EFFECT OF GIBBERELLIC ACID AND SILICON ON MORPHO-PHYSIOLOGICAL CHARACTERS AND YIELD OF DIFFERENT TOMATO VARIETIES

A THESIS

BY

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CERTIFICATE

This is to certify that the thesis entitled “EFFECT OF GIBBERELLIC ACID AND SILICON ON MORPHO-PHYSIOLOGICAL CHARACTERS AND YIELD OF DIFFERENT TOMATO VARIETIES” submitted to the Department of Agricultural Botany, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of MASTERS OF SCIENCE in AGRICULTURAL BOTANY, embodies the result of a piece of bona fide research work carried out by MAHBUBA SIDDIKA, Registration No. 11-04532 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: June, 2017 Prof. Dr. Mohammad Mahbub Islam

Dhaka, Bangladesh Supervisor

Dedicated to

My

Beloved Parents

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The Author

EFFECT OF GIBBERELLIC ACID AND SILICON ON MORPHO-PHYSIOLOGICAL CHARACTERS AND YIELD OF DIFFERENT TOMATO VARIETIES

ABSTRACT

The experiment was conducted at research field, Sher-e-Bangla Agricultural University, (SAU) Dhaka-1207, Bangladesh during the period from October 2016 to March 2017 to investigate the effect of gibberellic acid and silicon on changes in morpho-physiological characters and yield of different tomato varieties. The experiment was consisted of two factors as follows: factor A (Different varieties of tomato) *viz.*, V_1 = BARI tomato 2, V_2 = BARI tomato 14, V_2 = BARI tomato 15 and V_4 = BARI tomato 16; factor B (Different composition of GA_3& Si) *viz.*, H_0 = Control, G = 20 ppm GA_3, Si= 0.4 mM Silicon and GSi = 20 ppm GA_3 + 0.4 mM Silicon. The experiment was laid out in Randomized Complete Block Design (RCBD) with three (3) replications. Result demonstrated that, most of the parameters had significantly influenced by the application of silicon in combination with gibberellic acid on different tomato varieties. Result revealed that, the variety, BARI tomato 14 exhibited the superior one over other tomato varieties for most of the traits studied under present experiment. Among the treatments, GSi*i.e.*, 20 ppm GA_3 + 0.4 mM Silicon performed the best one for most the cases. Among the sixteen combinations the highest yield (96.1 t/ha) was found from the V_2GSi and the lowest yield(73.6 t/ha) was in V_1H_0. From the present study it may be said that, BARI tomato 14 exhibited the best one for higher yield when treated with 20 ppm GA_3 + 0.4 mM Silicon under the climatic and edaphic condition of SAU.

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ABBREVIATIONS AND ACCORONYMS

AEZ	=	Agro-ecological Zone
Agric.	=	Agricultural
ANOVA	=	Analysis of Variance
BARI	=	Bangladesh Agricultural Research Institute
Biol.	=	Biology
cm	=	Centi meter
CV	=	Coefficient Variance
DAT	=	Days after Transplanting
EPB	=	Export Promotion Bureau
et al.	=	And others
FAO	=	Food and Agriculture Organization
GDP	=	Gross Domestic Product
i.e.	=	That is
J.	=	Journal
LSD	=	Least Significance difference
mm	=	Millimeter
m^2	=	Meter squares
mg	=	Milligram
RCBD	=	Randomized Complete Blocked Design
Res.	=	Research
SAU	=	Sher-e-Bangla Agricultural University
Sci.	=	Science
Technol.	=	Technology
t/ha	=	Ton per hectare
Viz.	=	*videlicet* (L.), Namely

CHAPTER I

INTRODUCTION

Tomato (*Solanumlycopersicum 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 is 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 2 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).

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 the yield of tomato in our country is much lower than other country due to the lack of knowledge and skill of production technologies including selection of suitable of varieties, management practices, use of balanced fertilizer and plant growth regulators etc.

Bangladesh Agricultural Research Institute(BARI) has developed or several tomato varieties named as BARI Tomato-6, BARI Tomato-8, BARI Tomato-10, BARI Tomato-12, BARI Tomato-14, BARI Tomato-16, BARI Tomato-17 etc. It was also reported that different varieties have different yield potential; tolerance to pest and diseases. The influence of variety on yield and quality has been documented (Stevens et al., 1977). Fruit number and weight (Balibrea et al., 1997) determine the yield of tomato. There is positive correlation between fruit number and yield. Adedeji et al. (2006) indicated that important quality parameters of tomato fruits varies with the types of cultivar including fruit size, volume, juice, specific gravity, maturity etc. Agriculture is changing with changing climate. Selection of suitable crop varieties is an important factor for desirable yield of crop.it is essential to promote better varieties to the growers of Bangladesh. However to my knowledge little is known about the comparative performance of BARI tomato-2, BARI tomato-14, BARI tomato-15, BARI tomato-16 under the edaphic and climatic condition of SAU.

It is well established that PGRs alters crop growth, development and yield..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 applications of certain PGRs like auxin and GA3 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 $C_{19}H_{22}O_6$. It is well known that gibberelic acid (GA_3) is a well-established plant hormone to increase the yield of tomato. The most widely available plant growth regulator is GA_3, which induces stem and internode elongation, seed germination, enzyme production during germination and fruit setting and growth (Davies, 1995). Tomato fruit setting was promoted by GA_3 at low concentration (Sasaki *et al*., 2005; Khan *et al.*, 2006). The $GA_3$when applied to flowers controlled fruit drop in tomato (Feofanova, 1960).In addition, it was reported that the fruit yield of tomato was varied from year to year along with variety to variety to GA. It has importance to find the response of tomato to GA for sustainable agriculture.

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 (SiO2.nH2O) (Inanaga and Okasaka, 1995; Epstein, 1999). The Si showed beneficial roles in numerous crop plants to enhancing plant defense response against disease (Rodrigues and Datnoff, 2015), protecting plants against insects attacks (Hunt *et al*., 2008), increasing photosynthesis and growth (Gong *et al*., 2005), preventing lodging (Epstein, 1994), alleviating water shortage (Agarie, 1998) and mineral toxicity stresses (Horiguchi, 1988; Savant *et al.*, 1997), and improving fertilizer use efficiency (Friesen *et al*., 1994). It was also reported that the use 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).

So far the information about the foliar application of Si which improves the growth, yield and quality of tomato. Therefore, it is necessary to find out the role of Si and GA_3 in promoting morpho-physiology and yield and quality of different varieties of tomato under SAU.

Therefore this research was undertaken to achieve the following objectives:

- To identify suitable crop varieties for *rabi* season
- To investigate the sole or combined effects of GA and Si on changes of morpho-physiology and yield summer tomato during rabi season
- 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 *rabi* season

CHAPTER II

REVIEW OF LITERATURE

Among the crops of solanaceae family, tomato playing a major role in many developed country mostly in Bangladesh. Improvement of growth and yield attributes of tomato is much more important for growing hungry people around the world through processing and exporting industry. In Bangladesh the yield of tomato is much lower than other major tomato growing developed countries. But, the yield potential of tomato is plastic nature those could be changed by nutritional management including mediated new cultivation systems. The research on growth promoting substance applications on tomato are more or less availed in our country but research on the optimum rate for better tomato is not well known to us. Some more related research findings regarding production of tomato against variety, gibberellic acid and silicon have been reviewed under this chapter.

2.1 Performance of different tomato varieties

Hossain*et al*. (2017) conducted a pot culture experiment to study the morpho-physiologycal and yield performance of different varieties of tomato during winter season. Five tomato varieties *viz*., BARI Tomato-2, BARI Hybrid Tomato-4 and BARI Hybrid Tomato-5, BARI Tomato-14 and BARI Tomato-15 were used as planting material. BARI Hybrid Tomato-4 produced highest number of fruits plant^{-1} (41.33) with lowest average fruit weight (32.69 g fruit) whereas BARI Tomato-14 produced lowest number of fruits plant^{-1} (28.66) with highest average fruit weight (74.19 g). Fruit of BARI Hybrid Tomato-5 contained highest level of Total Soluble Solid (5.42% TSS). The highest fruit yield plant^{-1} (2.09 kg) was obtained from BARI Tomato-14 followed by BARI Hybrid tomato-5 (1.98 kg) and BARI Tomato-2(1.95 kg) all of which were statistically none significant.

Rashid *et al.* (2000) carried out an experiment to evaluate thirty seven tomato varieties or lines for resistance to bacterial within the sick bed in replicated trial. Result found that 26, 66, 33.33 and 30% incidence of wilt in BARI Tomato-4, BARI Tomato-10 respectively.

Kibri et al. (2013) conducted a field experiment to study growth and yield of ten improved varieties of tomato (CLN3125A, CLN3125E, CLN3125L, CLN3125O, CLN3125P, CLN3125Q, CLN3070J, CLN3078A, CLN3078C, CLN3078G) of the Asian Vegetable Research and Development Centre, Taiwan and five varieties (BARI-3, BARI-8, BARI-9, BARI-14, BARI-15) released by Bangladesh Agricultural Research Institute, Joydevpur. It was observed that plant height, number of branches and number of leaves varied from 50 to 80 cm, 8 to 19 and 112 to 282 at 30 days after transplanting (DAT) and 64 to 100 cm, 19 to 29 and 307 to 612 at 45 DAT, respectively. The number of fruits/plant ranged from 19 to 52 and single fruit weight of tomato varied from 35.04 g to 72.05 g. The yield of tomato varied from 36.36 ton/ha to 122.21 ton/ha among the varieties. Results further depicted that in respect of yield and quality, CLN3125P was found to be the best suitable and promising variety for growing in the valley soil of Chittagong. Similar result was found with CLN3125E, CLN3125L, CLN3078J and BARI tomato 15.

Bhati (2017) laid out an investigation was to evaluation of tomato genotypes *viz.*, TODVAR-1, TODVAR-2, TODVAR-3, TODVAR-4, TODVAR-5, TODVAR-6, TODVAR-7, TODVAR-8 and H -86 (C) for their growth, yield and quality under foothills condition. The results showed that there were significant differences in evaluated parameters among cultivars. Among the genotype, TODVAR-8 was found superior genotype and recorded maximum plant height (64.75 cm), number of branches plant^{-1}(14.22), number of leaves plant^{-1} (47.81), fruit length (4.24 cm), fruit diameter (5.28 cm),number of fruits plant^{-1} (34.01), fresh weight of fruit (37.00 g), yield ha (46.62 tones),ascorbic acid content (52.73 mg 100^{-1} g) and total soluble solids (5.13% Brix). The findings of this study may provide valuable information about nutritional value of studied cultivars for vegetable experts, researchers and growers under foothill condition of Nagaland andother hill or cool growing areas.

Singh and Sahu (1998) conducted a field experiment at Keonjhar, Orissa, India during *robi* 1991-92 and 1992-93 to evaluate 23 tomato cultivars to find out a suitable variety for winter season cultivation. They reported that, BT 12 produced the highest yield (34.09 t ha^{-1}) closely followed by BT 17, PED, BT14, Sel 120, BT 1 and Punjab Chhuhara. The variety Sel 120 had the highest weight and girth of fruit, whereas Punjab chhuhara produced the maximum number of fruits $plant^{-1}$and took less time to mature. The variety ArkaAlok was earliest and large fruits.

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

Naeem *et al*. (2001) reported that both the time and concentrations of gibberellic acid had affected significantly the growth parameters of plants. Maximum days to flowering (42.67), fruits $plant^{-1}$(77.69), plant height (77.78 cm), fruit weight (71.15 gm), number of branches (12.33) $plant^{-1}$and total yield (26840 kg/ha) were recorded in the plants sprayed with 60 mg/lit of gibberellic acid 10 days before transplantation, while minimum values were noted in controlled treatment. Maximum fruit drop per plant was found for control treatment and minimum for the plants treated with gibberellic acid at 60 mg lit^{-1}. It is suggested that tomato should be supplied with gibberellic acid at 60 mg lit^{-1}. 10 days before transplantation under the agro-climatic conditions of Peshawar.

Shittu and Adeleke (1999) investigated the effects of foliar application of GA_3 (0, 10, 250 or 500 ppm) on growth and development of tomatoes cv, 158-3 grown on pots. Plant height and number of leaves were significantly enhanced by GA3 treatment. Plants treated with GA_3 with 250 ppm were the tallest plant the highest number of leaves.

Tomar and Ramgiry (1997) studied that tomato plant treated with GA_3 showed significantly greater number of branches plant^{-1} than untreated controls.

Gabal*et al.* (1990) found that 100 ppm of GA^3 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 GA_3 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 GA_3 and 4-CPA on fruit yield and quality were investigated. Many of the treatments significantly increased fruit set percentage and total fruit yield, but also the percentages of puffy and parthenocarpic fruits compared to the controls.

Lilov and Donchev (1984) observed that by the application of GA_3 at 20, 40 or 100 mgL^{-1} the yields were reduced compared with the non-treated control.

Onofegharn (1981) carried out an experiment with tomato and sprayed GA_3 at 25-1000 ppm. He observed that GA_3 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 GA_3*(*25 or 50 ppm) applied 3 times in June or early July. They reported that GA_3 stimulated plant growth. The substance reduced the total number of flowers plant^{-1} but increased the total yield compared with the control. GA_3 also improved fruit quality.

Chern*et al.* (1983) presented that one month old transplanted tomato plants were sprayed with 1, 10 or 100 ppm GA_3 and observed that GA_3 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 GA_3 at 1, 10 or 100 ppm and reported that GA_3 100 ppm increased plant height and leaf area.

Briant (1974) sprayed GA_3 on the growth of leaves of young tomato plants and observed that total leaf weight and area were increased by GA_3.

Bora and Selman (1969) worked with tomato demonstrated that four foliar sprays of GA_3 (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 GA_3 at 22^0C.

Jansen (1970) reported that tomato plants treated with GA_3 neither increased the yield nor accelerated fruit ripening. He also mentioned that increasing concentration of GA_3 reduced both the number and size of fruits.

Mehta and Malhi (1975) reported that GA_3 application at 25 ppm improved the yield of tomato. GA_3 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 GA_3 applied with 50, 100 and 200 ppm produced an increased fruit 15 set. However, GA_3 treatment induced small size fruit production. A gradual increase in the yield plant^{-1} was obtained with higher concentration of GA_3.

Sawhney and Greyson (1972) reported that application of GA_3 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 GA_3 at 50 and 100 ppm, the fruit setting increased by 5% with higher concentration.

Kaushik*et al.* (1974) carried out an experiment where GA_3 applied at 1, 10 or 100 mg L^{-1} on tomato plants at two leaf stage and then at weekly interval until 5 leaf stage. They reported that GA_3 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 GA_3 (35 and 70 ppm) and found that GA_3 improved fruit set but reduced fruit weight of tomato.

Rapport (1960) noted that GA_3 had no significant effect on fruit weight and size either at cool (11^0C) or warm (23°C) night temperatures; but it strikingly reduced fruit size at an optimum temperature (17^0C).

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

Korkmaz *et al*. (2017) conducted an experiment to determine the effects of silicon on the stem + leaf dry weight, fruit yield, quality and nutrient levels of tomatoes, cultured under saline stress on an artificial medium. Silicon doses (0, 0.5, 1.0, 2.0 mM) were combined in nutrient solution with 0, 44.4 and 70.4 mMNaCl in a factorial experiment with three replications. All silicon concentrations without NaCl increased stem + leaf dry weight and 1.0 mM Si increased fruit yield. Silicon increased fruit yield at 44.4 mMNaCl and steam + leaf dry weight at high NaCl concentrations. NaCl significantly increased the level of soluble solids in fruit and decreased the pH of fruit juice. Silicon significantly increased the pH of the tomato juice and decreased the number of fruits at high concentrations of NaCl. The effects of NaCl, Si and their interaction on nutrient contents and Si levels in leaves were statistically significant at different concentrations.

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).

Raven (1983) noted that 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 SiO2 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) mentioned that 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. reported that 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 18 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 research field of Sher-e-Bangla Agricultural University (SAU), Dhaka-1207, Bangladesh during the period from October 2016 to March 2017. A brief description about the locations of the experimental site, characteristics of soil , climate, materials, layout and design of experiment, land preparation, fertilizing, transplanting of seedlings, intercultural operations, harvesting, data recording procedure, economic and statistical analysis etc, are presented as follows:

3.1 Experimental site

The research work was carried out at the Shere-e-Bangla Agricultural University research field, Dhaka-1207 during October 2016 to March 2017.

3.2 Geographical Location

The experimental area was situated at $23^{o}77$N latitude and $90^{o}33$E longitude at an altitude of 8.6 meter above sea level. The experimental field belongs to the Agro-economical zone of “The Modhupur Tract”, AEZ-28. This was a region of complex relief and soils developed over the Modhupur clay, where floodplain sediments buried the dissected edges of the Mohupur Tract leaving small hillocks of red soils as ‘islands’ surrounded by floodplain. The experimental site was shown in the map of AEZ of Bangladesh (Appendix I).

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 October 2016 to March 20176 have been presented in Appendix II including minimum and maximum temperature, rainfall, relative humidity and sunshine hours etc.

3.4 Characteristics of soil

Soil of the experimental site belongs to the general soil type, Shallow Red Brown Terrace Soils under Tejgoan Series. Top soils were clay loam in texture, olive- gray with common fine to midium distinct dark yellowish brown mottles. Soil pH ranged from 6.0- 6.6 and had organic matter 0.84%.

Experimental area was flat having available irrigation and drainage system and above flood level. Soil samples from 0-15 cm depths were collected from experimental field. The analyses were done by SAU Soil Science lab.

Physicochemical properties of the soil are given below **:**

Soil characteristics of experimental field as analyzed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

A. Morphological properties of the soil

Morphological features	Characteristics
Location	Agronomy field , SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

B. Physical properties of the soil

Particle size analysis	Results
Sand (%) (0.0-0.02 mm)	21.75
Silt (1%) (0.02-0.002 mm)	66.60
Clay (%) (<0.002 mm)	11.65
Soil textural class	Silty loam
Colour	Dark grey
Consistency	Grounder

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

3.5 Planting materials

The genetically pure and physically healthy seeds were collected from Bangladesh Agricultural Research Institute (BARI), Gazipur, Dhaka. BARI tomato-2, BARI tomato -14, BARI tomato-15 and BARI tomato-16 were used for the present research work, the purity and germination percentage were leveled as around 100 and 80, respectively.

3.6. Treatments of the experiment

The experiment consisted of two factors as follows:

Factor A (Different varieties of tomato)

i. V_1 = BARItomato 2

ii. V_2 = BARItomato14

iii. V_3 = BARItomato 15

iv. V_4 = BARItomato 16

Factor B (Different composition of GA_3 & Si)

i. H_0 = Control

ii. G = 20 ppm GA_3

iii. Si = 0.4 mM Silicic acid

iv. GSi = 20 ppm GA_3 + 0.4 mM Silicic acid

The following total 16 treatment combinations were considered:

V_1Ho	:	BARI tomato 2 (Without GA + Without Si)
V_1G	:	BARI tomato 2 (20 ppm GA + Without Si)
V_1Si	:	BARI tomato 2 (Without GA + 0.4 mM Si)
V_1GSi	:	BARI tomato 2 (20 ppm GA + 0.4 mM Si)
V_2Ho	:	BARI tomato 14 (Without GA + Without Si)
V_2G	:	BARI tomato 14 (20 ppm GA + Without Si)
V_2Si	:	BARI tomato 14 (Without GA + 0.4 mM Si)
V_2GSi	:	BARI tomato 14 (20 ppm GA + 0.4 mM Si)
V_3Ho	:	BARI tomato 15 (Without GA + Without Si)
V_3G	:	BARI tomato 15 (20 ppm GA + Without Si)
V_3Si	:	BARI tomato 15 (Without GA + 0.4 mM Si)
V_3GSi	:	BARI tomato 15 (20 ppm GA + 0.4 mM Si)
V_4Ho	:	BARI tomato 16 (Without GA + Without Si)
V_4G	:	BARI tomato 16 (20 ppm GA + Without Si)
V_4Si	:	BARI tomato 16 (Without GA + 0.4 mM Si)
V_4GSi	:	BARI tomato 16 (20 ppm GA + 0.4 mM Si)

3.7 Design and layout of the experiment

The two factors experiment was laid out following Randomized Complete Block Design (RCBD) with three (3) replications. The plot size was $3m^2$. The distance was 0.75 m from block to block and plant to plant distance was 40 cm.

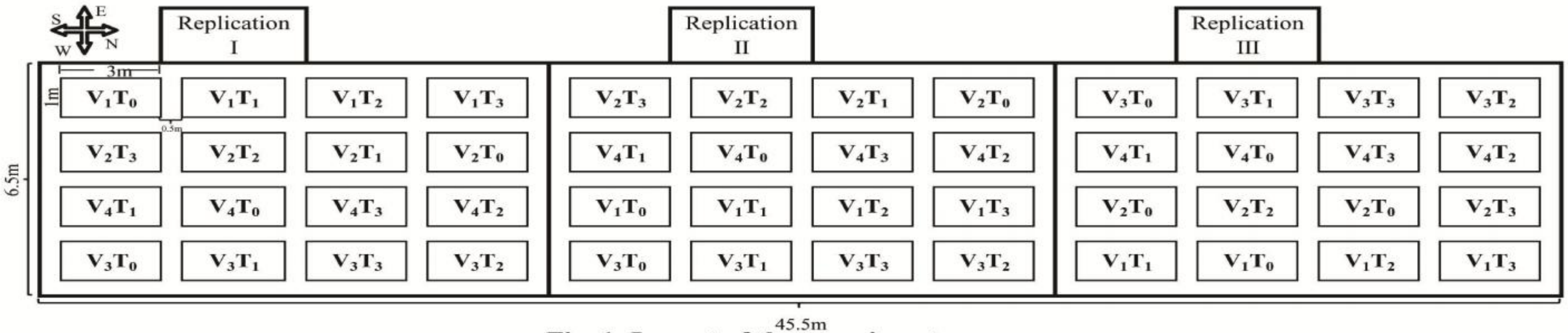


Fig. 1: Layout of the experiment

3.8 Seedbed preparation and raising seedling

The seed sowing was done on 1 October 2016 in the seedbed. Before sowing the seeds were treated with Bavistin for 5 minutes. Seedlings were raised in the seedbeds in the SAU farm. The seedlings were transplanted in the main field. when the seedlings become 25 days old.

3.9 Land preparation

The experimental plot was prepared by several plowing and cross plowing followed by laddering and harrowing with power tiller to bring about to good filth in the second week of October 2016. Weeds and other stubbles were removed carefully from the experimental plot and leveled properly. Then the area was divided into plots of 2.0 m x 1.5 m according to the layout of the experiment.

3.10 Manure and fertilizers applications

Manures and fertilizers were applied at the rate of cowdung 15t/ha, urea 400kg ha^{-1}, triple super phosphate (TSP) 250 kg $ha^{-1}$and muriate of potash (MOP) 200 kg ha^{-1}. The entire amount of organic manure, TSP and half of the MOP were applied during final land preparation. The remaining half of the MOP and entire urea were applied in two equal installments, 1^{st} at 15 days after planting and 2^{nd} at flowering.Dose of manure and fertilizers used in the study are showing in (Table 1).

Table1. Doses of manures and fertilizers used in the Experiment

SL No.	Fertilizers/Manures	Dose	
		Applied in the plot	Quantity/ha
1	Urea	0.12 kg	400 Kg
2	TSP	0.075 Kg	250 Kg
3	MOP	0.06 Kg	200 Kg
4	Cowdung	4.5 Kg	15 ton

3.11 Transplanting Seedlings

The seedlings were raised in the seedbed in usual way and 25 days old seedlings were transplanted in the main field on October 2016. The transplanted seedlings were watered regularly to make a firm relation with roots and soil to stand along.

3.12 Application of Gibberelic Acid and Silicon (GA + Si)

In the study Gibberelic Acid (GA) was applied in the form of GA_3 and Silicon was applied in the form of Silicic Acid. According to the treatment plants were treated with 20 ppm GA and 0.4 mM Si. The stock solution of 1000 ppm of GA3 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 25 and 40 days after transplanting independently. Tween 20 was mixed in the GA_3 and Silicic Acid solution as a adhesive materials.

3.13 Intercultural operations

When the seedlings were well established weeding were done uniformly in all the plots. Second weeding was done after 20 days of the first one.

3.13.1 Gap filling

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

3.13.2 Staking

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

3.13.3 Irrigation

After transplanting the seedlings were properly irrigated for 4 consecutive days. Then flood irrigation was given to the plants after each top dressing of urea. Final irrigation was given during active fruiting stage.

3.13.4 Pesticide application

During the cropping period, since there was no significant pest infestation in the field, hence no control measure was undertaken. In order to prevent disease infestation, ‘Ripcord’ was used for 6 times at an interval of 7 days. There were different types of weeds which were controlled effectively by hand weeding.

3.14 Harvesting

Fruits were picked on the basis of horticultural maturity, size, color and age being determined for the purpose of consumption as the fruit grew rapidly and soon get beyond the marketable stage, frequent picking was done throughout the harvesting period.

3.15 Data collection

The plants in each entry were selected randomly and were tagged. These tagged plants were used for recording observations for the following characters.

i. Plant height (cm)
ii. Number of leaves plant^{-1}
iii. Number of branches plant^{-1}
iv. Days to first flowering
v. Days to first fruiting
vi. Chlorophyll content (SPAD value
vii. Number of flowers plant^{-1}
viii. Number of fruits plant^{-1}
ix. Fruit diameter (cm)
x. Fruit length (cm)
xi. Pericarp thickness (cm)

xii. Single fruit weight (g)

xiii. Yield plant^{-1} (kg)

xiv. Yield plot^{-1} (kg)

xv. Yield ha^{-1} (ton)

3.16 Detailed procedures of data collection

3.16.1 Plant height (cm)

The plant height was measured from ground level to tip of the plant expressed in centimeters (cm) and mean was computed.

3.16.2 Number of leaves plant^{-1}

The number of leaves per plant was counted from the selected plants and their average was taken as the number of green leaves per plant. It was recorded during final harvest.

3.16.3 Number of branches plant-1

The number of branches arising from the main stem above the ground was recorded by counting each plant and mean were calculated.

3.16.4 Days to first flowering

Days to first flowering was recorded from the date of sowing (50% of the plants in a plot when opened flowers fully).

3.16.5 Days to first fruiting

Days to first fruiting was recorded from the date of final flower blooming (50% of the plants in a plot when fruit set fully).

3.16.6 Chlorophyll content (%)

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.

3.16.7 Number of flowers plant^{-1}

The total number of marketable fruits harvested from the five plants was counted and the average number of fruits per plant was calculated.

3.16.8 Number of fruits plant-1

The total number of marketable fruits harvested from the five plants was counted and the average number of fruits plant^{-1} was calculated.

3.16.9 Fruit diameter (cm)

The fruit diameter was measured from bottom level to tip of the fruit into three segments and expressed in centimeters(cm) by slide calipersand mean was computed.

3.16.10 Fruit length (cm)

The fruit length was measured from bottom level to tip of the fruit expressed in centimeters and mean was computed.

3.16.11 Pericarp thickness (cm)

The fruit length was measured from bottom upper layer to lower layer of fruit and expressed in centimeters and mean was computed.

3.16.12 Single fruit weight (g)

It was measured from a single fruit by using electrical balance.

3.16.13 Yield plant-1 (kg)

Yield plant-1 was calculated in gram by a balance from the total weight of fruits per selected plants harvested at different periods and was recorded.

3.16.14 Yield plot^{-1} (kg)

Yield plot^{-1} was calculated in gram by a balance from the total weight of fruits per selected plots harvested at different periods and was recorded.

3.16.15 Yield ha^{-1} (ton)

Yield hectare^{-1} was calculated from the yield obtained in each of the experimental unit and was expressed in tons per hectare.

3.17 Statistical analysis

The recorded data for different characters were analyzed statistically using 'MSTAT-C' program to find out the significance of variation among the treatments. The analysis of variance (ANOVA) was performed by F-test, while the significance of difference between the pairs of treatment means were evaluated by the Least Significant Difference (LSD) test at 5% level of probability (Gomez and Gomez, 1984).

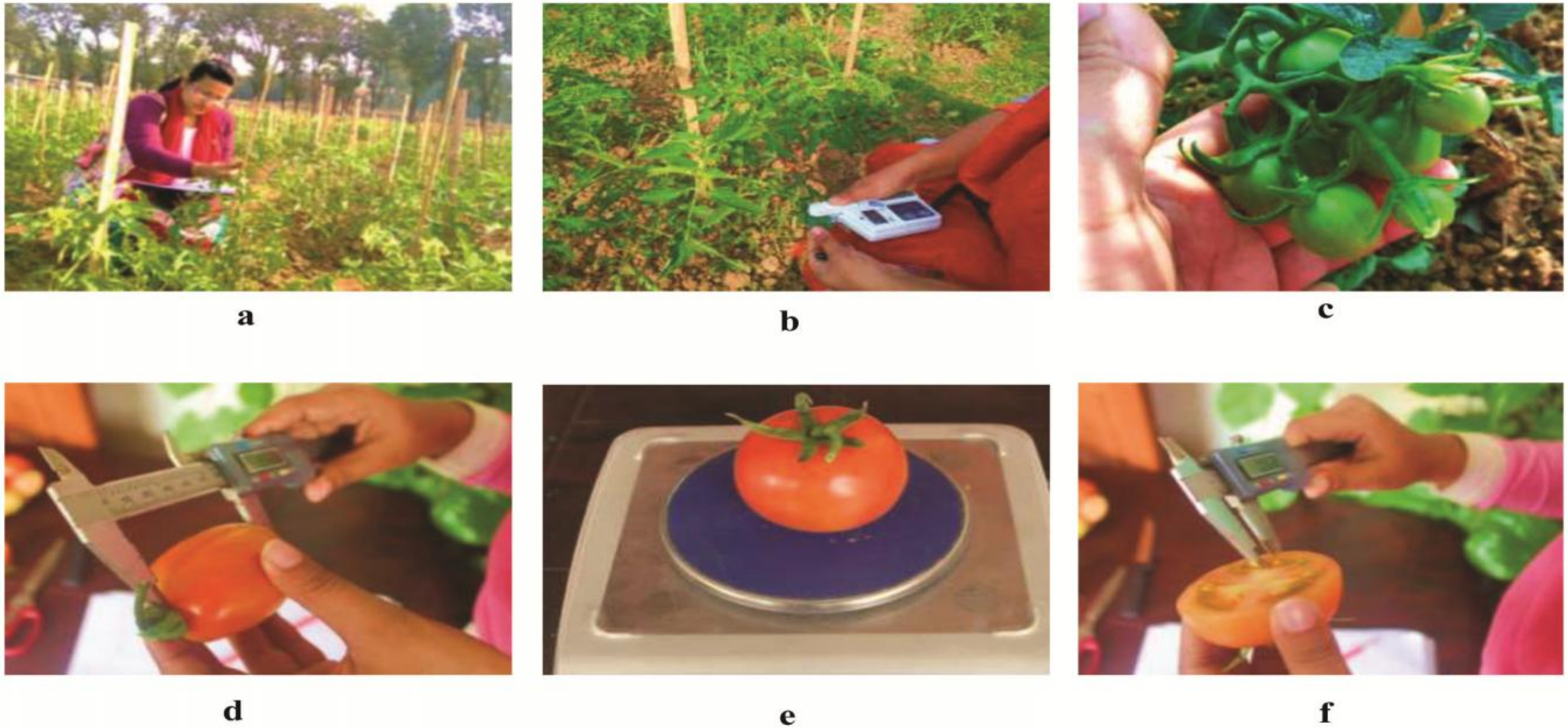


Plate 1. Pictorial presentation a. Measurement of Plant height using Meter scale , b. Measurement of chlorophyll percentage using SPAD c. Fruit count, d. Fruit length & diameter measurement using DigitalCaliper -515 (DC- 515); e. Measurement of Fruit weight using Electronic Precision Balance, f. Pericarp thickness measurement using DigitalCaliper -515 (DC- 515).

CHAPTER IV

RESULTS AND DISCUSSION

The results obtained with different varieties, gibberellic acid and silicic acid and their combinations are presented and discussed in this chapter. Data about morphological parameters, yield contributing characters and fruit yield of tomato have been presented in both Tables and Figures and analyzes of variance and corresponding degrees of freedom have been shown in Appendix (III-VIII).

4.1 Plant height

4.1.1 Effect of Variety

A significant variation was found in plant height and it differs from variety to variety (Figure 2 and Appendix III)at 30, 45, 60 and 75 days after transplanting (DAT) under the present trial at 30, 45, 60 and 75 DAT. The tallest plant (64.1, 86.9, 103.4 and 113.1 cm, respectively) was recorded from V_2, whereas the shortest plant (47.7, 70.6, 87.1and 96.8 cm, respectively) was recorded from V_1.

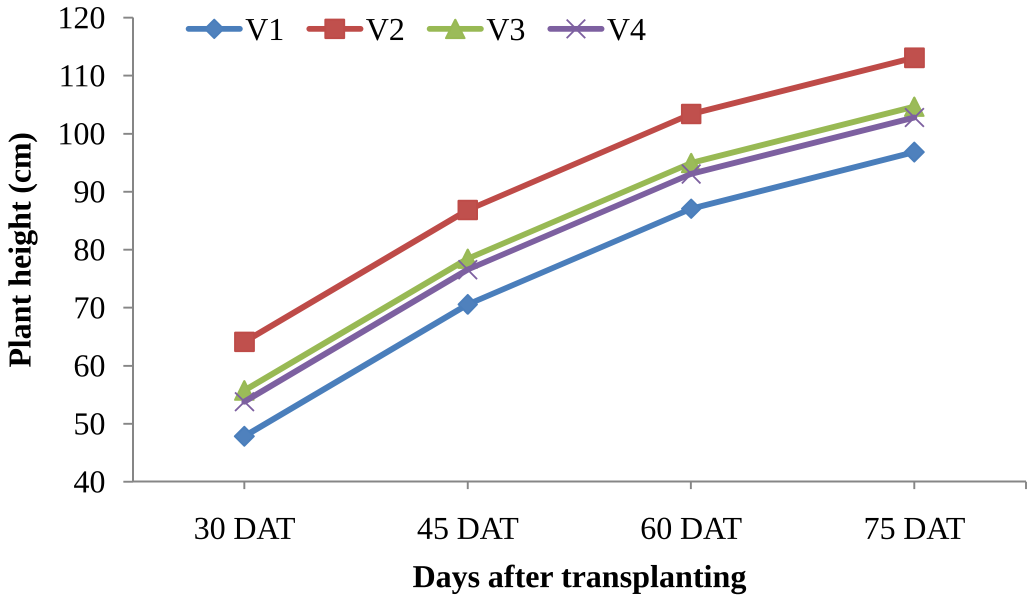


Figure 2: Effect of variety on plant height at different days after transplanting (DAT) (LSD$_{(0.05)}$= 1.5,1.5,1.5 at 30,45,60 DAT, respectively) Here, Here, V_1=BARI tomato-2, V_2=BARI tomato-14, V_3= BARI tomato-15, V_4= BARI tomato-16

4.1.2 Effect of gibberellic acid andsilicic acid

Significant variation was recorded for different levels of salicylic acid on plant height of tomato at 30, 45, 60 and 75 DAT (Appendix III). Data revealed that at 30, 45, 60 and 75 DAT, the tallest plant (62.0, 88.0, 108.0 and 120.0 cm, respectively) was found from GSi, while the shortest plant (49.9, 69.9, 82.9, and 89.9 cm, respectively) was recorded from H_0 (Figure 3).These results are partially supported by Metwally (2016).

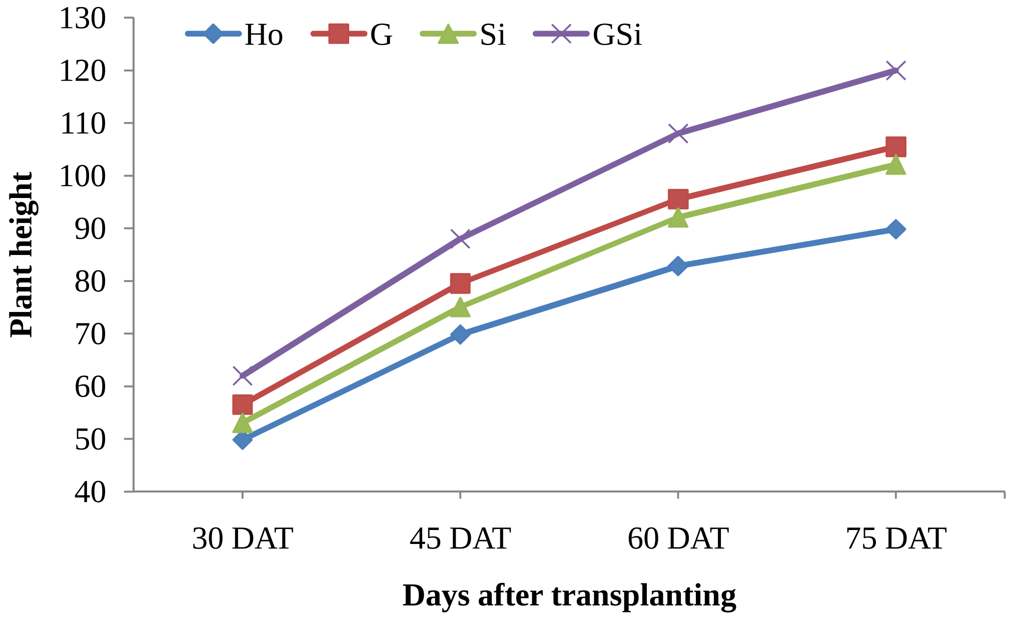


Figure 3: Effect of gibberellic acid and silicic acid on plant height at different days after transplanting (DAT) (LSD $_{(0.05)}$= 1.8,3.5,3.7, 2.4 at 30,45,60,75 DAT, respectively)
Here, Ho=0 ppm GA+0 mM Si G=20 ppm GA+0 mM Si, Si=0 ppm GA+0.4 mM Si, GSi=20 ppm GA+0.4 mM Si

4.1.3 Combined effect of variety and silicic acid and silicon

After 30 DAT, plant height was maximum in V_2GSi and it was 70.8 cm. Second highest plant height was found in V_2G(65.8) though it was statistically similar with V_3Si. The lowest plant height was inV_1H_0 (42.4 cm). After 45, 60 and 75 DAT in all cases maximum plant height was found in V_2GSi and it was

96.8 cm, 116.8 cm and 128.8 cm respectively and lowest plant height was found in V_1T_0 and 62.4 cm, 75.4 cm and 82.4 cm respectively.

After 30 DAS second highest plant height was found in V_2G and it was statistically similar with V_3GSi again V_3GSi was statistically similar with V_2Si and V_4GSi. After 45 DAT almost similar result was found but after 60 DAS and 75 DAS in both cases second highest plant height was found in V_3GSi and it was similar with V_4GSi(Table 2 and Appendix III)

Table 2: Effect of combination of variety and silicic acid and gibberellic acid on plant height at different DAT

Combinations	Plant height (cm)			
	30 DAT	45 DAT	60 DAT	75 DAT
V_1H_0	42.4 k	62.4 i	75.4 i	82.4 j
V_1G	49.5 hi	72.5 fg	88.5 g	98.5 g
V_1Si	45.3 jj	67.3 h	84.3 h	94.3 h
V_1GSi	54.1 fg	80.1 d	100.1 d	112.1 cd
V_2Ho	58.2 de	78.2 de	91.2 fg	98.2 g
V_2G	65.8 b	88.8 b	104.8 c	114.8 c
V_2Si	61.8 c	83.8 c	100.8 d	110.8 d
V_2GSi	70.8 a	96.8 a	116.8 a	128.8 a
V_3H_0	50.2 hi	70.2 gh	83.2 h	90.2 i
V_3G	56.2 ef	79.2 d	95.2 e	105.2 e
V_3Si	53.5 fg	75.5 ef	92.5 ef	102.5 ef
V_3GSi	63.0 bc	89.0 b	109.0 b	121.0 b
V_4Ho	48.6 i	68.6 h	81.6 h	88.6 i
V_4G	54.7 fg	77.7 de	93.7 fe	103.7 ef
V_4Si	51.8 gh	73.8 f	90.8 fg	100.8 fg
V_4GSi	60.2 cd	86.2 bc	106.2 bc	118.2 b
CV%	3.2	2.3	1.9	1.7
LSD $_{(0.05)}$	2.9	2.9	2.9	2.9

Values with common letter (s) within a column do not differ significantly at 5% level of probability

Here, Ho=0 ppm GA+0 mM Si G=20 ppm GA+0 mMSi ,Si=0 ppm GA+0.4 mM Si, GSi=20 ppm GA+0.4 mM Si and V_1=BARI tomato-2, V_2=BARI tomato-14, V_3= BARI tomato-15, V_4= BARI tomato-16

4.2 Number of leaves

4.2.1 Effect of variety

Like plant height no. of leaves was also higher in V_2(31.7, 42.6, 50.7 and 55.5) after 30, 45, 60 and 75 DAT but after, 45, 60 and 75 DAS V_3 was statistically similar with V_2. In all cases V_1(21.5, 31.7, 39.2 and 43.5) showed the lower number of leaf (Figure 4 and Appendix IV).

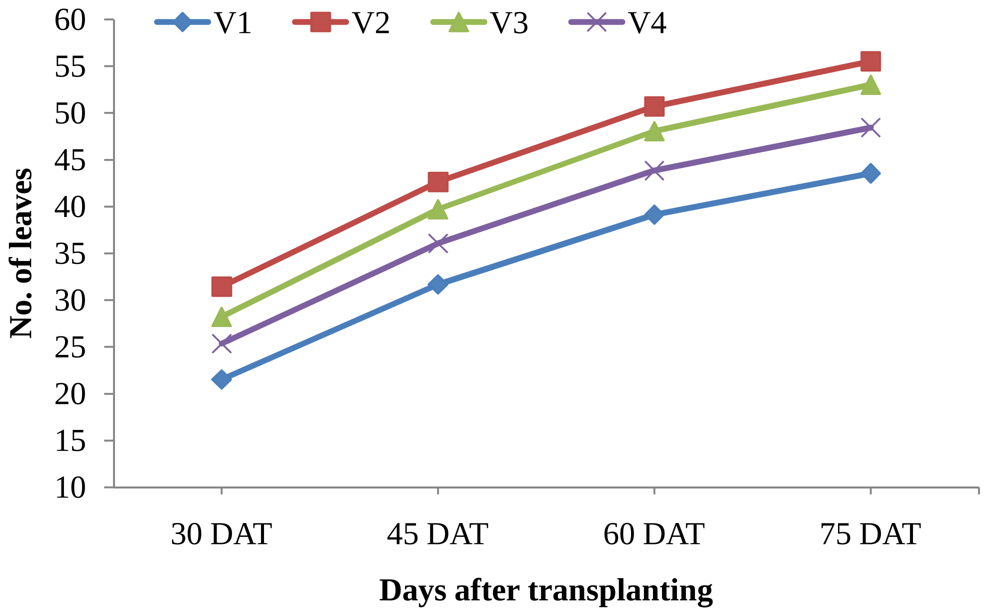


Figure 4. Effect of variety on no. of leaves at different DAT($LSD_{(0.05)}$= 2.2,3.9,3.4,3.8 at 30,45,60,75 DAT, respectively) Here, V_1=BARI tomato-2, V_2=BARI tomato-14, V_3= BARI tomato-15, V_4= BARI tomato-16

4.2.2 Effect of gibberellic acid andsilicic acid

Here higher no. of leaf was found in GSi(32.9, 46.7, 57.3 and 63.6) in case of all time and lower no. of leaf was found in H_0(21.5, 30.0, 35.6, and 38.5) though after 30, 45, 60 and 75 DAT Si and H_0 were statistically similar with each other. These results are partially supported by the findings of Wu *et al.* (1983) who reported increased plant height with GA_3 (Figure 5 and Appendix IV).

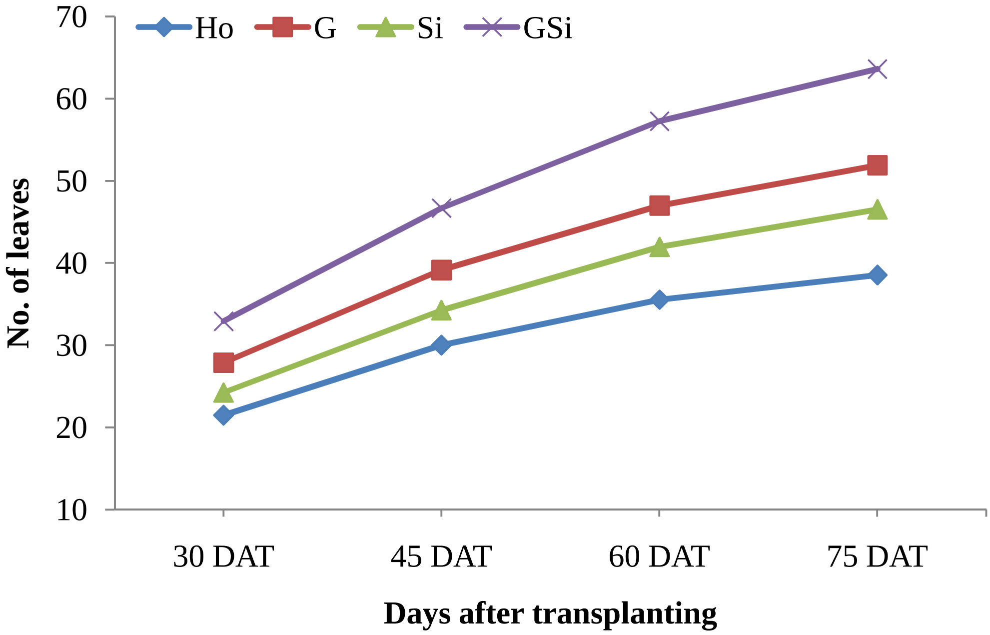


Figure 5. Effect of treatments on no. of leaves at different DAT
($LSD_{(0.05)}$)= 2.2,3.9,3.4,3.8 at 30,45,60,75 DAT, respectively) Here, Ho=0 ppm GA+0 mM Si G=20 ppm GA+0 mMSi ,Si=0 ppm GA+0.4 mM Si, GSi=20 ppm GA+0.4 mM Si

4.3.3 Combined effect of variety and silicic acid and silicon

Number of leaves plant^{-1} of tomato showed significant differences due to combined effect of different variety and salicylic acid at 30, 45, 60 and 75 DAT (Table 3 and Appendix IV). The maximum number of leaves plant^{-1} (38.1, 52.1, 62.9 and 69.4 respectively) was found from V_2GSi treatment combination.The minimum number of leaves plant^{-1} (16.7, 24.5, 29.6 and 32.3 at 30, 45, 60 and 75 DAT, respectively) was found from V_1H_0 treatment combination. These results are also supported by Balasta*et al*. (1989) and Abro*et al.* (2009).

Table 3: Effect of variety and silicic acid and gibberellic acid on number of leaves at different DAT

Combinations	No. of leaves			
	30 DAT	45 DAT	60 DAT	75 DAT
V_1H_0	16.7 h	24.5 j	29.6 g	32.3 g
V_1G	21.9 fg	32.0 g-i	39.1 ef	43.5 ef
V_1Si	19.3 gh	28.5 ij	35.7 fg	39.9 fg
V_1GSi	28.3 cd	41.8 b-e	52.2 b-d	58.4 b-d
V_2Ho	26.4 d-f	35.5 e-h	41.4 ef	44.6 ef
V_2G	32.7 bc	44.2 bc	52.1 b-d	57.1 cd
V_2Si	28.5 cd	38.7 c-f	46.5 de	51.2 de
V_2GSi	38.1 a	52.1 a	62.9 a	69.4 a
V_3Ho	22.6 e-g	31.6 hi	37.4 f	40.5 f
V_3G	30.0 b-d	42.2 b-d	50.7 cd	56.1 cd
V_3Si	26.2 d-f	36.9 d-h	45.2 de	50.1 de
V_3GSi	34.2 ab	48.2 ab	59.0 ab	65.5 ab
V_4Ho	20.2 gh	28.5 ij	33.8 fg	36.7 fg
V_4G	26.9 de	38.2 c-g	46.1 de	51.0 de
V_4Si	23.1 e-g	32.9 f-i	40.5 ef	44.9 ef
V_4GSi	31.2 b-d	44.6 bc	55.0 bc	61.2 bc
CV%	10.0	9.3	9.1	9.0
LSD $_{(0.05)}$	4.4	5.8	6.9	7.5

Values with common letter (s) within a column do not differ significantly at 5% level of probability

Here, Ho=0 ppm GA+0 mM Si G=20 ppm GA+0 mMSi ,Si=0 ppm GA+0.4 mM Si, GSi=20 ppm GA+0.4 mM Si and V_1=BARI tomato-2, V_2=BARI tomato-14, V_3= BARI tomato-15, V_4= BARI tomato-16

4.3 No. of branches

4.3.1 Effect of variety

It was visible that in V_2(7.0) maximum number of branches was found .Whereas lower number of branch was found in V_4 (5.3) andV_1(6.3)showed second highest number of branches per plant and V_3(5.8) showed statistically similar with V_1(6.3)(Table 4 and Appendix V).

4.3.2 Effect of gibberellic acid andsilicic acid

It was visible that GSi(8.3) showed the highest number of branches and H_0(3.8) showed the lowest number of branches. The result showed that GA_3 and silicic acid together increased the branch number but only GA_3 (G)(6.8) is better than only silicic acid acid (Si)(5.8). Combined application of GA_3 and Silicic acid has been found more effective than the other combinations and gibberellic acid has been found given more branches than Silicic acid (Table 4 and Appendix V). These results are partially supported by Tomar and Ramgiry (1997) who reported that tomato plant treated with GA_3 showed significantly greater number of branches plant^{-1} than untreated controls.

4.3.3 Combined effect of variety and silicic acid and gibberellic acid

It was visible that highest number of branches was found in V_2GSi (10) and second higher number of branches was found in V_1GSi(8.7) and it was similar with V_2G(8.0). The lowest number of branches was found in V_4H_0 (3.0) and it was statistically similar with V_1H_0(4.0),V_2H_0(4.0),V_3H_0(4.0). So it was clearly visible that where no GA_3 or no silicic acid was applied there branch number was also reduced (Table 4 and Appendix V).

4.4 Days to first flowering

4.4.1 Effect of Variety

It was observed that V_1(36.5) showed the early flowering followed by V_2 and then V_3 whereas V_1 showed the very late flowering among all the variety (Table 4 and Appendix V).

4.4.2 Effect of gibberellic acid and silicic acid

It was found that G (27.3) where GA_3 was applied it showed very early flowering and both silicic acid and GA_3 together took 29.4 days to flowering. Where no GA_3 or silicic acid was used it took more days to flowering and it was 36.8 days (Table 5 and Appendix V).

4.4.3 Combined effect of variety, silicic acid and gibberellic acid

There was a significant variation among the treatments (Table 6 and Appendix V). It was found that first flower was appeared in V_2G(22.0) and then V_2GSi(25.3) , V_4G(26.0) and V_4GSi(26.3). These three were statistically similar. Here it was observed that in case of using GA_3 and both silicic acid and GA_3 induced quick flowering. V_1H_0(43.7) took maximum time for flowering. V_1Si(39.0) and V_3H_0(4.0) and they were statistically similar.

4.5 Days to first fruiting

4.5.1 Effect of variety

It was found that V_2(27) took less time for flowering. Likewise V_2 took less time for first fruiting and it was 49 days where as V_1(59.5 days) took more time for first fruiting. Here V_3 required 55.6 days and V_4 need 49.8 days (Table 4 and Appendix V).

4.5.2 Effect of gibberellic acid and silicic acid

From Table no. 4 first fruit was appeared where only GA_3(G) was applied and it took 49 days and then where both GA_3 and silicic acid was applied fruit was seen in 51.2 days.Where no GA_3 or silicic acid was applied it took more time for fruit setting and it is 58.6 (Table 5 and Appendix V).

4.5.3 Combined effect of variety, silicic acid and gibberellic acid

From Table no.5 like days to flowering, there was a significant variation among the treatments. It was found that first fruit was appeared in V_2Gand it took only 44 days and then V_2GSi, V_4Gand V_4GSi. These three were statistically similar and they took 47.3 days. Here it was also observed that in case of using GA_3 and silicic acid induced early fruiting and V_1H_0 took maximum time for fruit setting. It took 66.7 days. Then V_1Si and V_3H_0 took 62 days and 60.3 days respectively for fruiting but they were statistically similar (Table 6 and Appendix V).

Table 4. Effect of variety on number of branches, days to first flowering and days to first fruiting

Treatment	Number of branches/ plant	Days to first flowering	Days to first fruiting
V_1	6.3 b	36.5 a	59.5 a
V_2	7.0 a	27.0 d	49.0 d
V_3	5.8 bc	34.6 b	55.6 b
V_4	5.3 c	28.8 c	49.8 c
CV%	10.6	2.9	1.7
LSD $_{(0.05)}$	0.5	0.8	0.8

Values with common letter (s) within a column do not differ significantly at 5% level of probability

Here, V_1=BARI tomato-2, V_2=BARI tomato-14, V_3= BARI tomato-15, V_4= BARI tomato-16

Table 5. Effect of gibberellic acid and silicic acid on number of branches, days to first flowering and days to first fruiting

Treatments	Number of branches/plant	Days to first flowering	Days to first fruiting
Ho	3.8 d	36.8 a	58.6 a
G	6.8 b	27.3 d	49.0 d
Si	5.8 c	33.4 b	55.2 b
GSi	8.3 a	29.4 c	51.2 c
CV%	10.6	2.9	1.7
LSD $_{(0.05)}$	0.5	0.8	0.8

Values with common letter (s) within a column do not differ significantly at 5% level of probability
Here, Ho=0 ppm GA+0 mM Si G=20 ppm GA+0 mMSi ,Si=0 ppm GA+0.4 mM Si, GSi=20 ppm GA+0.4 mM Si

Table 6. Effect of variety, gibberellic acid and silicic acid on number of branches, days to first flowering and days to first fruiting

Combinations	Number of branches/plant	Days to first flowering	Days to first fruiting
V_1H_0	4.0 gh	43.7 a	66.7 a
V_1G	6.7 de	30.0 gh	53.0 e
V_1Si	6.0 ef	39.0 b	62.0 b
V_1GSi	8.7 b	33.3 d	56.3 d
V_2Ho	4.0 gh	31.7 ef	53.7 e
V_2G	8.0 bc	22.0 j	44.0 h
V_2Si	6.0 ef	29.0 h	51.0 f
V_2GSi	10.0 a	25.3 i	47.3 g
V_3Ho	4.0 gh	39.3 b	60.3 c
V_3G	6.3 de	31.0 fg	52.0 ef
V_3Si	6.0 ef	35.3 c	56.3 d
V_3GSi	7.0 c-e	32.7 de	53.7 e
V_4Ho	3.0 h	32.7 de	53.7 e
V_4G	6.0 ef	26.0 i	47.0 g
V_4Si	5.0 fg	30.3 f-h	51.3 f
V_4GSi	7.3 cd	26.3 i	47.3 g
CV%	10.6	2.9	1.7
LSD $_{(0.05)}$	1.1	1.5	1.5

Values with common letter (s) within a column do not differ significantly at 5% level of probability

Here, Ho=0 ppm GA+0 mM Si G=20 ppm GA+0 mMSi ,Si=0 ppm GA+0.4 mM Si, GSi=20 ppm GA+0.4 mM Si and V_1=BARI tomato-2, V_2=BARI tomato-14, V_3= BARI tomato-15, V_4= BARI tomato-16

4.6 Chlorophyll content (SPAD value)

4.6.1 Effect of variety

It was visible that in V_2(63.0)maximum SPAD value was found followed by V_1(53.8), V_3(54.6)and V_4(55.7)(Table 7 and Appendix VI).

4.6.2 Effect of gibberellic acid andsilicic acid

It was visible that GSi(61.0) showed the highest SPAD value which was statistically similar to Si(57.1) and H_0 showed the lowest one which is 54.5. The result showed that GA_3 and silicic acid together increased the SPAD value but only GA_3 (G)(54.5) is not better than only silicic acid acid (Si)(57.1). Combined application of GA_3 and Silicic acid has been found more effective than the other combinations and gibberellic acid has been found given more SPAD value than Silicic acid (Table 8 and Appendix VI). These results are partially supported by Tomar and Ramgiry (1997) who reported that tomato plant treated with GA_3 showed significantly greater SPAD value than the untreated controls.

4.6.3 Combined effect of variety, silicic acid and gibberellic acid

It was visible that highest SPAD value was found in V_2GSi (67.0) and it was similar with V_2G(64.1) and V_2Si(62.2). The lowest number of branches was found in V_1H_0(50.3). So it was clearly visible that where no GA_3 or no silicic acid was applied there SPAD value was also reduced (Table 9 and Appendix VI).

4.7 No. of flowers/plant

4.7.1 Effect of variety

Variety plays a significant role in determining the flowers number.V_3(59.7) showed the higher number of flowers/plant and V_1(49.9) showed the lowest number.V_2andV_4 gave statistically similar result and produce 52.6 and 53.7 flowers/plant respectively (Table 7 and Appendix VI).

4.7.2 Effect of silicic acid and silicon

From the figure it was observed that maximum number of flowers was found in GSi(58.4) when GA_3 and silicic acid are used together whereas H_0(49.0) gave the lowest number of flowers. It was also found that GA_3 had better role in increasing fruit number than the silicic acid (Table 8 and Appendix VI). Findings are partially supported by those of Leonard *et al*. (1983) and Onofegharn (1981) who reported that inflorescence development and flower primordial production in tomato was promoted by GA_3 application.

4.7.3Combined effect of variety and silicic acid and silicon

Maximum number of flowers/plant was obtained from the V_3G(62.9) and V_3GSi(64.3). They were statistically similar.And second highest number of flowers/plant was found from V_2GSi(59.2) and it was statistically similar with V_3H_0(55.4), V_3Si(56.1), V_4G(55.9) and V_4GSi(56.6). Lowest number of flowers/plant was obtained from the V_1H_0(44.6), V_2H_0(46.9)though V_2H_0 was statistically similar with V_1Si(49.3), V_2Si(50.7), and V_4H_0 (49.1). (Table 9 and Appendix VI).

4.8 No. of fruits/plant

4.8.1 Effect of variety

Maximum number of fruit/plant was found in variety V_3 (47) and lowest fruits/plant was found from V_1 (37.8). It was also found that V_2(40.9) and V_4(40.4) produced statistically similar number of fruits (Table 7 and Appendix VI).

4.8.2 Effect of silicic acid and silicon

GA_3 and silicic acid both have a role in increasing fruit number. Maximum number of fruits was found when these are used together. GSi(46.1) produced maximum number of fruits and H_0(36.8) gave lowest fruit number It was found that GA_3(G)(43.0) has better role in increasing fruit number than the silicic acid (40.3)(Table 8 and Appendix VI).

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.

4.8.3 Combined effect of variety and silicic acid and silicon

Different combinations of GA_3 and Silicic acid with variety exhibited significant effect on number of fruits/plant (Table 9 and Appendix VI). The highest number of fruits/plant was observed in V_2GSi (48.5), V_3G (49.6) and V_3GSi (50.3). They were statistically similar and lowest number of fruits was found from V_1H_0 (33.3) which was statistically similar to V_2H_0 (35.5). 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 $GA_3$and silicic acid application.

Table 7. Effect of varity on SPAD value, number of flowers/plant and number of fruits/plant of tomato

Variety	Chlorophyll content (SPAD value)	No. of flowers/plant	No. of fruits/plant
V_1	53.8 b	49.9 c	37.8 c
V_2	63.0 a	52.6 b	40.9 b
V_3	54.6 b	59.7 a	47.0 a
V_4	55.7 b	53.7 b	40.4 b
CV (%)	8.57	4.0	3.2
LSD(0.05)	4.0	1.8	1.1

Values with common letter (s) within a column do not differ significantly at 5% level of probability

Here, V_1=BARI tomato-2, V_2=BARI tomato-14, V_3= BARI tomato-15, V_4= BARI tomato-16

Table 8. Effect of gibberellic acid and silicic acid on SPAD value, number of flowers/plant and number of fruits/plant of tomato

Treatments	Chlorophyll content (SPAD value)	No. of flowers/plant	No. of fruits/plant
Ho	54.5 b	49.0 d	36.8 d
G	54.5 b	56.2 b	43.0 b
Si	57.1 ab	52.3 c	40.3 c
GSi	61.0 a	58.4 a	46.1 a
CV (%)	8.57	4.0	3.2
LSD (0.05)	4.0	1.8	1.1

Values with common letter (s) within a column do not differ significantly at 5% level of probability

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

Table 9. Effect of variety, gibberellic acid and silicic acid on SPAD value, number of flowers/plant and number of fruits/plant of tomato

Combinations	Chlorophyll content (SPAD value)	No. of flowers/plant	No. of fruits/plant
V_1H_0	50.3 f	44.6 h	33.3 i
V_1G	54.4 c-f	52.4 d-f	39.1 ef
V_1Si	53.5 d-f	49.3 fg	37.6 f-h
V_1GSi	57.1 b-f	53.5 c-e	41.1 de
V_2Ho	58.9 a-e	46.9 gh	35.5 hi
V_2G	64.1 ab	53.7 c-e	41.4 de
V_2Si	62.2 a-c	50.7 e-g	38.3 fg
V_2GSi	67.0 a	59.2 b	48.5 a
V_3Ho	54.7 c-f	55.4 b-d	42.1 cd
V_3G	53.7 d-f	62.9 a	49.6 a
V_3Si	51.7 ef	56.1 b-d	46.1 b
V_3GSi	58.5 b-f	64.3 a	50.3 a
V_4Ho	51.2 ef	49.1 fg	36.1 gh
V_4G	56.4 b-f	55.9 b-d	41.9 cd
V_4Si	54.0 d-f	53.3 c-e	39.3 ef
V_4GSi	61.4 a-d	56.6 bc	44.3 bc
CV%	8.57	4.0	3.2
LSD (0.05)	8.1	3.6	2.2

Values with common letter (s) within a column do not differ significantly at 5% level of probability

Here, Ho=0 ppm GA+0 mM Si G=20 ppm GA+0 mMSi ,Si=0 ppm GA+0.4 mM Si, GSi=20 ppm GA+0.4 mM Si and V_1=BARI tomato-2, V_2=BARI tomato-14, V_3= BARI tomato-15, V_4= BARI tomato-16

4.9 Fruit length

4.9.1 Effect of variety

Variety has a significant role in determining the fruit length. It was found that V_2 produced the fruit of maximum length (6.9 cm) and lowest length was found from V_1 (3.7 cm). The length of the fruits of V_4 was 6.3 cm (Table 10 and Appendix VII).

4.9.2 Effect of silicic acid and silicon

Combined use of GA_3 and silicic acidGSi(6.0) increased the fruit length and shortest fruits were found from H_0(5.1). Silicic acid(Si)(5.6) showed a better result than GA_3 as it increased the fruit length than GA_3 (Table 11 and Appendix VII). Korndorfer*et al.* (2001) found the same result.

4.9.3 Combined effect of variety and silicic acid and silicon

Fruit length was significantly varied with the application of GA_3 and silicic acid and also it was different from variety to variety (Table 12 and Appendix VII). It was found that maximum fruit length was found from V_2GSi (7.5) and the lowest fruit length was found from V_1H_0 (3.4) and V_1G (3.5). V_2G(6.8), V_2Si(6.8), V_2H_0(6.6). V_4GSi(6.7) all were statistically similar with each other and they produce second maximum length of fruits. Rodrigues and Datnoff, 2005 found the role of silicic acid.

4.10 Fruit diameter

4.10.1 Effect of variety

From the result It was found that both V_2(6.2) and V_4(6.1)produced the maximum diameter of fruit and lowest diameter was found from V_1 (4.7 cm). The diameter of the fruits of V_3 was 5.5 cm (Table 10 and Appendix VII).

4.10.2 Effect of silicic acid and silicon

Like fruit length, combined use of GA_3 and silicic acid GSi(6.1) increased the fruit diameter and shortest fruits were found from H_0 (5.2 cm). Silicic acid (Si)(5.7) showed a better result than GA_3(5.5) as it increased the fruit diameter than the GA_3 (Table 11 and Appendix VII).

4.10.3 Combined effect of variety and silicic acid and silicon

Fruit diameter was significantly varied with the application of GA_3 and silicic acid and also it was different from variety to variety. In some variety fruit diameter is large and some are small also it influenced by GA_3 and silicic acid. It was found that maximum fruit diameter was found from V_2GSi(6.6) and V_4GSi (6.7)whereas the lowest fruit diameter was found from V_1H_0 (4.4) and V_1G(4.5). V_2G(6.1), and V_2Si(6.2) all were statistically similar with each other and second highest diameter of fruits was found from them (Table 12 and Appendi VII).

4.11 Pericarp thickness

4.11.1 Effect of variety

Thickest pericarp was found from V_3(6.2) and V_4(6.3). There was no significant variation among them. Again V_1 showed the least thickness of fruit and it was 4.5 cm (Table 10 and Appendix VII).

4.11.2 Effect of silicic acid and silicon

Thickest pericarp was found from GSi(7.0) and second highest was Si(5.8). Again H_0showed the least thickness of fruit and it was 4.2 cm (Table 10 and Appendix VII).

4.11.3 Combined effect of variety and silicic acid and silicon

Highest pericarp thickness was found from V_4GSi (8.1) and it was statistically similar with V_3GSi (7.3) though V_1GSi(6.4) and V_4Si(7.0) was statistically similar with V_3GSi(7.3)

The lowest amount of pericarp thickness was found from the V_1H_0(3.3) which was statistically similar with V_1G(4.0). Again V_1G was similar withV_2H_0(4.5), V_2G(4.6), V_3H_0(4.7), and V_4H_0(4.3)(Table 10 and Appendix VII).

Table 10. Effect of variety on fruit length, diameter and pericarp thickness of tomato

Variety	Fruit length (cm)	Fruit diameter (cm)	Pericarp thickness (cm)
V_1	3.7 d	4.7 c	4.5 c
V_2	6.9 a	6.2 a	5.2 b
V_3	5.2 c	5.5 b	6.2 a
V_4	6.3 b	6.1 a	6.3
CV (%)	2.5	2.5	9.5 a
LSD(0.05)	0.1	0.1	0.4

Values with common letter (s) within a column do not differ significantly at 5% level of probability

V_1=BARI tomato-2, V_2=BARI tomato-14, V_3= BARI tomato-15, V_4= BARI tomato-16

Table 11. Effect of gibberellic acid and silicic acid on fruit length, diameter and pericarp thickness of tomato

Treatments	Fruit length (cm)	Fruit diameter (cm)	Pericarp thickness (cm)
Ho	5.1 d	5.2 d	4.2 d
G	5.4 c	5.5 c	5.2 c
Si	5.6 b	5.7 b	5.8 b
GSi	6.0 a	6.1 a	7.0 a
CV (%)	2.5	2.5	9.5
LSD (0.05)	0.1	0.1	0.4

Values with common letter (s) within a column do not differ significantly at 5% level of probability

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

Table 12. Effect of variety, gibberellic acid and silicic acid on fruit length, diameter and pericarp thickness of tomato

Combinations	Fruit length (cm)	Fruit diameter (cm)	Pericarp thickness (cm)
V_1H_0	3.4 k	4.4 j	3.3 h
V_1G	3.5 k	4.5 j	4.0 gh
V_1Si	3.7 j	4.7 i	4.4 fg
V_1GSi	4.1 I	5.1 h	6.4 b-d
V_2Ho	6.6 bc	5.7 ef	4.5 fg
V_2G	6.8 b	6.1 bc	4.6 fg
V_2Si	6.8 b	6.2 b	5.4 ef
V_2GSi	7.5 a	6.6 a	6.3 c-e
V_3Ho	4.7 a	5.1 h	4.7 fg
V_3G	5.1 g	5.4 g	6.3 c-e
V_3Si	5.2 g	5.7 f	6.3 c-e
V_3GSi	5.6 f	5.9 c-f	7.3 ab
V_4Ho	5.9 e	5.8 d-f	4.3 g
V_4G	6.2 d	6.0 c-e	6.0 de
V_4Si	6.5 c	6.0 b-d	7.0 bc
V_4GSi	6.7 bc	6.7 a	8.1 a
CV%	2.5	2.5	9.5
LSD (0.05)	0.2	0.2	0.9

Values with common letter (s) within a column do not differ significantly at 5% level of probability

Here, Ho=0 ppm GA+0 mM Si G=20 ppm GA+0 mMSi ,Si=0 ppm GA+0.4 mM Si, GSi=20 ppm GA+0.4 mM Si and V_1=BARI tomato-2, V_2=BARI tomato-14, V_3= BARI tomato-15, V_4= BARI tomato-16

4.12 Single fruit weight

4.12.1 Effect of variety

Single fruit weight varies from variety to variety. Here it was showed that maximum weight of single fruit was found from V_2(6.9) and lowest weight was found from V_1(3.7). It was also showed that single fruit weight (g) was higher in V_4(6.3)than the V_3(5.2)(Table 13 and Appendix VIII).

4.12.2 Effect of silicic acid and silicon

Single fruit weight was higher in GSi(85.6) than any other of the treatments and lowest weight was found from H_0(76.4). GA_3 increased single plant weight than the silicic acid (Table 14 and Appendix VIII). It was obvious from the results that combined application of GA_3 and Si has privileged more weight gain than the other treatment combinations that was supported by Kaushik*et al*. (1974).

4.12.3 Combined effect of variety and silicic acid and silicon

Interaction between different treatments and different combination showed the significant effect on fruit weight (Table 15 and Appendix VIII). The maximum numbers of fruit weight was observed in V_2GSi (94.9). Second highest fruit weight was found from V_2G(90), V_2Si(87.8) and V_4GSi (90.1) and they were statistically similar with each other. The lowest weight of single fruit was found from V_3H_0(60.3)and V_3Si(63.4). These results are partially supported by Kaushik*et al*. (1974) GA_3 increased the number and weight of fruits plant^{-1}.

4.13 Yield/plant

4.13.1 Effect of variety

Variety played a significant role in yield/plant (Table 13 and Appendix VIII). Different variety had different potentiality for increasing yield. Here V_2(2.7) gave higher yield and then V_3(2.4). V_1 gave lower yield among the four varieties.

4.13.2 Effect of silicic acid and silicon

Like other parameters yield also determined by the use of GA_3 and silicic acid. It was noticed that GA_3 and silicic acid(GSi)(3.0 kg) gave higher yield when they applied together and H_0(1.9 kg) gave lower yield/plant (Table 14 and Appendix VIII). It was supported by Adlakha and Verma (1964) and Kaushik*et al.* (1974)

4.13.3 Combined effect of variety and silicic acid and silicon

Interaction between different treatments and different combination showed the significant effect on yield/plant (Table 15 and Appendix VIII). The maximum yield/plant was obtained from the V_2GSi and second highest yield/plant was found from V_4GSi. Lowest yield/plant was obtained from the V_1H_0 though V_3H_0 was statistically similar with V_1H_0.

4.14 Yield/plot

4.14.1 Effect of variety

From the experiment it was found that among different variety V_2gave more yield/plot (32.4 kg) and V_1(26.6 kg)gave lower yield as well as V_4(30.1kg) gave better result than the V_3(28.5kg)(Table 13 and Appendix VIII).

4.14.2 Effect of silicic acid and silicon

Both GA_3 and silicic acid has a role in increasing yield. The maximum yield was obtained from the combined application of GA_3 and Silicic acid(GSi)(35.9) and the minimum yield was observed in Si(27.4) (Table 14 and Appendix VIII).

4.14.3 Combined effect of variety and silicic acid and silicon

Yield/plot was significantly affected by the interaction of different treatments and variety (Table 15 and Appendix VIII). The maximum number of yield/plot (kg) was found from V_2GSi (42.8) and second highest V_4GSi (36). Lowest value (21.2) was found from V_1H_0 which was statistically similar to V_3H_0 (22.5

kg) and V_3H_0 was statistically similar with V_4H_0(24.2) although there was no significant difference among V_4H_0(24.2), V_1Si(25.6), V_2H_0(25.3) and V_4H_0(24.2).

4.15 Yield/ha

4.15.1 Effect of variety

Yield usually significantly varied from variety to variety (Table 13 and Appendix VIII). Among the four varieties it was found that highest yield was found from the V_2 (91.1 t/ha) and the lowest yield was found from the V_1 (77.8 t/ha) again V_4(88.2) gave higher yield than V_3(81.7).

4.15.2 Effect of silicic acid and silicon

From the data it was clearly observed that combined application of GA_3 and silicic acid(GSi)(89.8) increased the yield and it gave maximum yield the lowest yield was found from the H_0(80..9)(Table 14 and Appendix VIII). If we consider only GA_3 or silicic acid then GA_3(85.4) gave better amount of yield than the silicic acid(Si)(82.80.Saleh and Abdul (1980) and Yoshida (1981) found the same result.

14.15.3 Combined effect of variety and silicic acid and silicon

There was a significant difference between the treatments and the variety as well as with their interaction (Table 15 and Appendix VIII). From the experiment it was found that highest yield/ ha was found from the V_2GSi (96.1 t/ha) and second highest was V_4GSi (93.1t/ha) which was similar with the V_2G(91.4t/ha). The lowest yield/ha was found from the V_1H_0 (73.6) and V_1Si (75.6). These results are partially supported by Saleh and Abdul (1980) who performed an experiment with GA_3 and found increase in the total yield compared with the control. These results are also supported by Yoshida (1981).

Table 13. Effect of variety on yield and yield components of tomato

Variety	Single fruit weight (g)	Yield/plant (kg)	Yield/plot (kg)	Yield/ha (ton)
V_1	82.4 c	2.2 d	26.6 d	77.8 d
V_2	89.7 a	2.7 a	32.4 a	91.1 a
V_3	65.6 d	2.4 c	28.5 c	81.7 c
V_4	85.0 b	2.5 b	30.1 b	88.2 b
CV (%)	2.6	4.5	4.4	1.8
LSD(0.05)	1.7	0.1	1.1	1.2

Values with common letter (s) within a column do not differ significantly at 5% level of probability
V_1=BARI tomato-2, V_2=BARI tomato-14, V_3= BARI tomato-15, V_4= BARI tomato-16

Table 14. Effect of gibberellic acid and silicic acid on yield and yield components of tomato

Treatments	Single fruit weight (g)	Yield/plant (kg)	Yield/plot (kg)	Yield/ha (ton)
Ho	76.4 d	1.9 d	23.3 d	80.9 d
G	81.9 b	2.6 b	31.1 b	85.4 b
Si	78.7 c	2.3 c	27.4 c	82.8 c
GSi	85.6 a	3.0 a	35.9 a	89.8 a
CV (%)	2.6	4.5	4.4	1.8
LSD (0.05)	1.7	0.1	1.1	1.2

Values with common letter (s) within a column do not differ significantly at 5% level of probability
Here, Ho=0 ppm GA+0 mM Si G=20 ppm GA+0 mMSi ,Si=0 ppm GA+0.4 mM Si, GSi=20 ppm GA+0.4 mM Si

Table 15. Effect of variety, gibberellic acid and silicic acid on yield and yield components of tomato

Combinations	Single fruit weight (g)	Yield/plant (kg)	Yield/plot (kg)	Yield/ha (ton)
V_1H_0	79.3 f	1.8 i	21.2 i	73.6 i
V_1G	84.2 cd	2.4 e	28.4 e	79.0 g
V_1Si	80.1 ef	2.1 fg	25.6 fg	75.6 hi
V_1GSi	86.1 cd	2.6 d	31.2 d	82.9 e
V_2Ho	85.9 cd	2.1 fg	25.3 fg	87.8 d
V_2G	90.0 b	2.7 cd	32.8 cd	91.4 bc
V_2Si	87.8 bc	2.4 e	28.8 e	89.1 cd
V_2GSi	94.9 a	3.6 a	42.8 a	96.1 a
V_3Ho	60.3 i	1.9 hi	22.5 hi	78.0 gh
V_3G	67.3 h	2.6 d	31.2 d	82.1 ef
V_3Si	63.4 i	2.2 ef	26.7 ef	79.7 fg
V_3GSi	71.2 g	2.8 c	33.6 c	87.0 d
V_4Ho	80.3 ef	2.0 gh	24.2 gh	83.9 e
V_4G	86.1 cd	2.7 cd	32.0 cd	89.2 cd
V_4Si	83.5 de	2.4 e	28.4 e	86.8 d
V_4GSi	90.1 b	3.0 b	36.0 b	93.1 b
CV%	2.6	4.5	4.4	1.8
LSD (0.05)	3.4	0.2	2.1	2.5

Values with common letter (s) within a column do not differ significantly at 5% level of probability

Here, Ho=0 ppm GA+0 mM Si G=20 ppm GA+0 mMSi ,Si=0 ppm GA+0.4 mM Si, GSi=20 ppm GA+0.4 mM Si and V_1=BARI tomato-2, V_2=BARI tomato-14, V_3= BARI tomato-15, V_4= BARI tomato-16

CHAPTER IV

SUMMARY AND CONCLUSIONS

The experiment was conducted at SAU research field, Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh during the period from October 2016 to March 2017. The experimental area was situated at 23^o77N latitude and 90^o33E longitude at an altitude of 8.6 meter above sea level. The experimental field belongs to the Agro-economical zone of "The Modhupur Tract", AEZ-28. Soil of the experimental site belongs to the general soil type, Shallow Red Brown Terrace Soils under Tejgoan Series. Top soils were clay loam in texture, olive- gray with common fine to midium distinct dark yellowish brown mottles. Soil pH ranged from 6.0- 6.6 and had organic matter 0.84%. Here, V_1=BARI tomato-2, V_2=BARI tomato-14, V_3= BARI tomato-15, V_4= BARI tomato-16 tomato were used for the present research work. The experiment consisted of two factors as follows: factor A (Different varieties of tomato) *viz*., Here, V_1=BARI tomato-2, V_2=BARI tomato-14, V_3= BARI tomato-15, V_4= BARI tomato-16; factor B (Different composition of GA_3& Si) *viz*., H_0 = Control, G= 20 ppm GA_3, Si = 0.4 mM Silicic acid and GSi = 20 ppm GA_3 + 0.4 mM Silicic acid. The two factors experiment was laid out following Randomized Complete Block Design (RCBD) with three (3) replications. The plot size was $3m^2$. Different intercultural operations were done as per when needed. Data on different growth and yield contributing traits were collected. The recorded data for different characters were analyzed using 'MSTAT-C' program treatment means were compared by the Least Significant Difference(LSD) test at 5% level of probability. Most of the parameters had significantly influenced by the application of silicic acid in combination with gibberellic acid under different tomato varieties. Different combinations of GA_3 and Silicic acid with variety exhibited significant effect on number of fruits/plant.

Highest number of fruits/plant was observed in V_2GSi (48.5), V_3G (49.6) and V_3GSi (50.3). They were statistically similar and lowest number of fruits was found from V_1H_0 (33.3) which was statistically similar to V_2H_0 (35.5). Highest pericarp thickness was found from V_4GSi (8.1) and it was statistically similar with V_3GSi (7.3) though V_1GSi and V_4Si was statistically similar with V_3GSi. The lowest amount of pericarp thickness was found from the V_1H_0 which was statistically similar with V_1G. Again V_1G was similar with V_1Si, V_2H_0, V_2G, V_3H_0, and V_4H_0. Interaction between different treatments and different combination showed the significant effect on fruit weight. Maximum numbers of fruit weight was observed in V_2GSi (94.9). Second highest fruit weight was found from V_2G, V_2Si and V_4GSi and they were statistically similar with each other. The lowest weight of single fruit was found from V_3H_0 and V_3Si. Interaction between different treatments and different combination showed the significant effect on yield/plant. Maximum yield/plant was obtained from the V_2GSi and second highest yield/plant was found from V_4GSi. Lowest yield/plant was obtained from the V_1H_0 though V_3H_0 was statistically similar with V_1H_0. There was a significant difference between the treatments and the variety as well as with their interaction. From the experiment it was found that highest yield/ha was found from the V_2GSi (96.1 t/ha) and second highest was V_4GSi (93.1t/ha) which was similar with the V_2G. The lowest yield/ha was found from the V_1H_0 (73.6) and V_1Si (75.6).

On the basis of the findings of the investigation, BARI tomato-14 exhibited the best one for higher yield when treated with 20 ppm GA_3 + 0.4 mM Silicic acid. To validate the result of present study more and more research should be conducted at different Agro-ecological zones of Bangladesh.

REFERENCES

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 J. of Bot*. **41**:1985-1390.

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.

Agarie, S., Agata, W. and Kaufman, P. B. (1998). Involvement of silicon in the senescence of rice leaves. *Plant Production Science*,**1**:104 –105.

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 J. of Bot.* **67**:2356-2363.

Bhati, V. (2017).Evaluation of Tomato Genotypes for Growth, Yield and Quality Traits under Foothills Condition of Nagaland, India.International Journal of Current Microbiology and Applied Sciences.Int.J.Curr.Microbiol.App.Sci (2017) 6(3): 1645-1649.

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.

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

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.

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

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 of the USA, **91**:11–17.

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,* September, Beijing, China. pp**. 46**: 13-18

Feofanova, N. D. (1960). Effect of gibberellins on fruit development in tomatoes.*Bot. J*., **45**: 1781-1786.

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

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

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.

Gong, H. J., Randall, D. P., Flowers, T. J. (2006).Silicon deposition in the root reducessodium uptake inrice (*Oryza sativa L*.) seedlings by reducing bypass flow.*Plant Cell Environ*.**29**: 1970–1971.

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

Horiguchi, T. (1988).Mechanism of manganese toxicity and tolerance of plants vii. Effect of light intensity on manganese induced chlorosis. *J. Plant Nutr*.,**11**: 235 – 245.

Hossain, E., Ahamed, K. U., Shamsuzzaman, A. M. M., Haque, M. and Nahar, K. (2017).Yield and Morphophysiological Performance of Different Tomato Varieties in Winter Season. *Middle-East J. Sci. Res.* **25**(6): 1216-1224.

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.

Hunt, J. W., Dean, A. P., Webster, R. E., Johnson, G. N. and Ennos, A. R. (2008). Novel mechanism by which silica defends grasses againstherbivory. *Ann Bot.,***102**:653-656.

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.

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.

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

Kibria, M. G., Islam, M. and Osman, K. T. (2013).Study of growth, yield and quality of some tomato varieties in valley soils of Chittagong. *IOSR J. Agric. Vet. Sci*. **2**: 12-17.

Korkmaz, A., Karagol, A., Akınoglu, G. and Korkmaz, H. (2017).The effects of silicon on nutrient levels and yields of tomatoes under saline stress in artificial medium culture. *J. Plant Nutr.* **41**(1): 123-135.

Korndorfer, 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.

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

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 (*Cucumissativus*) 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 *(Lycoperciconesculentum*Mill.*)Haryana Hort. Sci.* **4** (34):167-176.

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.

Naeem, N., Ishtiaq, M., Khan, P., Mohammad, N., Khan, J. and Jamiher, B. (2001).Effect of gibberellic acid on growth and yield of tomato Cv. *Roma. J. Biol. Sci*. **1**(6): 448-450.

Onofeghara, F.A. (1981). The effects of growth substancees on flowering and fruiting of *Lycopersiconesculentum*and*Vignaunguiculata.*Phytol. Argentina. **40**(1):107-116.

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

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

Rashid, M.A., Rahman, A.K.M. and Hossain, M.M. 2000. Screening of wild rootstocks brinjal lines and tomato varieties against bacterial wilt. Review of progress. Activity-TI. IPM-CRSP (Intrgrsted Pest Management Collaborative Research Support Program), HRC, BART, Gazipur, l7p

Rodrigues, F. Á., and Datnoff. L. E. (2015). Silicon and plant diseases. 1st ed. *Springer,* 67–100.

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

Saleh, M.M.S. and Abdul, K.S. (1980).Effect of gibberellic acid and cycocel on growth, flowering and fruiting of tomato (LycopersicenesculentumMill.) 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 (LycopersiconesculetumMill) .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 byplant growth regulators. *JARQ*, **39**: 135-138.

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

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.

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

Singh, D.N. and Sahu, A.A. 1998. Performance of tomato cultivars in winter season on entisol of Orissa.*Environ. AndEcol*,**16**(4): 766-762.

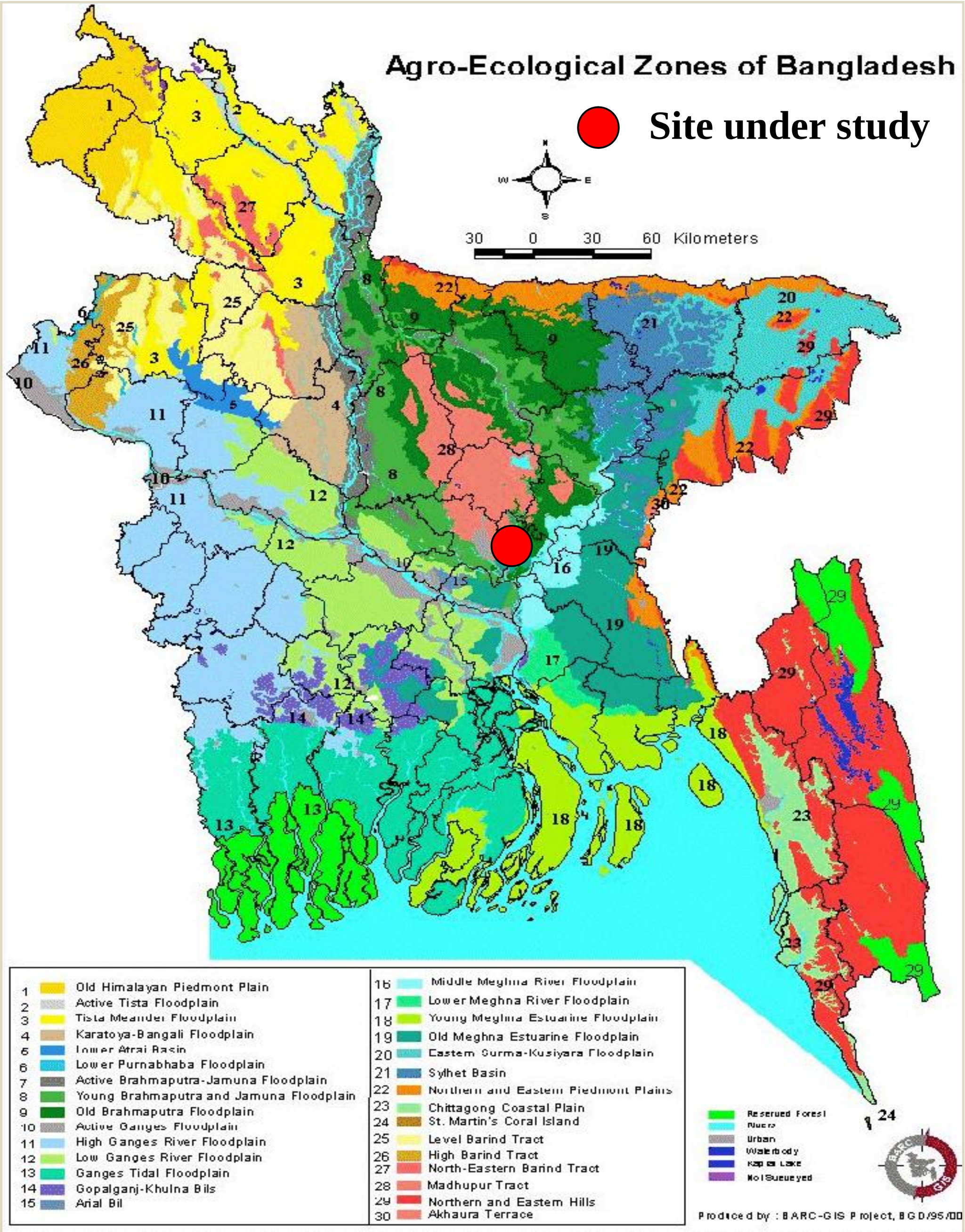
Tomar, J.S. and Ramgiry, S. R. (1997). Effect of growth regulator on yield and yield attributes 10 tomato*(Lycopersiconesculetum*Mill.) *Advan. Plant Sci.* **10** (2) 29-31.

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.

Yoshida, S. (1981). “Fundamentals of rice crop science”. *International Rice Research Institute*, Los Banos, Laguna, Philippines, 269.

APPENDICES

Appendix I. Map showing the site used for present study



Appendix II. Monthly meteorological information during the period from October, 2016 to March, 2017

Year	Month	Air temperature (^oC)		Relative Humidity (%)	Total rainfall (mm)
		Maximum	Minimum		
2015-2016	November	25.22	9.66	56.52	55
	December	25.03	8.76	66.98	1.29
	January	23.87	9.02	70.49	Trace
	February	25.88	11.88	75.21	Trace
	March	27.51	14.96	65.76	64

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

Appendix III. Mean square values for plant height of tomato

Source of variance	df	Mean square value			
		30 DAT	45 DAT	60 DAT	75 DAT
Replication	2	81.248	81.248	81.248	81.248
Variety	3	544.921**	544.921**	544.921**	544.921**
Treatments	3	324.848**	710.115**	1300.982**	1848.84**
Combination	9	0.619**	0.619**	0.619**	0.619**
Error	30	3.094	3.094	3.094	3.094

**, indicates significant at 1 % level of probability

Appendix IV. Mean square values for number of leaves/plant of tomato

Source of variance	df	Mean square value			
		30 DAT	45 DAT	60 DAT	75 DAT
Replication	2	205.916	345.116	467.123	546.726
Variety	3	214.050**	267.727**	307.865**	335.469**
Treatments	3	293.847**	615.686**	1008.163**	1329.45**
Combination	9	0.891	1.964**	3.027**	3.980**
Error	30	7.074	12.246	17.035	20.265

**, indicates significant at 1 % level of probability

Appendix V. Mean square values for number of branches /plant, days to first flowering and fruiting of tomato

Source of variance	df	Number of branches /plant	Days to first flowering	Days to first fruiting
Replication	2	18.063	42.771	42.771
Variety	3	6.083**	246.632**	296.132**
Treatments	3	42.750**	217.243**	217.243**
Combination	9	1.120*	5.688**	5.688**
Error	30	0.418	0.838	0.838

** indicate significant at 5 and 1 % level of probability

Appendix VI. Mean square values for SPAD value, number of flowers and fruit/plant of tomato

Source of variance	df	SPAD value	Number of flowers/plant	Number of fruits/plant
Replication	2	34.398	17.657	26.690
Variety	3	213.175**	202.750**	183.016**
Treatments	3	111.118**	208.318**	187.674**
Combination	9	9.239**	5.997**	6.282**
Error	30	23.715	4.766	1.801

** indicates significant at 1 % level of probability

Appendix VII. Mean square values for fruit diameter, length and pericarp thickness of tomato

Source of variance	df	Fruit length	Fruit diameter	Pericarp thickness
Replication	2	0.378	0.378	12.990
Variety	3	24.481**	5.941**	8.461**
Treatments	3	1.432**	1.432**	16.858**
Combination	9	0.032**	0.032**	0.680*
Error	30	0.019	0.019	0.280

** indicatesignificant at 5 and 1 % level of probability

Appendix VIII. Mean square values for single fruit weight, yield/plant, yield/plot and yield/ha of tomato

Source of variance	df	Single fruit weight	Yield/ plant	Yield/ plot	Yield/ ha
Replication	2	24.307	0.475	69.748	23.018
Variety	3	1322.91**	0.487**	73.011**	439.88**
Treatments	3	189.44**	2.467**	346.478**	178.67**
Combination	9	2.174**	0.070**	9.739**	0.522**
Error	30	4.267	0.012	1.659	2.190

**, indicates significant at 1 % level of probability