R.M. 2011. Phenolic profile and hydrophilic antioxidant capacity as chemotaxonomic markers of tomato varieties. J. Agric. Food Chem. *59*: 3994–4001.

Witter, S. H., Bukovac, M. J., Sell, M. H. and Weller, L. E. 1957. Effects of gibberellin on flowering and fruit setting. Plant Physiology. 32: 39-41.

Wong, E. Akbari, H, Bell, R. and Cole, D. 2011. Reducing urban heat islands: compendium of strategies Environmental Protection Agency.

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. Effect of plant growth regulators on vegetative growth of tomato. *J. Agric. China.* **124**:31-42.

Yanar Y, Yanar D, Gebologlu N. 2011. Control of powdery mildew (*Leveillula taurica*) on tomato by foliar sprays of liquid potassium silicate. African Journal of Biotechnology. 10:3121-3123.

Yearbook of Agricultural Statistics. 2014-15.

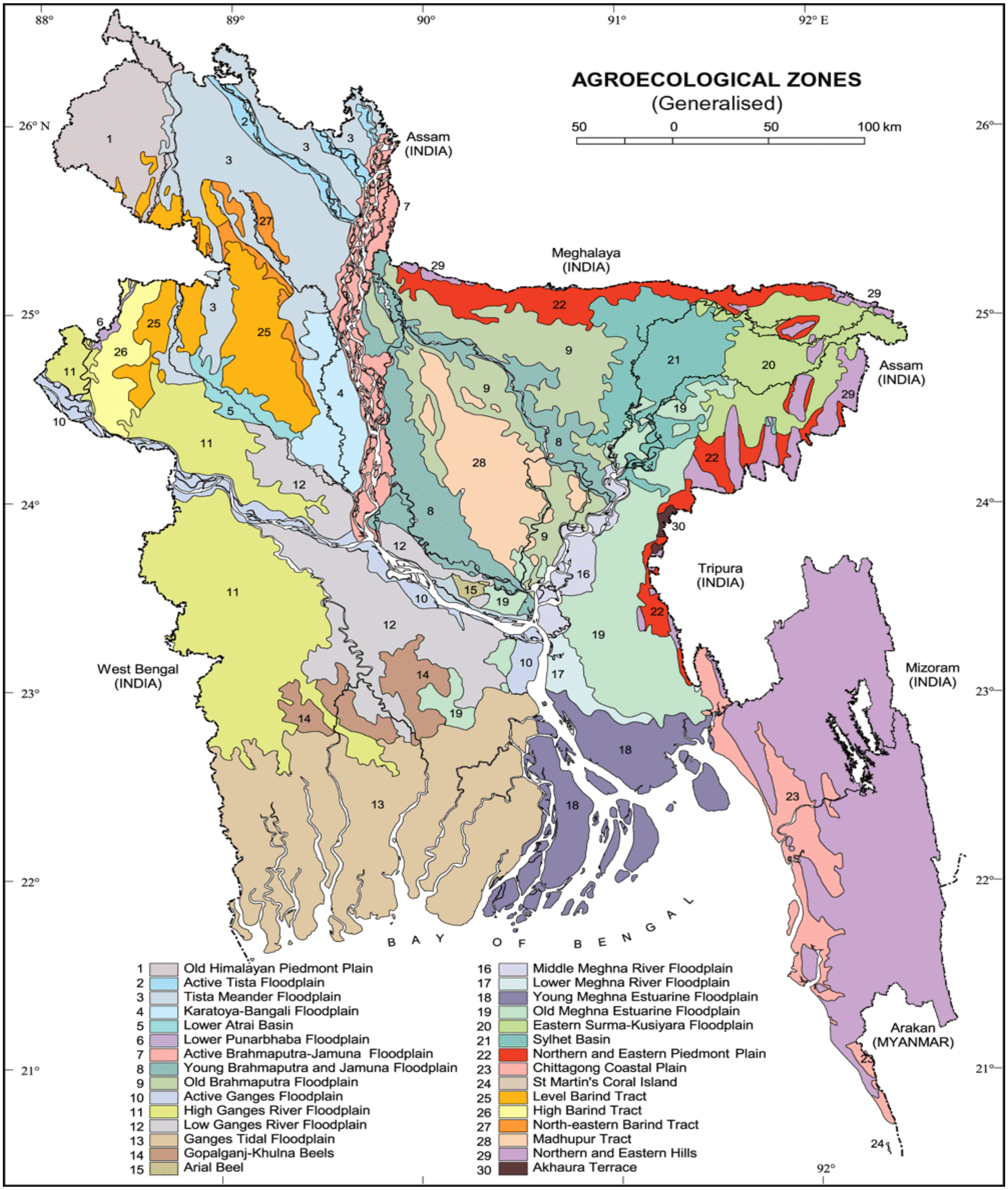
Yordanov, M. 1983. Heterosis in tomato. Monogr. Theory. Appl. Genet. 6: 189-219.

Yoshida, S. 1981. “Fundamentals of rice crop science”. International Rice Research Institute, Los Banos, Laguna, Philippines.

Zheng, Q. and Li, X. 1998. Characteristics of tolerance to weak light during the seedling stage in tomato and measurement of several morphological and physiological indices. Jiangsu Agril. Sci. **6**: 51-52.

APPENDICES

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



Appendix II: Monthly record of air temperature, rainfall, relative humidity and sunshine hours of the experimental site during the period from June to October 2016.

Year	Month	Average Air temperature (^{0}F)			Total rainfall (inch)	Average RH (%)	Average sunshine hours
		Maximum	Minimum	Average			
2016	June	97	82	91	5.37	74%	131.3
	July	94	81	89	8.5	76%	102
	August	94	81	89	6.39	76%	102.3
	September	95	80	89	8.26	78%	109.5
	October	94	78	88	3	74%	103.3

Source: https://us.worldweatheronline.com

Appendix III. Analysis of variance of the data on plant height of tomato as influenced by combined effect of plant growing structures and different combinations of Gibberellic acid and Silicon at different days after transplanting

Source of variation	df	Mean square of plant height at different days after transplanting		
		20	40	60
Replication	3	1.11	22.35	13.24
Factor A	2	1209.65*	391.15*	1507.65*
Factor B	3	76.06*	139.52*	587.35*
A x B	6	1.95*	3.23*	3.23*
Error	33	9.91	43.16	95.43

*Significant at 5% level of significance

^{NS} Non significant

Appendix IV. Analysis of variance of the data on number of leaves plant^{-1} of tomato as influenced by combined effect of plant growing structures and different combinations of Gibberellic acid and Silicon at different days after transplanting

Source of variation	df	Mean square of Leaf Number at different days after transplanting		
		20	40	60
Replication	3	0.576	5.389	30.910
Factor A	2	26.688*	397.771*	9436.750*
Factor B	3	19.965*	73.722*	1107.910*
A x B	6	3.049*	1.993*	23.639*
Error	33	0.425	5.904	37.334

*Significant at 5% level of significance

^{NS} Non significant

Appendix V. Analysis of variance of the data on number of branch plant^{-1} of tomato as influenced by combined effect of different plant growing structures and different combinations of Gibberellic acid and Silicon at different days after transplanting

Source of variation	df	Mean square of Branch Number		
		20	40	60
Replication	3	0.180	1.188	1.410
Factor A	2	2.583*	33.250*	41.813*
Factor B	3	11.556*	23.299*	23.188*
A x B	6	0.222*	0.194*	0.063*
Error	33	0.213	0.748	1.137

*Significant at 5% level of significance

^{NS} Non significant

Appendix VI. Analysis of variance of the data on stem diameter plant^{-1} and leaf water loss (%) of tomato as influenced by combined effect of plant growing structures and different combinations of Gibberellic acid and Silicon at different days after transplanting

Source of variation	df	Mean square of stem diameter and leaf Water loss (%)	
		Stem Diameter	Leaf Water loss (%)
Replication	3	0.001	0.889
Factor A	2	0.288*	3.175*
Factor B	3	0.087*	3.886*
A x B	6	0.012*	0.081*
Error	33	0.007	0.519

*Significant at 5% level of significance

^{NS} Non significant

Appendix VII. Analysis of variance of the data on yield contributing characters and yield of tomato as influenced by plant growing structures and different combinations of Gibberellic acid and Silicon

Source of variation	df	Mean square of Flower clusters plant^{-1}, Flowers plant^{-1}, Fruits plant^{-1}, Individual fruit weight and Fruit yield plant^{-1}				
		Flower clusters plant^{-1}	Flowers plant^{-1}	Fruits plant^{-1}	Individual fruit weight (g)	Fruit yield plant^{-1} (g)
Replication	3	0.014	14.854	1.424	1.009	594.194
Factor A	2	176.521*	1289.313*	40.896*	54.316*	22062.525*
Factor B	3	31.806*	80.299*	18.243*	38.873*	12824.513*
A x B	6	1.493*	0.924*	0.035*	1.731*	296.103*
Error	33	0.696	3.778	0.439	1.605	180.554

*Significant at 5% level of significance

^{NS} Non significant

Appendix VIII. Analysis of variance of the data on SPAD Value of tomato leaf as influenced by plant growing structures and different combinations of Gibberellic acid and Silicon at different days after transplanting

Source of variation	df	Mean square of SPAD Value at different days after transplanting		
		40	50	60
Replication	**3**	10.904	19.210	42.684
Factor A	**2**	174.441*	429.920*	244.817*
Factor B	**3**	70.567*	58.147*	54.497*
A x B	**6**	1.134*	2.143*	8.672*
Error	**33**	7.880	22.101	16.424

*Significant at 5% level of significance

NS Non significant

Appendix IX. Physical and chemical composition of soil sample

Characteristics	Value
% Sand	20.84
% Silt	57.46
% Clay	21.7
Textural class	Silt loam
pH	6.9
Organic matter (%)	0.86
Available K (ppm)	25
Available Na (ppm)	70