EFFECT OF SALICYLIC ACID ON GROWTH, YIELD AND QUALITY OF TOMATO

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CERTIFICATE

This is to certify that the thesis entitled **'Effect of Salicylic Acid on Growth, Yield and Quality of Tomato'** submitted to the Department of Agricultural Botany, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **Master of Science in Agricultural Botany,** embodies the results of a piece of bonafide research work carried out by **Afrin Sayed,** Registration No. **14-06304** 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:
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TO

MY BELOVED PARENTS

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The Author

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ABSTRACT

The experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh during November 2014 to March 2015 to find out the effect of salicylic acid on growth, yield and quality of tomato. The experiment comprised of two factors as Factor A: Different tomato varieties (2 varieties)- V_1: Ratan, V_2: Mintoo hybrid; and Factors B: Different levels of salicylic acid -SA (4 levels)- SA_0: 0 mM SA (control), SA_1: 0.1 mM SA, SA_2: 0.2 mM SA and SA_3: 0.3 mM SA. The two factors experiment was laid out in a Randomized Complete Block Design (RCBD) with four replications. In consideration of varieties, the taller plants (18.13, 43.24, 64.01, 78.71, 87.01 and 89.68 cm, respectively) was found from V_2, whereas the shorter plants (17.13, 40.00, 59.97, 74.38, 82.55 and 86.25 cm, respectively) was recorded from V_1. The higher (64.36%) fruit setting was recorded from V_2, whereas the lower (63.81%) from V_1. The higher (85.13 ton) fruit yield per hectare was recorded from V_2 and the lower (71.00 ton) from V_1. The highest (4.34%) total soluble solid was found from V_2 and the lowest (4.22%) total soluble solid was observed from V_1. In case of different levels of salicylic acid, at 20, 30, 40, 50, 60 DAT and final harvest, the tallest plant (18.51, 43.54, 64.44, 80.59, 87.78 and 90.99 cm, respectively) was recorded from SA_3, while the shortest plant (16.56, 38.74, 57.28, 69.24, 79.17 and 83.04 cm, respectively) was found from SA_0. The highest (65.10%) fruit setting was recorded from SA_3, while the lowest (61.89%) from SA_0. The highest (86.27 ton) fruit yield per hectare was found from SA_3, while the lowest (64.63 ton) from SA_0. The highest (4.41%) total soluble solid was found from SA_3, while the lowest (4.09%) was observed from SA_0. For the interaction effect of different varieties and levels of salicylic acid at 20, 30, 40, 50, 60 DAT and final harvest, the tallest plant (20.05, 46.38, 67.86, 85.09, 92.27 and 94.82 cm, respectively) was observed from V_2SA_3 and the shortest plant (15.92, 36.26, 55.04, 68.24, 78.49 and 83.96 cm, respectively) was recorded from V_1SA_0. The highest (64.71%) fruit setting was observed from V_2SA_3 and the lowest (59.31%) from V_1SA_0. The highest (99.26 ton) fruit yield per hectare was recorded from V_2SA_3, whereas the lowest (62.18 ton) from V_1SA_0 treatment combination. The highest (4.58%) total soluble solid was found from V_2SA_3, whereas the lowest (4.08%) total soluble solid was recorded from V_1SA_0. Data revealed that among the combination of different varieties and levels of salicylic acid, Mintoo hybrid with 0.3 mM SA encouraged superior growth, yield contributing characters, yield and quality of tomato.

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CHAPTER I

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) is a vegetable crop under the family Solanaceae and has been originated in tropical America (Salunkhe *et al*., 1987) which includes Peru, Ecuador, Bolivia areas of Andes (Kallo, 1986). Tomato is one of the most popular and important vegetable crop grown in Bangladesh (Mondal *et al*., 2011). Though it is a winter crop, nowadays, it is grown round the year and there has been a gradual increase in the area of land cropped to tomato and this led to marginal increases in tomato production. The present leading tomato producing countries of the world are China, United States of America, Turkey, India, Egypt, Italy, Iran, Spain, Brazil Mexico, and Russia (FAOSTAT, 2013). The total production of tomato was 339 lac tons in China, 137 lac tons in USA, 109 lac tons in Turkey, 103 lac tons in India and 92 lac tons in Egypt (FAO, 2010). Due to increasing consumption of tomato products, the crop is becoming promising. At present Bangladesh is producing a good amount of tomatoes and it is using for the preparation of different delicious food. In Bangladesh, it occupies an area of 26,316.2 hectares in the year of 2012-2013 with the total production of 251 thousand metric tons (BBS, 2013).

The yield of tomato in our country is not satisfactory in comparison to other country and its requirement (Aditya *et al.*, 1999). The low yield of tomato in Bangladesh, however, is not an indication of low yielding ability of this crop, but of the fact that low yielding variety, poor crop management practices and lack of improved technologies. Use of high yielding variety and modern technology of cultivation is prerequisite for increasing the production of tomato in Bangladesh. Plant growth regulators (PGR's) are organic compounds, which need in small amounts, somehow modify a given physiological plant process. It plays an important role in many aspects of different plant growth and development of tomato plants (Patil *et al*., 1987; Dharmender *et al*., 1996). Generally PGR's are responses differently for yield contributing characters and yield of tomato and

different germplasms/variety in different concentration, time and methods of their application. It is well known that variety plays an important role in producing high yield of tomato because different varieties perform differently for their genotypic characters.

Different types of local races, advanced lines and exotic materials of tomato seed are available in our country. Bangladesh Agricultural Research Institute (BARI), Bangladesh Institute of Nuclear Agriculture (BINA) released some tomato varieties. These varieties are showed yield potentiality in different agro climatic condition of Bangladesh (Hossain *et al*., 2013). Besides these, there are some hybrid varieties also available in farmers level and they cultivated these varieties without no well known cultivation procedure also but it is necessary to identify the suitable variety in farmer's level for attaining highest yield. Variety is the key component to produce higher yield of tomato depending upon their differences in genotypic characters, different input requirements and responses, growth process and off course the prevailing growing environmental conditions during the entire growing season. Improved variety is the first and foremost requirement for initiation and accelerated crop production program (Ojo *et al*., 2013). Yield contributing characters and yield of tomato varied significantly due to different variety (Kayum *et al*., 2008; Biswas *et al*., 2015).

Plant growth regulators are extensively used in horticultural crops like as promoters, inhibitors or retardants play a key role in controlling internal mechanisms of plant growth by interacting with key metabolic processes such as, nucleic acid metabolism and protein synthesis (Kumar *et al*., 2014). Salicylic acid ($C_7H_6O_3$) is an endogenous growth regulator of phenolic nature, which participates in the regulation of physiological processes in plant, such as stomatal closure, ion uptake, inhibition of ethylene biosynthesis, transpiration and stress tolerance (Khan *et al*., 2010). Endogenous salicylic acid is said to act like a growth regulator and functions as an indirect signal stimulating many physiological, biochemical and molecular processes and therefore it affects the

plant growth and development (Klessig and Malamy, 1994, Malamy *et al*., 1990). Numerous studies have documented the influence of endo and exogenous salicylic acid on the content of photosynthetic pigments in leaves (Yildirim *et al*., 2008), on plant photosynthesis (Fariduddin *et al*., 2003) and on nitrogen metabolism owing to salicylic acid producing a positive impact on the activity of nitrate reductase (Fariduddin *et al*., 2003; Miguel *et al*., 2002), synthesis of secondary plant metabolites (Eraslan *et al*., 2007). Salicylic acid increased fruit number and yield also facilitate transferring sugar to the fruit from leaves (Elvwan and Hamahyomy, 2009). Thus, application of salicylic acid affected yield and quality characters of tomato (Javaheri *et al*., 2012).

Considering the above mentioned facts and based on the prior observation, an investigation was undertaken with the following objectives:

- To assess the performance of different variety in terms of yield attributes, yield and quality of tomato;
- To evaluate the different concentration of salicylic acid for attaining optimum yield attributes, yield and quality of tomato and
- To identify the suitable variety and appropriate concentration of salicylic acid for better yield attributes, yield and quality of tomato.

CHAPTER II

REVIEW OF LITERATURE

Tomato is one of the leading and nutritious vegetables not only in our country but also all other countries of the world. Vegetable production is far below of actual requirements in Bangladesh and the demand of vegetables is also increasing day by day due to increase of population. Horizontal expansion of vegetable yield per unit area should be increased to meet this ever-increasing demand of vegetables but it will require adoption of new technology such as high yielding cultivars, appropriate management practices, higher input use etc. Among these, growth regulator is a modern concept as a management practices and improved variety is a pre-requisite factor for successful tomato production. Number of studies has been performed evaluating the influence of variety and salicylic acid as growth regulators on growth parameters and yield of tomato but the information is not definite and conclusive. Nevertheless, some of the important and informative works regarding variety and salicylic acid on tomato so far been done at home and abroad have been reviewed below under the following headings:

2.1 Effect of variety on yield attributes and yield of tomato

Biswas *et al*. (2015) carried out an experiment at Agronomy Farm of the Sher-e-Bangla Agricultural University, Dhaka with four varieties, viz. BARI Tomato-4 (V_1), BARI Tomato-5 (V_2), BARI Tomato-7 (V_3) and BARI Tomato-9 (V_4). Data revealed that the tallest plant (101.3 cm), maximum number of leaves (114.1/plant) and maximum number of branches (16.0/plant) was recorded from BARI Tomato-7, while maximum number of flowers (6.1/cluster), number of fruits (5.0/cluster), number of clusters (17.9/plant) were found from BARI Tomato-9. However, maximum fruit diameter (20.1 mm), individual fruit weight (115.9 g), yield (34.7 kg/plot and 95.9 t/ha) and number of locule (4.4/fruit) were also recorded from BARI Tomato-7 among the variety under the study.

Degri and Sani (2015) conducted a field experiments at Gombe State Agricultural Development trial farm, Kwadon, Gombe State with four improved tomato varieties and one local variety as treatments. Plant height, mean number of branches, fruits, damaged and undamaged fruits were recorded. The results indicated that improved tomato varieties used for the study had less insect pest species, produced taller plants, more branches and fruits compared to the local variety. Tomato farmers in the study area should be advised to adopt the use of improved tomato varieties for cultivation.

Field experiments were conducted by Enujeke and Emuh (2015) in the Teaching and Research Farm of Delta State University, Asaba Campus, Asaba, Nigeria to assess some growth and yield indices of five varieties of tomato (DT97/215A, UC82B, Roma VF, Kwale and Asaba Local). The results of the 2 years investigation showed that hybrid variety UC82B was superior to other varieties tested with mean height of 52 cm, mean number of leaves/plant of 53 cm, mean number of flowers/plant of 26 cm, mean number of fruits/plant of 27 cm, and mean fresh fruit weight of 18.5 t/ha.

Nnabude *et al*. (2015) carried out a study to find out the response of three varieties of tomatoes to liquid organic fertilizer and inorganic fertilizer by in the Teaching and Research Farm of the Faculty of Agriculture, Chukwuemeka Odumegwu Ojukwu Univerrsity. The treatments comprised 1.4 ml Alfa life (organic fertilizer) mixed with 81 ml of water, 180 g NPK 20:10:10 and control where no treatment was applied. The results of the study indicated higher fruit yield in local variety. The interaction between fertilizers and tomato varieties significantly affected the plant height relative to other growth parameters and was effective as week after planting increased.

The agronomic response of four tomato (*Solanum lycopersicum L.*) varieties to fertilizer application was examined at the CSIR-Crops Research Institute, Kwadaso-Kumasi in the Forest agro-ecological zone of Ghana by Agyeman *et al*. (2014). The four tomato varieties Shasta, Heinz, CRI POO and CRI 034 were

evaluated on different fertilizer types. The CSIR-CRI breeding lines were able to yield higher than the exotic varieties. CRI POO with Winner + Sulfan fertilizer application also produced significantly higher fruit yield (26.4 t/ha).

Ojo *et al*. (2013) conducted a field experiment at the Teaching and Research Farm of the University of Agriculture, Makurdi for evaluating the performance of tomato varieties in the Southern Guinea Savanna ecology of Nigeria. The experimental designed while four varieties of tomato namely Roma Savanna VF (an improved variety), two hybrid varieties (F_1 Lindo and F_1 Jaguar) and a local variety (Local check) constituted the treatments. Highly significant variety effect was observed for all the traits (days to flowering, fruit length, fruit diameter, number of fruit s/plant, weight of fruits/plant and fruit yield). The highest values for fruit length, fruit diameter, number of fruits/plant, weight of fruits/plant and fruit yield observed for Roma Savanna VF.

A study was conducted by Hossain *et al*. (2013) at Agricultural Research Station, Thakurgaon, Bangladesh to observe the effect of sowing dates on yield of tomato genotypes. Three sowing dates were considered as factor A and tomato variety viz., BARI Tomato-2, BARI Tomato-3, BARI Tomato-4, BARI Tomato-9 and BARI Hybrid Tomato-4 considered as factor B. Among the variety, BARI Tomat-2 produced the highest (68.12 t/ha) marketable yield followed by BARI Tomato-9 (56.16 t/ha) and BARI Tomato-3 while BARI Tomato-4 gave the lowest (36.91 t/ha) marketable yield.

Tigist *et al*. (2012) evaluated three processing and six fresh market tomato varieties for different yield and yield contributing charcters. The tomato varieties harvested at "mature green" stage were evaluated for changes in physical quality characteristics during the storage period of 32 days under ambient conditions. Data revealed that tomato varieties had significant effects on yield and quality and fresh market tomato variety *Fetane* was the highest yielder. *Marglobe Improved* had the highest physical quality characteristics while *Fetane* showed the lowest values. Melkashola had the highest physical quality characteristics

than the other two processing varieties while weight loss was almost similar with *Roma VF* during most of the storage periods.

Olaoye *et al*. (2009) conducted experiments to evaluate the growth, fruit yield and quality of seven varieties of tomato in the Guinea Savannah zone of South West Nigeria at the Teaching and Research farm of the Faculty of Agricultural Sciences, Ladoke Akintola University of Technology (LAUTECH), Ogbomoso. The varieties tested were, DT97/162A(R), DT97/215A, Tropical, Roma VF, UC82B, Ibadan local and Ogbomoso local. The results showed that DT97/162A(R) gave the highest plant height whereas Ogbomoso local recorded the highest number of leaves at 6 weeks after transplanting. Higher fruit yield was recorded from UC82B, closely followed by Ibadan and Ogbomoso local. Therefore UC82B, Ibadan and Ogbomoso local in that descending order are better in terms of fruit yield and quality.

An experiment was conducted by Ahammad *et al*. (2009) to observe the effect of planting date and variety on the yield of late planting tomato at Jessore. The potentiality of fruiting in the late season were evaluated for BARI tomato 4, 5, 6 and different planting time. A combination of December 01 planting with BARI Tomato 5 variety performed better in respect of yield (57.07 t/ha). The variety BARI Tomato 5 also showed potential fruiting capability during late winter season and February 01 planting produced 11 ton/ha of potential yield.

Three separate field experiments were conducted to study the effect of two conventional tillage methods on yield of tomato (*Lycopersicon esculentum*) at the Teaching and Research Farm, University of Ilorin, Nigeria by Olaoye *et al*. (2009). The conventional tillage treatments were used to assess the response of the varieties to four N-Fertilizer regimes, two different growing seasons and two moisture regimes respectively. Roma (check variety) significantly yielded higher than other varieties while Periondonta was superior for fruit yield.

Kayum *et al*. (2008) conducted an experiment to identify the potential mulch on growth and yield, where the experiment consisted of four mulching treatments Three popular tomato varieties namely, Ratan, BARI tomato-3 and BARI tomato-6 were experimentally evaluated. In the experiment, variety Ratan produced the highest (73.74 t/ha) fruit yield, while BARI tomato-3 showed the lowest (58.89 t/ha) fruit yield. The combination of water hyacinth and Ratan produced the maximum yield (82.16 t/ha).

A field study conducted by Rajashekar *et al*. (2006) on the effect of planting seasons on seed yield and quality of tomato varieties *Viz.,* Nandi, Sankranthi, and Vybav resistant to leaf curl virus. The results revealed that in seed crop raised in *rabi* season record significantly higher growth and yield parameters. Maximum fruit yield (71 t/ha) and seed yield (287.38 kg/ha) was noticed in *rabi* season followed by *kharif.* There was drastic reduction in fruit and seed yield in summer. Among varieties, Vybav recorded highest fruit yield in all the three planting seasons, but has recorded lowest fruit to seed ratio (0.19%), while the highest seed to fruit ratio was observed in Arka Vikas.

Hamid *et al*. (2005) carried out an experiment to study the performance of five Russian (Raickoi Naclazdenie, Belai Nalev, Ceberckoi Ckorocpelai, Novichok, Patris) and one local variety of tomato under Rawalakot conditions at Research Farm of University College of Agriculture, Rawalakot, Azad Kashmir. The results indicated that maximum plant height and size of fruit were observed in variety Raickoi Naclazdenie, whereas maximum number of flower clusters and fruits per plant were observed in 'Paths'. Minimum plant height, number of flower clusters and fruits were noted in Novichok, where as minimum number of branches and fruit weight/plant was noted in Local Kashmir. Varieties Ceberckoi ckorocpelai and Patris gave maximum fruit weight of 4.96 and 4.85 kg/plant compared to the minimum of 1.60 kg/plant by local check and Novichok.

2.2 Effect of salicylic acid on yield attributes and yield of tomato

In order to improve the germination of tomato seeds under high temperature stress conditions seed priming by salicylic acid was investigated by Singh and Singh (2016). The experiment was conducted to study the effect of salicylic acid on the tomato vegetative growth, yield and fruit quality of tomato. These factors included salicylic acid in three levels (0.25 mM, 0.5 mM and 0.75 mM) applied on tomato. Results indicated that germination and vegetative and reproductive growth of tomato severely reduced by high temperature. The TSS, TA, vitamin C and lycopene content of tomato fruit had significantly affected by application of salicylic acid. The exogenous applications of salicylic acid improved the yield contributing factors that resulted in significant increases in tomato fruit yield.

Javaheri *et al*. (2014) carried out an experiment to study the effects of salicylic acid on some quality characters of tomato different concentration of salicylic acid (10^{-2}, 10^{-4}, 10^{-6}, 10^{-8} molar and control) was done in seedling stage as foliar replication. Obtained results of this study show that salicylic acid significantly affected number of panicle in a bush, yield, fruit number in panicle, fruit number in bush, fruit weight and fruit diameter. Among foliar application, the highest rate of tomato yield with mean of 3059.5 g obtained in SA_3 (SA at 10^{-6} M), highest numbers of panicle in tomato bushes with mean of 31.25 measured in SA_1 (SA at 10^{-2} M). Highest fruit number in panicle and highest fruit number in bush obtained by mean of 3.5 and 66.75 in SA_1 (SA at 10^{-2} M), respectively and minimum amount of all this characters was recorded in control and the highest amount of fruit weight and also fruit diameter was measured in SA_1 (SA at 10^{-2} M) with mean of 61.50 g and 51.75 mm, respectively.

Lakzayi *et al*. (2014) reported that effect of drought is among the environmental constraints that affect crop growth and crop production worldwide. Drought or water deficit stress elicits many different physiological responses in plants. The decrease in chlorophyll content under drought stress has been considered a typical symptom of oxidative stress and may be the result of pigment photo-oxidation and chlorophyll degradation. Relative water content (RWC), leaf water

potential, stomatal resistance, the rate of transpiration, leaf temperature and canopy temperature are important characteristics that influence plant water relations. Salicylic acid (SA) as a potent signaling molecule in plants is involved in eliciting specific responses to biotic and abiotic stresses.

Kazemi (2014a) conducted a study to find out the effect of salicylic acid and methyl jasmonate as pre-harvest treatments on the tomato vegetative growth, yield and fruit quality. These factors included salicylic acid in 2 levels (0.5 and 0.75 $mmolL^{-1}$) and methyl jasmonate in 3 levels (0.25, 0.5 and 0.75 $mmolL^{-1}$) applied on tomato. Results indicated that salicylic acid (0. 5 $mmolL^{-1}$) increased vegetative and reproductive growth, yield and chlorophyll content. The application of salicylic acid (0. 5 $mmolL^{-1}$) alone significantly increased dry weight. The TSS, TA and vitamin C content of tomato fruit had significantly affected by the application of salicylic acid.

To study the role of pre-application with salicylic acid (SA) (0.5 and 1 mM) and methyl jasmonate (MJ) (0.5 and 1 mM) and their combination on yield quantity and quality of tomato fruits an experiment was conducted by Kazemi (2014b). The results showed that the foliar spray of SA (0.5 mM) significantly increased vegetative and reproductive growth, yield and fruit quality, while reduced blossom end rot. On the contrary, MJ (1 mM) application significantly decreased vegetative growth while increasing reproductive growth. The application of 0.5 mM MJ+0.5 mM SA increased total soluble solids (TSS), titratable acidity (TA) and vitamin C content. In conclusion, application of 0.5 mM MJ+0.5 mM SA improved the yield and fruit quality of tomato.

Guzman-Tellez *et al*. (2014) carried out a study to determine the change in the SA leaf concentration over time in response to the SA spraying in leaves of greenhouse grown tomato. In sprayed leaves the SA concentration showed changes over time similar to the reported responses to environmental stress. Two days after the first application, the SA foliar concentration reached the maximum of 8 $\mu g \cdot g^{-1}$, equivalent to twice the amount observed in the control plants. SA

decreased until it reached the level of control plants eight days later. A second application showed actually the same response, but with a faster decline of SA in two days.

Hafeznia *et al*. (2014) conducted an experiment using salicylic acid (SA) on tomato cv. Sopera based with foliar application of SA, with 10^{-4} molar concentration, performed 20 days after transplanting with 15 days interval, from planting to harvesting the products, planting to the flowering, flowering period up to the fruiting, and water spray as a control. Results revealed that the maximum leaf area, number of clusters and number of fruits per plant, sucrose, fructose, glucose, total soluble solid (TSS), vitamin C and lycopene were related to SA spray from planting up to harvesting. Sucrose became triple by utilizing of SA throughout planting period. Consequently, foliar application of SA in growth duration lead to biomass accumulation which guide to enhance of carbohydrates, TSS and vitamin C.

Kowalska and Smolen (2013) carried out a study to evaluate the effect of an increased salt concentration in a nutrient solution and foliar application of salicylic acid (SA) and $KMnO_4$ on the yield, fruit quality and nutritional status of tomato plants. The experiment included two sub-blocks with two EC levels (2.5 and 4.5 mS cm^{-1}). Within each sub-block, the following foliar application variants were distinguished: control (without foliar application) salicylic acid (SA) and SA/$KMnO_4$. Data revealed that irrespective of the EC of the nutrient solution, foliar application of SA as well as SA/$KMnO_4$ had no significant effect on the tomato yield, total acidity and dry matter or soluble sugar content in fruits.

Javaheri *et al*. (2012) carried out an experiment to study the effects of salicylic acid on yield quantity and quality of tomato, at research center of Shirvan Agricultural Faculty. Foliar application of five concentrations of salicylic acid (0, 10^{-2}, 10^{-4}, 10^{-6}, 10^{-8} M) were used. Results showed that application of salicylic acid affected tomato yield and quality characters of tomato fruits so that

tomato plants treated with salicylic acid 10^{-6} M significantly had higher fruit yield (3059.5 g per bush) compared to non-treated plants (2220 g per bush) due to an increase in the number of bunch per bush. Results also indicated that application of salicylic acid significantly improved the fruit quality of tomato. Application of salicylic acid increased the amount of vitamin C, lycopene, diameter of fruit skin and also increased rate of pressure tolerance of fruits. Fruit of tomato plants treated with salicylic acid 10^{-2}M significantly had higher vitamin C (32.5 mg per 100 g of fruit fresh weight) compared to non treated plants (24 mg per 100 g fruit fresh weight). Salicylic acid concentration 10^{-2}M also increased the diameter of fruit skin (0.54 mm) more than two fold compared to control (0.26 mm). Fruit Brix index of tomato plants treated with salicylic acid 10^{-2}M significantly increased (9.3) compared to non-treated plants (5.9). These results suggest that foliar application of salicylic acid may improve quantity and quality of tomato fruits.

Consequently pot experiment was conducted by Salehi *et al*. (2011) to evaluate the effect of SA on tomato growth under salt stress condition. The experiment was complete randomized block with 3 replications, 4 levels of irrigation water salinity (0, 4, 8 and 12 dS/m) and 4 levels of SA concentration (0, 10^{-6}, 10^{-4} and 10^{-2} M) which was foliar sprayed. There was highly significant reduction in shoot fresh and dry weights and number of flowers per plant with increasing salinity. There was no significant difference between shoot fresh and dry weighs and number of flowers per plant for SA treated plants and control. However, fresh weight of plants treated with 10^{-4} M SA was significantly higher than the other two concentrations. Within each salinity level, SA application did not have significant effects on the measured characteristics. Based on these results, under this experimental condition, SA acid did not improve the salt tolerance of tomato. However, lower concentrations of SA needs to be evaluated.

Zahra *et al*. (2010a) planted tomato seeds in pots containing perlite were put in a growth chamber under controlled conditions of 27 ± 2^{0}C and 23 ± 2^{0}C temperature,

16 hour lightness and 8 hour darkness, 15 lux light intensity and 75% humidity; NaCl concentration of 0, 25, 50, 75 and 100 mM and salicylic acid concentration of 0, 0.5, 1 and 1.5 mM were used. Salinity increases the soluble sugar in leaf and root tissues, and salicylic acid decreases it. The leaf protein level decreased because of salinity effect, but salicylic acid could increase it. In the root, salinity increases protein, but salicylic acid with 1.5 mM concentration decreases it. Salinity increases the proline level in leaf and root, and salicylic acid did not significantly change in low salinity levels.

Tomato seeds planted by Zahra *et al*. (2010b) in pots containing perlite in a growth chamber under controlled conditions of 27 ± 2^0C and 23 ± 2^0C temperature, 16 hours lightness and 8 hours darkness respectively, 15 Klux light intensity and 75% humidity; NaCl concentration of 0, 25, 50, 75 and 100 mM and salicylic acid concentration of 0, 0.5, 1 and 1.5 mM. Results show that germination was decreased with salinity increasing. At low levels of salinity, SA leads to decrease in germination and had no effect in high levels of salinity. The length of shoots was not affected by salinity but decrease with increase in SA concentration. Low salinity concentrations led to significant increase in root length and high concentrations don't have significant difference with control. SA also had no effect on it. The highest amount of a, b, c and total chlorophyll and carotenoid was show in 50 mM salinity levels.

Yildirim and Dursun (2009) conducted an experiment to determine the effect of foliar salicylic acid (SA) applications on fruit quality, growth and yield of tomato under greenhouse conditions. In the study, fruit diameter, fruit length, fruit weight, fruit number per plant, Vitamin C, pH, Total Soluble Solids (TSS), titratable acidity (TA), stem diameter, leaf dry matter ratio, chlorophyll content, early yield and total yield were determined. Tomato plants were treated with foliar SA applications at different concentrations (0.00, 0.25, 0.50 and 1.00 mM). SA was applied with spraying four times during the vegetation at 10-days interval two weeks after planting. In the study, it was determined that foliar

applications of SA showed positive effect on some fruit characteristics, plant growth, chlorophyll content in leaves, early yield and total yield. SA treatments had no effect on pH, AA and TA of tomato. Total soluble solids (TSS) increased with foliar SA applications. The greatest stem diameter, leaf dry matter and chlorophyll content were obtained from 0.50 mM SA treatment. SA treatments increased the early yield of tomato compared to the control. The yield of tomato was significantly influenced by foliar SA applications. The highest yield occurred in 0.50 mM SA treatment. According to the results, applications of 0.50 mM SA should be recommended in order to improve yield.

Two field experiments were conducted by Mady (2009) to study the effect of foliar application with 50 and 100 ppm of salicylic acid (SA) and vitamin E and their combination on some growth aspects, photosynthetic pigments, minerals, endogenous phytohormones, flowering, fruiting and fruit quality of tomato cv. Super strain B. Plants were sprayed two times at 30 and 45 days after transplanting. Results indicated that, different applied treatments significantly increased all studied growth parameters as well as number of branches and leaves per plant, leaf area per plant and leaves dry weight as well. In addition, chemical composition of minerals and some bioconstituents such as carbohydrates, vitamin C, total soluble solids in tomato fruits were also increased at the same treatments. Therefore, the present study strongly admit the use of salicylic acid and vitamin E as foliar application not only increased early and total yields but also getting a good fruit quality as well.

The above cited reviews revealed that variety and salicylic acid greatly affect the growth and as well as the yield of tomato. But the literature on the effects of salicylic acid on different variety of tomato have not been well defined and have no definite conclusion in this aspects under the agro climatic condition of Bangladesh.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted to find out the effect of salicylic acid on growth, yield and quality of tomato. The materials and methods includes for this experiment are a short description of the experimental site, climatic and soil condition, materials used for the experiment, design of the experiment, data collection and analysis procedure. The details materials and methods for this experiment have been presented in this chapter under the following headings-

3.1 Experimental period

The experiment was conducted in field condition during the period from November 2014 to March 2015.

3.2 Experimental site

The experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh. The location of the site is $23^0 74^/$N latitude and $88^0 35^/$E longitude with an elevation of 8.2 meter from sea level.

3.3 Characteristics of soil

The soil of the experimental field belongs to the Tejgaon series under the Agroecological Zone, Madhupur Tract (AEZ- 28) and the general soil type is Shallow Red Brown Terrace soil. A composite sample was made by collecting soil from several spots of the field at a depth of 0-15 cm before the conduction of the experiment. The soil was having a texture of silty clay with pH and organic matter 6.1 and 1.13, respectively. The results showed that the soil composed of 27% sand, 43% silt and 30% clay, which have been presented in Appendix I.

3.4 Climatic condition

The climatic condition of experimental site is subtropical and characterized by three distinct seasons, the post-monsoon from November to February and the

pre-monsoon period or hot season from March to April and the monsoon period from May to October. The monthly average temperature, humidity and rainfall during crop growing period were collected from Weather Yard, Bangladesh Meteorological Department, and presented in Appendix II. During the experimental period the maximum temperature (27.1^0C) was recorded from February 2015 and the minimum temperature (12.4^0C) was recorded from January 2015, the highest relative humidity (78%) was observed from November 2014, whereas the lowest relative humidity (67%) and the highest rainfall (30 mm) was recorded in February, 2015.

3.5 Treatment of the experiment

The experiment comprised of two factors

Factor A: Different tomato varieties (2 varieties)

i) V_1: Ratan

ii) V_2: Mintoo hybrid

Factors B: Different levels of salicylic acid -SA (4 levels)

i) SA_0: 0 mM SA (control)

ii) SA_1: 0.1 mM SA

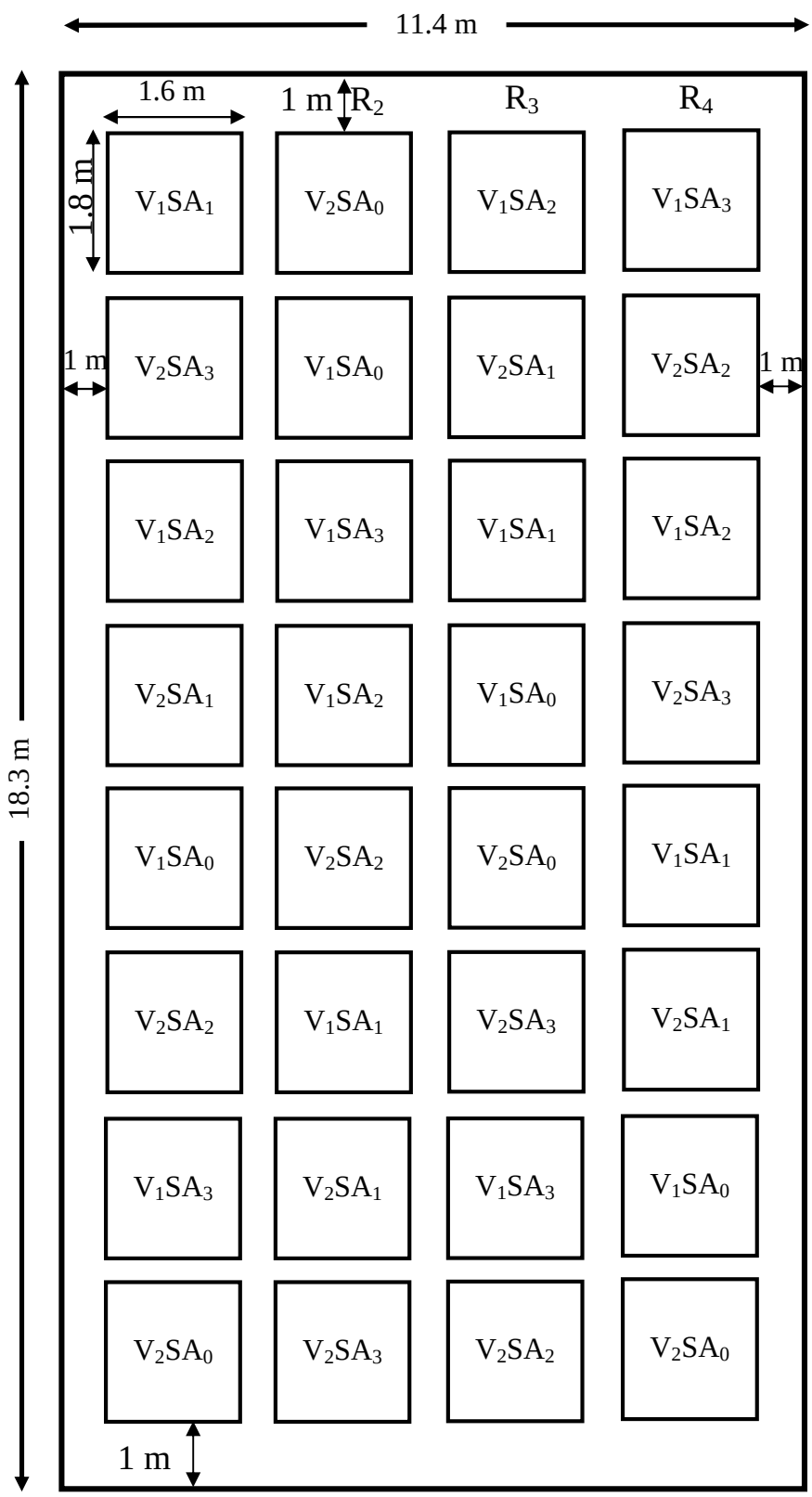
iii) SA_2: 0.2 mM SA

iv) SA_3: 0.3 mM SA

There were in total 8 (2×4) treatment combinations such as V_1SA_0, V_1SA_1, V_1SA_2, V_1SA_3, V_2SA_0, V_2SA_1, V_2SA_2 and V_2SA_3.

3.6 Experimental design and layout

The two factors experiment was laid out in a Randomized Complete Block Design (RCBD) with four replications. The experimental area was divided into four equal blocks containing 8 plots in a block where 8 treatment combinations were allotted randomly. There were 32 unit plots altogether with the size of 1.8 m × 1.6 m. The distance between two blocks and two plots were 1.0 m and 0.5 m, respectively. The layout of the experiment is presented in Figure 1.



Plot size: 1.8 m × 1.6 m

Plot spacing: 50 cm

Between replication: 1.0 m

Treatment

Factor A: Different tomato varieties (2 varieties)

i) V_1: Ratan

ii) V_2: Mintoo hybrid

Factors B: Different levels of salicylic acid -SA (4 levels)

i) SA_0: 0 mM SA (control)

ii) SA_1: 0.1 mM SA

iii) SA_2: 0.2 mM SA

iv) SA_3: 0.3 mM SA

Figure 1. Layout of the experimental plot

3.7 Preparation of the main field

The selected experimental plot was opened in the November 04, 2014 with a power tiller, and left exposed to the sun for a week. Subsequently ploughing cross ploughing was done five times with a country plough followed by laddering to make the land suitable for transplanting of tomato seedlings. All weeds, stubbles and residues were removed from the field. Finally, a good tilth was achieved for transplanting of tomato seedlings. The soil was treated with insecticides (Cinocarb 3G @ 4 kg/ha) at the time of final land preparation to protect young plants from the attack of soil inhibiting insects such as cutworm, mole cricket etc.

3.8 Application of manure and fertilizers

Manures and fertilizers were applied to the experimental plot as per the recommended fertilizer doses of tomato of Banglaesh Agriculture Research Institute (BARI). The fertilizers N, P and K were used in the form of urea, TSP and MoP, respectively and were applied following the below mentioned application procedure (BARI, 2014).

Table 1. Dose and method of application of fertilizers in tomato field

Fertilizers and Manures	Dose/ha	Application (%)			
		Basal	10 DAT	30 DAT	50 DAT
Cowdung	10 tonnes	100	--	--	--
Urea	300 kg	--	33.33	33.33	33.33
TSP	200 kg	100	--	--	--
MoP	220 kg	50	--	25.00	25.00

The entire amount of cowdung and TSP were applied as basal dose at the time of final land preparation and properly mixed with soil. The total amount of urea was applied carefully in three equal installments at 10, 25 and 40 day after transplanting (DAT). Half amounts of MoP were applied during final land preparation and rest amount of MoP were applied carefully in two equal installments at 25 and 40 DAT.

3.9 Seed collection

Tomato variety Ratan and Mintoo hybrid were used as plating materials for this experiment. Variety Ratan was developed by BARI, Joydebpur, Gazipur and it was a high yielding variety. Mintoo hybrid was developed by Lal Teer Seed company. The seeds of Ratan and Mintoo hybrid were collected from BARI, Gazipur and Siddique bazaar, Dhaka, respectively.

3.10 Raising of seedlings

The seedlings of two tomato varieties were raised at the Laboratory Farm, SAU, Dhaka under special care in a 3.0 m × 1.0 m size seed bed. The soil of the seed bed was well ploughed with a spade and prepared into loose friable dried masses and to obtain good tilth to provide a favorable condition for the vigorous growth of young seedlings. Weeds, stubbles and dead roots of the previous crop were removed. The seedbed was dried in the sun to destroy the soil insect and protect the young seedlings from the attack of damping off disease. To control damping off disease Cupravit fungicide were applied. Decomposed cowdung was applied @ 10 t/ha for the preparation of seedbed for seedling raising. Ten (10) grams of seeds from each variety were sown in seedbed on November 14, 2014. After sowing, the seeds were covered with the finished light soil. At the end of germination shading was provided with bamboo mat (chatai) over the seedbed to protect the young seedlings from scorching sunshine and heavy rainfall. Light watering, weeding was done as and when necessary to provide seedlings with ideal condition for growth.

3.11 Transplanting of seedlings

Healthy and uniform seedlings were transplanted in the experimental plots on 18 December, 2014. The seedlings were uploaded carefully from the seed bed to avoid damage to the seedlings roots. To minimize the damage to the roots of seedlings, the seed beds were watered one hour before uprooting the seedlings. Transplanting was done in the afternoon and the seedlings were watered immediately after transplanting. Seedlings were sown in the plot with

maintaining distance between row to row was 60 cm and plant to plant was 40 cm. As a result 12 seedlings were accommodated in each plot according to the plot size of 1.8 m × 1.6 m. The young transplanted seedlings were shaded by banana leaf sheath during day to protect them from scorching sunshine up to 7 days until they were set in the soil. They (transplants) were kept open at night to allow them receiving dew. A number of seedlings were also planted in the border of the experimental plots for gap filling if necessary.

3.12 Collection, preparation and application of salicylic acid

Plant growth regulator salicylic Acid (SA) was collected from Hatkhola Road, Dhaka. A 1000 ppm stock solution of SA was prepared by dissolving 1 g of SA in a small quantity of ethanol prior to dilution with distilled water in one litre containing volumetric flask. The stock solution was used to prepare the required concentration for different treatment i.e. 10 ml of this stock solution was diluted in 1 litre of distilled water to get 0.1 mM SA solution. In a similar way, 20 and 30 ml stock solutions were diluted to 1 litre of distilled water to get 0.2 mM SA and 0.3 mM SA solution. Control solution also prepared only by adding a small quantity of ethanol with distilled water. Tween 20 detergent was used as surfactant to prevent dropout of salicylic acid solution from leaves and SA was applied as per treatment at two times 15, and 35 days after transplanting (DAT) by a mini hand sprayer.

3.13 Intercultural operation

Various intercultural operations such as gap filling, weeding, earthing up, irrigation, pest and disease control etc. were accomplished for better growth and development of the tomato seedlings.

3.13.1 Gap filling

The transplanted tomato seedlings in the experimental plot were kept under careful observation. Very few number seedlings were damaged after transplanted and such seedling were replaced by new seedlings from the same stock. Replacement was done with healthy seedling having a boll of earth which was

also planted on the same date by the side of the unit plot. The transplants were given shading and watering for 7 days for their proper establishment.

3.13.2 Weeding

The hand weeding was done 10, 25 and 40 DAT tomato seedlings to keep the plots free from weeds.

3.13.3 Earthing up

Earthing up was done at 25 and 40 DAT of tomato seedlings on both sides of rows by taking the soil from the space between the rows by a small spade.

3.13.4 Irrigation

Light watering was given by a watering can at every morning and afternoon after seedling transplanting and it was continued for a week for rapid and well establishment of the transplanted seedlings. Beside this a routine irrigation was given at 3 days intervals.

3.13.5 Pest and disease control

Insect infestation was a serious problem during the period of establishment of tomato seedlings in the field. Cirocarb 3G were applied during final land preparation. Few young plants were damaged due to attack of mole cricket and cut worm. Cut worms were controlled both mechanically and spraying Darsban 29EC @ 3%. Some plants were infected by *Alternaria* leaf spot diseases caused by *Alternaria spp.* and for preventing disease Rovral @ 2 g per liter of water was sprayed in the field. The diseased leaves were also collected from the infested plant and removed from the field.

3.14 Harvesting

Harvesting of all the tomato was not possible on a certain or particular date because the fruits initiation as well as ripening in different plants were not uniform. Fruits were harvested at 5 days interval when they were attained slightly reddish color. Harvesting was started from February, 2015 and was continued up to March, 2015.

3.15 Data collection

Data were collected from 5 plants of each unit plot.

3.15.1 Plant height

Plant height was measured from plant of each unit plot from the ground level to the tip of the longest stem and mean value was calculated and expressed in cm. Plant height was recorded at 10 days interval starting from 20 DAT and continued upto 60 DAT and at final harvest to observe the growth rate of plants.

3.15.2 Number of branches per plant

The total number of branches per plant was counted from plant of each unit plot. Data were recorded was recorded at 10 days interval starting from 20 DAT and continued upto 60 DAT and at final harvest.

3.15.3 Leaf area

Leaf area (LA) was determined from plant samples by using an automatic leaf area meter (Model LI-3100, Li-COR, Lincoln, NE, USA) immediately after removal of leaves from plants to avoid rolling and shrinkage. Leaf area was recorded at 10 days interval starting from 20 DAT and continued upto 60 DAT and at final harvest and expressed in cm^2.

3.15.4 Days from transplanting to 1st flowering

Days required from transplanting to initiation of flowering was counted from the date of transplanting to the initiation of 1st flower and was recorded.

3.15.5 Number of flower clusters per plant

The number of flower clusters was counted from the plants of each unit plot and the numbers of flower clusters produced per plant were recorded.

3.15.6 Number of flowers per cluster

The number of flower was counted from the plants of each unit plot and number of flowers produced per cluster was recorded on the basis of flowers per cluster.

3.15.7 Number of flowers per plant

The number of flower per plant was counted from the plants of each unit plot and the number of flowers per plant was recorded.

3.15.8 Number of fruits per cluster

The number of fruits per cluster was counted from the plants of each unit plot and the number of fruits per clusters was recorded.

3.15.9 Number of fruits per plant

The number of fruits per plant was counted from the plant of each unit plot and the number of fruits per plant was recorded.

3.15.10 Percentage of fruit setting

Percentage of fruit setting was calculated by using the following formula and recorded from the plant of each unit plot and expressed in %.

$$\text{Percentage of fruit setting} = \frac{\text{Number of fruits per plant}}{\text{Number of flowers per plant}} \times 100$$

3.15.11 Length of fruit

The length of fruit was measured with a measure scale from the neck of the fruit to the bottom of 5 selected marketable fruits from each plot and there average was taken and expressed in cm.

3.15.12 Diameter of fruit

Diameter of fruit was measured at the middle portion of 5 selected marketable fruits from each plot with a slide calipers and there average was taken and expressed in cm.

3.15.13 Dry matter content in plant

After harvesting, 150 g plant sample previously sliced into very thin pieces were put into envelop and placed in oven maintained at 70^0C for 72 hours. The sample was then transferred into desiccators and allowed to cool down at room

temperature. The final weight of the sample was taken. The dry matter contents in plant were computed by simple calculation from the weight recorded by the following formula and expressed in %.

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

3.15.14 Dry matter content in fruit

After harvesting, randomly selected 150 g fruit sample previously sliced into very thin pieces were put into envelop and placed in oven maintained at 60^0C for 72 hours. The sample was then transferred into desiccators and allowed to cool down at room temperature. The final weight of the sample was taken. The dry matter contents in fruit were computed by simple calculation from the weight recorded by the following formula and expressed in %.

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

3.15.15 Weight of individual fruit

Among the total number of fruits during the period from first to final harvest the fruits, except the first and final harvest, was considered for determining the individual fruit weight by the following formula and expressed in g.

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

3.15.16 Yield per plant

Yield of tomato per plant was recorded as the whole fruit per plant harvested in different time and was expressed in kilogram.

3.15.17 Yield per hectare

The weight of fruits from each plot was measured using a weighing balance and converted into hectare and was expressed in ton.

3.15.18 Total Soluble Solids-TSS

Total soluble solids content of tomato pulp was estimated by using Abbes, Refractometer. A drop of tomato juice squeezed from the fruit pulp on the prism of the refractometer. Percent TSS was obtained from direct reading of the instrument. Temperature corrections were made by using the methods described by Ranganna (1994).

3.15.19 β-Caroten

Carotenoids exhibit certain absorption spectrum exposed to specific wave length. An absorption spectrum depends on the unique absorption characteristics of a compound. These absorption properties will be utilized to make quantitative determination of carotene.

Procedure

Two g sample (tomato) was taken in a clean mortar. The sample was then grinded in the mortar with 80% acetone in presence of quartz sand (very small amount) and calcium carbonate (0.5 mg). The resulting colored solution was then filtered by continuous washing with 80% acetone. The filtered was collected in a 50 ml volumetric flask and made to a final volume of 50 ml with 80% acetone. The filtered colored solution was carefully transferred to a separatory funnel and 20 ml petroleum ether was added to the solution. The funnel was shaken and placed for 20 minutes. The lower aqueous phase was discarded very carefully keeping the ether layer. To the ether layer about 5 ml ethanol containing 5% KOH was added and shaken well and kept about 10 hours for complete saponification. Then, water was added gently to the saponified solution. By adding water, two distinct phases were visible. The lower aqueous phase was discarded carefully. The upper phase containing β carotene was washed with water several times for complete remove of KOH. The ether layer containing β carotene was transferred to a 25 ml volumetric flask and the flask was volume upto the mark by adding petroleum ether. From the petroleum ether extract, β carotene was estimated with the spectrophotometer at 451 nm wave

length against petroleum ether as blank, by using the equation proposed by Shiraishi (1972).

$$\beta \text{ carotene } (\mu g/g) = [3.984(OD_{451})\ V]/1000\ W$$

Where,

V = Final volume of the petroleum ether β carotene extract (ml)

W = Fresh weight of the sample taken (g)

OD_{451} = Spectrophotometer reading at 451 nm wave length.

For evidence of the study, the calculated results of β carotene were simply multiplied by 100.

3.15.20 Reducing sugar

Sugar content of tomato fruits pulp was determined to the method of Lane and Eynon (1923) by the following procedure:

a) Standardization of Fehling's solution

Fifty (50) ml of both Fehling's solution A and Fehling's solution B were mixed together in a beaker. Ten millimeter of the mixed solution was pipetted into a 250 ml conical flask and 25 ml distilled water was added to it standard sugar solution was taken in a burette. The conical flask containing mixed solution was heated on a hot plate. When the solution began to boil, three drops of methylene blue indicator solution was added to it without removing the flask from the hot plate. Mixed solution was titrated by standard sugar solution. The end point was indicated by depolarization of the indicator. Fehling's factor was calculated by using the following formula-

$$\text{Factor for Fehling's solution (g of invert sugar)} = (\text{Titre} \times 2.5)/1000$$

b) Preparation of sample

Twenty gram of fresh tomato fruit pulp was taken in a 100 ml beaker an then it was transferred to a blender machine and homogenized with distilled water.

After blending it was made up to the mark with distilled water. The pulp solution was filtered. One hundred milliliter of filtrate was taken in a 250 ml volumetric flask. Five milliliter of 45% neutral lead acetate solution was added to it and then shaken and waited for 10 minute. Five milliliter of 22% potassium oxalate solution was further added to the flask and the volume was made up to the mark with distilled and filtered.

Ten milliliter of mixed Fehling's solution was taken in a 250 ml conical flask and 50 ml distilled water was added to it. Filtrated pulp solution was taken in a burette. Conical flask containing the mixed Fehling's solution was heated on a hot plate. Three to five drops of methylene blue indicator were added to the flask when boiling started, and titrate with solution taken in the burette. The end point was indicated by decoloruization of indicator. Percentage of reducing sugar was calculated according to the following formula-

$$\text{Reducing sugar content (\%)} = \frac{F \times D \times 100}{T \times W \times 100}$$

Where, Fehling's factor

D = Dilution

T = Titre and

W = Weight or volume of the sample

Titration of total invert sugar

Fifty (50) milliliter purified solution (filtrate) was taken in a 250 ml conical flask. Five gram citric acid and 50 ml distilled water were added to it. The conical flask containing sugar solution was boiled for inversion of sucrose and finally cooled. Then the solution was transferred to a 250 ml volumetric flask and neutralized by 1N NaOH using phenolphthalein indicator. The volume was made up to the mark with distilled water. Then the mixed Fehling's solution was titrated using similar procedure followed as in case of invert sugar (reducing

sugar) mentioned earlier. The percentage of total invert sugar was calculated by using the formula used in case of reducing sugar.

3.15.21 Non-reducing sugar

Non-reducing sugar of tomato fruit were computed by simple calculation using the following formula:

% non-reducing sugar = % total invert sugar - % reducing sugar

3.15.22 Total sugar

Total sugar of tomato fruit were computed by simple calculation using the following formula:

% total sugar = % reducing sugar + % non-reducing sugar

3.16 Statistical analysis

The data obtained for different parameters were statistically analyzed by using MSTAT-C computer package program to find out the significance of the differences for the different variety and levels of salicylic acid on yield and yield contributing characters of tomato. The mean values of all the recorded parameters were evaluated and analysis of variance was performed by the ‘F’ (variance ratio) test. The significance of the difference among the treatment combinations of means was estimated by Duncan’s Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to find out the effect of salicylic acid (SA) on growth, different yield contributing characters, yield and quality of tomato. Data on different growth characters, yield attributes, yield and quality of tomato was recorded. The analyses of variance (ANOVA) of the data on different parameters have been presented in Appendix III-VIII. The results have been discussed with the help of different tables and graphs and possible interpretations given under the following headings:

4.1 Plant height

Plant height of tomato showed statistically significant variation due to different varieties at 20, 30, 40, 50, 60 days after transplanting (DAT) and final harvest (Appendix III). Data revealed that at 20, 30, 40, 50, 60 DAT and final harvest, the taller plants (18.13, 43.24, 64.01, 78.71, 87.01 and 89.68 cm, respectively) was found from V_2 (Mintoo hybrid), whereas the shorter plants (17.13, 40.00, 59.97, 74.38, 82.55 and 86.25 cm, respectively) was recorded from V_1 (Ratan) at 20, 30, 40, 50, 60 DAT and final harvest (Figure 2). Generally different varieties produced different plant height based on their varietal characters and environmental factor also influences the plant height. Although plant height of tomato depended upon their differences in genotypic characters, input requirements and response, growth process and off course the prevailing environmental conditions during the growing season but variety is the key component for producing different size of plant. Different earlier experiment reported that different variety produced different size of tomato plant. Improved variety is the first and foremost requirement for initiation and accelerated crop production program (Ojo *et al*., 2013). Biswas *et al*. (2015) reported that plant height of tomato varied significantly due to different variety and the highest plant height of 101.3 cm was recorded from BARI Tomato-7.

Different levels of salicylic acid varied significantly in terms of plant height of tomato at 20, 30, 40, 50, 60 DAT and final harvest (Appendix III). At 20, 30, 40, 50, 60 DAT and final harvest, the tallest plant (18.51, 43.54, 64.44, 80.59, 87.78 and 90.99 cm, respectively) was recorded from SA_3 (0.3 mM SA) which was statistically similar (18.17, 43.41, 64.14, 80.10, 87.70 and 90.34 cm, respectively) to SA_2 (0.2 mM SA) and closely followed (17.27, 40.80, 62.09, 76.25, 84.47 and 87.49 cm, respectively) by SA_1 (0.1 mM SA), while the shortest plant (16.56, 38.74, 57.28, 69.24, 79.17 and 83.04 cm, respectively) was found from SA_0 (control i.e., 0 mM SA) at 20, 30, 40, 50, 60 DAT and final harvest (Figure 3). Singh and Singh (2016) reported that the exogenous applications of salicylic acid improved the growth parameters of tomato.

Statistically significant variation was recorded for the interaction effect of different varieties and levels of salicylic acid on plant height of tomato at 20, 30, 40, 50, 60 DAT and final harvest (Appendix III). At 20, 30, 40, 50, 60 DAT and final harvest, the tallest plant (20.05, 46.38, 67.86, 85.09, 92.27 and 94.82 cm, respectively) was observed from V_2SA_3 (Mintoo hybrid with 0.3 mM SA) and the shortest plant (15.92, 36.26, 55.04, 68.24, 78.49 and 83.96 cm, respectively) from V_1SA_0 (Ratan with 0 mM SA) treatment combination (Table 2).

4.2 Number of branches per plant

Different varieties of tomato varied significantly in terms of number of branches per plant at 20, 30, 40, 50, 60 DAT and final harvest (Appendix IV). At 20, 30, 40, 50, 60 DAT and final harvest, the maximum number of branches per plant (3.10, 7.92, 13.88, 15.48, 16.38 and 17.17, respectively) was recorded from V_2, whereas the minimum number of branches per plant (2.73, 6.65, 12.24, 13.65, 14.65 and 15.65) was found from V_1 at 20, 30, 40, 50, 60 DAT and final harvest, respectively (Figure 4). Although number of branches per plant is a genetical characters but the management practices also influences the number of branches per plant but varieties itself also manipulated it. Biswas *et al*. (2015) recorded maximum number of branches (16.0/plant) from BARI Tomato-7

Table 2. Interaction effect of different varieties and levels of salicylic acid on plant height of tomato at different days after transplanting (DAT) and final harvest

Treatment	Plant height (cm) at					
	20 DAT	**30 DAT**	**40 DAT**	**50 DAT**	**60 DAT**	**Final harvest**
V_1SA_0	15.92 c	36.26 d	55.04 d	68.24 d	78.49 d	83.96 de
V_1SA_1	17.19 bc	39.94 c	60.04 c	74.97 c	83.02 bc	85.85 cde
V_1SA_2	18.43 ab	43.11 abc	63.78 b	78.22 bc	85.39 b	88.04 cd
V_1SA_3	16.97 bc	40.70 bc	61.01 bc	76.10 c	83.30 bc	87.15 cd
V_2SA_0	17.20 bc	41.21 bc	59.53 c	70.23 d	79.86 cd	82.12 e
V_2SA_1	17.36 bc	41.66 bc	64.14 b	77.53 c	85.92 b	89.13 bc
V_2SA_2	17.92 bc	43.70 ab	64.49 b	81.98 ab	90.00 a	92.64 ab
V_2SA_3	20.05 a	46.38 a	67.86 a	85.09 a	92.27 a	94.82 a
$LSD_{(0.05)}$	**1.845**	**3.135**	**3.332**	**4.086**	**4.088**	**4.352**
Level of significance	*	*	*	*	*	*
CV(%)	**7.12**	**5.12**	**6.66**	**3.63**	**4.28**	**5.36**

In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 5% level of probability

* Significant at 0.05 level of probability

V_1: Ratan

V_2: Mintoo hybrid

SA_0: 0 mM SA (control)

SA_1: 0.1 mM SA

SA_2: 0.2 mM SA

SA_3: 0.3 mM SA

Statistically significant variation was recorded due to different levels of salicylic acid on number of branches per plant of tomato at 20, 30, 40, 50, 60 DAT and final harvest (Appendix IV). At 20, 30, 40, 50, 60 DAT and final harvest, the maximum number of branches per plant (3.28, 7.78, 13.85, 15.63, 16.38 and 17.30, respectively) was found from SA_3 which was statistically similar (3.20, 7.60, 13.80, 15.18, 16.13 and 16.95, respectively) to SA_2 and closely followed (2.93, 7.15, 13.20, 14.63, 15.60 and 16.35, respectively) by SA_1, while the minimum number of branches per plant (2.25, 6.63, 11.38, 12.83, 13.95 and 15.05, respectively) was observed from SA_0 at 20, 30, 40, 50, 60 DAT and final harvest (Figure 5).

Interaction effect of different varieties and levels of salicylic acid showed statistically significant variation in terms of number of branches per plant of tomato at 20, 30, 40, 50, 60 DAT and final harvest (Appendix IV). At 20, 30, 40, 50, 60 DAT and final harvest, the maximum number of branches per plant (3.50, 8.35, 15.05, 17.30, 18.05 and 18.90, respectively) was recorded from V_2SA_3, whereas the minimum number of branches per plant (2.20, 6.10, 10.95, 12.50, 14.10 and 15.25, respectively) was found from V_1SA_0 treatment combination (Table 3).

4.3 Leaf area

Significant variation was recorded due to different varieties on leaf area of tomato at 20, 30, 40, 50 and 60 DAT (Appendix V). At 20, 30, 40, 50 and 60 DAT, the maximum leaf area (55.80, 83.76, 131.48, 160.14 and 162.83 cm^2, respectively) was found from V_2 and the minimum leaf area (50.75, 79.99, 118.08, 150.03 and 153.70 cm^2, respectively) from V_1 at 20, 30, 40, 50 and 60 DAT, respectively (Table 4).

Different levels of salicylic acid showed statistically significant variation in terms of leaf area of tomato at 20, 30, 40, 50 and 60 DAT (Appendix V). At 20, 30, 40, 50 and 60 DAT, the maximum leaf area (55.48, 85.84, 133.34, 170.39 and 173.34 cm^2, respectively) was observed from SA_3 which was statistically

Table 3. Interaction effect of different varieties and levels of salicylic acid on number of branches per plant of tomato at different days after transplanting (DAT) and final harvest

Treatment	Number of branches per plant at					
	20 DAT	**30 DAT**	**40 DAT**	**50 DAT**	**60 DAT**	**Final harvest**
V_1SA_0	2.20 d	6.10 c	10.95 f	12.50 e	14.10 cd	15.25 d
V_1SA_1	2.60 c	6.20 c	12.30 de	13.75 de	14.75 cd	15.75 cd
V_1SA_2	3.00 b	7.10 b	13.05 c	14.40 cd	15.05 c	15.90 cd
V_1SA_3	3.05 b	7.20 b	12.65 cd	13.95 d	14.70 cd	15.70 cd
V_2SA_0	2.25 d	7.15 b	11.80 e	13.15 de	13.80 d	14.85 d
V_2SA_1	3.25 ab	8.10 a	14.10 b	15.50 bc	16.45 b	16.95 bc
V_2SA_2	3.40 a	8.10 a	14.55 ab	15.95 b	17.20 ab	18.00 ab
V_2SA_3	3.50 a	8.35 a	15.05 a	17.30 a	18.05 a	18.90 a
$LSD_{(0.05)}$	**0.283**	**0.536**	**0.701**	**1.264**	**1.125**	**1.445**
Level of significance	*	*	*	*	**	**
CV(%)	**6.64**	**5.01**	**3.65**	**5.90**	**4.93**	**5.98**

In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 5% level of probability

** Significant at 0.01 level of probability; * Significant at 0.05 level of probability

V_1: Ratan

V_2: Mintoo hybrid

SA_0: 0 mM SA (control)

SA_1: 0.1 mM SA

SA_2: 0.2 mM SA

SA_3: 0.3 mM SA

Table 4. Effect of different varieties and levels of salicylic acid on leaf area of tomato at different days after transplanting (DAT)

Treatment	Leaf area (cm^2) at				
	20 DAT	**30 DAT**	**40 DAT**	**50 DAT**	**60 DAT**
Different tomato varieties					
V_1	50.75 b	79.99 b	118.08 b	150.03 b	153.70 b
V_2	55.80 a	83.76 a	131.48 a	160.14 a	162.83 a
$LSD_{(0.05)}$	**2.048**	**2.441**	**6.305**	**6.000**	**6.101**
Level of significance	**	**	**	**	**
CV(%)	**5.23**	**4.05**	**6.87**	**5.26**	**5.24**
Different levels of salicylic acid					
SA_0	49.41 b	75.77 c	108.12 b	126.54 c	129.54 c
SA_1	53.01 a	81.51 b	125.92 a	157.04 b	160.33 b
SA_2	55.19 a	84.38 ab	131.75 a	166.39 a	169.85 a
SA_3	55.48 a	85.84 a	133.34 a	170.39 a	173.34 a
$LSD_{(0.05)}$	**2.896**	**3.451**	**8.916**	**8.485**	**8.628**
Level of significance	**	**	**	**	**
CV(%)	**5.23**	**4.05**	**6.87**	**5.26**	**5.24**

In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 5% level of probability

** Significant at 0.01 level of probability;

V_1: Ratan

V_2: Mintoo hybrid

SA_0: 0 mM SA (control)

SA_1: 0.1 mM SA

SA_2: 0.2 mM SA

SA_3: 0.3 mM SA

similar (55.19, 84.38, 131.75, 166.39 and 169.85 cm^2, respectively) to SA_2 and followed (53.01, 81.51, 125.92, 157.04 and 160.33 cm^2, respectively) by SA_1, while the minimum leaf area (49.41, 75.77, 108.12, 126.54 and 129.54 cm^2, respectively) from SA_0 at 20, 30, 40, 50 and 60 DAT, respectively (Table 4).

Statistically significant variation was recorded due to the interaction effect of different varieties and levels of salicylic acid in terms of leaf area of tomato at 20, 30, 40, 50 and 60 DAT (Appendix V). At 20, 30, 40, 50 and 60 DAT, the maximum leaf area (59.83, 90.11, 150.54, 181.77 and 184.39 cm^2, respectively) was observed from V_2SA_3, whereas the minimum leaf area (48.39, 75.05, 106.40, 123.69 and 126.36 cm^2, respectively) was found from V_1SA_0 treatment combination (Table 5).

4.4 Days from transplanting to 1st flowering

Statistically significant variation was recorded in terms of days from transplanting to 1st flowering of tomato for different varieties (Appendix VI). The lowest (42.88) days from transplanting to 1st flowering was recorded from V_2, whereas the highest (46.31) days was found from V_1 (Table 6).

Different levels of salicylic acid showed statistically significant variation in terms of days from transplanting to 1st flowering of tomato (Appendix VI). The lowest (43.25) days from transplanting to 1st flowering was recorded from SA_3 which was statistically similar (43.74 and 44.63) to SA_2 and SA_1, while the highest (46.75) days from transplanting to 1st flowering was observed from SA_0 (Table 6). Yildirim and Dursun (2009) reported that SA treatments increased the early yield of tomato compared to the control.

Days from transplanting to 1st flowering showed statistically significant variation due to the interaction effect of different varieties and levels of salicylic acid in terms of (Appendix VI). The lowest (40.25) days from transplanting to 1st flowering was found from V_2SA_3 and the highest (48.00) days from transplanting to 1st flowering was recorded from V_1SA_0 treatment combination (Table 7).

Table 5. Interaction effect of different varieties and levels of salicylic acid on leaf area of tomato at different days after transplanting (DAT)

Treatment	Leaf area (cm^2) at				
	20 DAT	**30 DAT**	**40 DAT**	**50 DAT**	**60 DAT**
V_1SA_0	48.39 d	75.05 e	106.40 e	123.69 d	126.36 d
V_1SA_1	51.53 cd	80.11 cde	120.13 cd	152.31 c	156.12 c
V_1SA_2	51.94 cd	83.24 bc	129.65 bc	159.44 c	163.65 bc
V_1SA_3	51.14 cd	81.56 bcd	116.14 de	159.00 c	162.30 c
V_2SA_0	50.44 cd	76.49 de	109.83 de	129.39 d	132.71 d
V_2SA_1	54.50 bc	82.90 bc	131.71 bc	161.78 bc	164.53 bc
V_2SA_2	58.43 ab	85.53 ab	133.84 b	173.33 ab	176.05 ab
V_2SA_3	59.83 a	90.11 a	150.54 a	181.77 a	184.39 a
$LSD_{(0.05)}$	**4.096**	**4.881**	**12.61**	**12.00**	**12.20**
Level of significance	*	*	**	*	*
CV(%)	**5.23**	**4.05**	**6.87**	**5.26**	**5.24**

In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 5% level of probability

** Significant at 0.01 level of probability; * Significant at 0.05 level of probability

V_1: Ratan

V_2: Mintoo hybrid

SA_0: 0 mM SA (control)

SA_1: 0.1 mM SA

SA_2: 0.2 mM SA

SA_3: 0.3 mM SA

Table 6. Effect of different varieties and levels of salicylic acid on yield contributing characters of tomato

Treatment	Days from transplanting to flowering	Number of flower clusters per plant	Number of flowers per cluster	Number of flowers per plant	Number of fruits per cluster	Fruit setting (%)
Different tomato varieties						
V_1	46.31 a	5.82 b	7.03 b	40.94 b	4.47 b	63.81
V_2	42.88 b	6.30 a	7.33 a	46.26 a	4.71 a	64.36
$LSD_{(0.05)}$	**1.218**	**0.188**	**0.164**	**1.940**	**0.138**	**--**
Level of significance	**	**	**	**	**	**NS**
CV(%)	**4.72**	**4.19**	**5.12**	**6.05**	**4.05**	**4.42**
Different levels of salicylic acid						
SA_0	46.75 a	5.65 b	6.95 b	39.27 b	4.30 b	61.89 b
SA_1	44.63 b	6.07 a	7.18 ab	43.69 a	4.63 a	64.68 a
SA_2	43.75 b	6.25 a	7.28 a	45.51 a	4.70 a	64.67 a
SA_3	43.25 b	6.28 a	7.30 a	45.93 a	4.75 a	65.10 a
$LSD_{(0.05)}$	**1.723**	**0.265**	**0.233**	**2.744**	**0.195**	**2.276**
Level of significance	*	**	*	**	**	*
CV(%)	**4.72**	**4.19**	**5.12**	**6.05**	**4.05**	**4.42**

In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 5% level of probability

** Significant at 0.01 level of probability; * Significant at 0.05 level of probability

V_1: Ratan

V_2: Mintoo hybrid

SA_0: 0 mM SA (control)

SA_1: 0.1 mM SA

SA_2: 0.2 mM SA

SA_3: 0.3 mM SA

Table 7. Interaction effect of different varieties and levels of salicylic acid on yield contributing characters of tomato

Treatment	Days from transplanting to flowering	Number of flower clusters per plant	Number of flowers per cluster	Number of flowers per plant	Number of fruits per cluster	Fruit setting (%)
V_1SA_0	48.00 a	5.60 d	7.00 c	39.19 d	4.15 c	59.31 b
V_1SA_1	46.75 ab	5.65 d	7.00 c	39.58 cd	4.55 b	65.36 a
V_1SA_2	44.25 bcd	6.10 bc	7.15 bc	43.63 bc	4.65 b	65.06 a
V_1SA_3	46.25 ab	5.95 cd	6.95 c	41.36 cd	4.55 b	65.48 a
V_2SA_0	45.50 abc	5.70 d	6.90 c	39.35 d	4.45 b	64.47 a
V_2SA_1	42.50 de	6.50 a	7.35 ab	47.79 a	4.70 ab	64.00 a
V_2SA_2	43.25 cd	6.40 ab	7.40 ab	47.39 ab	4.75 ab	64.27 a
V_2SA_3	40.25 e	6.60 a	7.65 a	50.49 a	4.95 a	64.71 a
$LSD_{(0.05)}$	**2.437**	**0.375**	**0.329**	**3.880**	**0.275**	**3.219**
Level of significance	*	*	*	**	*	*
CV(%)	**4.72**	**4.19**	**5.12**	**6.05**	**4.05**	**4.42**

In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 5% level of probability

** Significant at 0.01 level of probability; * Significant at 0.05 level of probability

V_1: Ratan

V_2: Mintoo hybrid

SA_0: 0 mM SA (control)

SA_1: 0.1 mM SA

SA_2: 0.2 mM SA

SA_3: 0.3 mM SA

4.5 Number of flower clusters per plant

Number of flower clusters per plant of tomato varied significantly due to different varieties (Appendix VI). The highest (6.30) number of flower clusters per plant was recorded from V_2, while the lowest (5.82) number of flower clusters per plant was observed from V_1 (Table 6).

Different levels of salicylic acid showed statistically significant variation in terms of number of flower clusters per plant of tomato (Appendix VI). The highest (6.28) number of flower clusters per plant was found from SA_3 which was statistically similar (6.25 and 6.07) to SA_2 and SA_1, whereas the lowest (5.65) number of flower clusters per plant was recorded from SA_0 (Table 6).

Statistically significant variation was recorded due to the interaction effect of different varieties and levels of salicylic acid in terms of number of flower clusters per plant (Appendix VI). The highest (6.60) number of flower clusters per plant was recorded from V_2SA_3 and the lowest (5.60) number of flower clusters per plant was found from V_1SA_0 treatment combination (Table 7).

4.6 Number of flowers per cluster

Number of flowers per cluster of tomato varied significantly due to different varieties (Appendix VI). The highest (7.33) number of flowers per cluster was found from V_2 and the lowest (7.03) number of flowers per cluster was observed from V_1 (Table 6). Biswas *et al*. (2015) reported the maximum number of flowers (6.1/cluster) from BARI Tomato-9.

Different levels of salicylic acid showed statistically significant variation in terms of number of flowers per cluster of tomato (Appendix VI). The highest (7.30) number of flowers per cluster was observed from SA_3 which was statistically similar (7.28 and 7.18) to SA_2 and SA_1, while the lowest (6.95) number of flowers per cluster was recorded from SA_0 (Table 6).

Statistically significant variation was recorded due to the interaction effect of different varieties and levels of salicylic acid in terms of number of flowers per

cluster (Appendix VI). The highest (7.65) number of flowers per cluster was recorded from V_2SA_3, whereas the lowest (6.90) number of flowers per cluster was found from V_2SA_0 treatment combination (Table 7).

4.7 Number of flowers per plant

Number of flowers per plant of tomato varied significantly due to different varieties (Appendix VI). The highest (46.26) number of flowers per plant was recorded from V_2, while the lowest (40.94) number of flowers per plant was observed from V_1 (Table 6).

Different levels of salicylic acid showed statistically significant variation in terms of number of flowers per plant of tomato (Appendix VI). The highest (45.93) number of flowers per plant was found from SA_3 which was statistically similar (45.51 and 43.69) to SA_2 and SA_1, whereas the lowest (39.27) number of flowers per plant was observed from SA_0 (Table 6). Yildirim and Dursun (2009) reported that SA treatments increased the yield contributing charcaters of tomato compared to the control.

Statistically significant variation was recorded due to the interaction effect of different varieties and levels of salicylic acid in terms of number of flowers per plant (Appendix VI). The highest (50.49) number of flowers per plant was observed from V_2SA_3, while the lowest (39.19) number of flowers per plant was recorded from V_1SA_0 treatment combination (Table 7).

4.8 Number of fruits per cluster

Number of fruits per cluster of tomato varied significantly due to different varieties (Appendix VI). The highest (4.71) number of fruits per cluster was found from V_2 and the lowest (4.47) number of fruits per cluster was observed from V_1 (Table 6). Biswas *et al.* (2015) reported the number of fruits (5.0/cluster) from BARI Tomato-9.

Different levels of salicylic acid showed statistically significant variation in terms of number of fruits per cluster of tomato (Appendix VI). The highest

(4.75) number of fruits per cluster was found from SA_3 which was statistically similar (4.70 and 4.63) to SA_2 and SA_1, while the lowest (4.30) number of fruits per cluster was recorded from SA_0 (Table 6). Javaheri *et al*. (2014) reported from earlier experiment that the highest fruit number in cluster obtained by mean of 3.5 in SA_1 (SA at 10^{-2} M).

Statistically significant variation was recorded due to the interaction effect of different varieties and levels of salicylic acid in terms of number of fruits per cluster (Appendix VI). The highest (4.95) number of fruits per cluster was recorded from V_2SA_3, whereas the lowest (4.15) number of fruits per cluster was found from V_1SA_0 treatment combination (Table 7).

4.9 Number of fruits per plant

Number of fruits per plant of tomato varied significantly due to different varieties (Appendix VI). The highest (29.75) number of fruits per plant was observed from V_2, while the lowest (26.09) number of fruits per plant was recorded from V_1 (Figure 6).

Different levels of salicylic acid showed statistically significant variation in terms of number of fruits per plant of tomato (Appendix VI). The highest (29.88) number of fruits per plant was found from SA_3 which was statistically similar (29.38 and 28.12) to SA_2 and SA_1, whereas the lowest (24.32) number of fruits per plant was observed from SA_0 (Figure 7). Javaheri *et al*. (2014) reported the highest fruit number in bush obtained by mean of 66.75 in the application of SA_1 (SA at 10^{-2} M) which is support the present study.

Statistically significant variation was recorded due to the interaction effect of different varieties and levels of salicylic acid in terms of number of fruits per plant (Appendix VI). The highest (32.67) number of fruits per plant was recorded from V_2SA_3 and the lowest (23.24) number of fruits per plant was observed from V_1SA_0 treatment combination (Figure 8).

4.10 Fruit setting

Fruit setting of tomato showed statistically non-significant variation due to different varieties (Appendix VI). The highest (64.36%) fruit setting was recorded from V_2, whereas the lowest (63.81%) fruit setting was found from V_1 (Table 6). Ahammad *et al*. (2009) reported that variety BARI Tomato 5 showed potential fruiting capability by producing maximum fruits.

Different levels of salicylic acid showed statistically significant variation in terms of fruit setting of tomato (Appendix VI). The highest (65.10%) fruit setting was recorded from SA_3 which was statistically similar (64.68% and 64.67%) to SA_1 and SA_2, while the lowest (61.89%) fruit setting was found from SA_0 (Table 6). Singh and Singh (2016) reported that the exogenous applications of salicylic acid improved the yield contributing factors of tomato.

Statistically significant variation was recorded due to the interaction effect of different varieties and levels of salicylic acid in terms of fruit setting (Appendix VI). The highest (64.71%) fruit setting was observed from V_2SA_3 and the lowest (59.31%) fruit setting was found from V_1SA_0 treatment combination (Table 7).

4.11 Length of fruit

Length of fruit of tomato varied significantly due to different varieties (Appendix VII). The highest (7.27 cm) length of fruit was found from V_2, while the lowest (6.61 cm) length of fruit was recorded from V_1 (Table 8). Different varieties responded differently for fruit length to input supply, method of cultivation and the prevailing environment during the growing season.

Different levels of salicylic acid showed statistically significant variation in terms of length of fruit of tomato (Appendix VII). The highest (7.37 cm) length of fruit was found from SA_3 which was statistically similar (7.32 cm) to SA_2 and closely followed (6.83 cm) by SA_1, whereas the lowest (6.22 cm) length of fruit from SA_0 (Table 8). Singh and Singh (2016) reported that the exogenous applications of SA improved the yield contributing factors of tomato.

Table 8. Effect of different varieties and levels of salicylic acid on yield contributing characters and yield of tomato

Treatment	Length of fruit (cm)	Diameter of fruit (cm)	Dry matter content in plant (%)	Dry matter content in fruit (%)	Weight of individual fruit (g)	Fruit yield per hectare (ton)
Different tomato varieties						
V_1	6.61 b	3.74 b	9.00 b	7.23 b	65.28 b	71.00 b
V_2	7.27 a	4.31 a	9.41 a	7.83 a	68.41 a	85.13 a
$LSD_{(0.05)}$	**0.140**	**0.158**	**0.174**	**0.231**	**2.616**	**4.035**
Level of significance	**	**	**	**	*	**
CV(%)	**6.75**	**5.34**	**5.58**	**4.19**	**5.32**	**7.03**
Different levels of salicylic acid						
SA_0	6.22 c	3.53 c	8.82 c	6.84 c	63.85 b	64.63 c
SA_1	6.83 b	3.96 b	9.13 b	7.38 b	66.42 ab	77.82 b
SA_2	7.32 a	4.27 a	9.34 ab	7.90 a	68.18 a	83.52 ab
SA_3	7.37 a	4.35 a	9.53 a	8.00 a	68.94 a	86.27 a
$LSD_{(0.05)}$	**0.197**	**0.223**	**0.246**	**0.327**	**3.699**	**5.707**
Level of significance	**	**	**	**	*	**
CV(%)	**6.75**	**5.34**	**5.58**	**4.19**	**5.32**	**7.03**

In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 5% level of probability

** Significant at 0.01 level of probability; * Significant at 0.05 level of probability

V_1: Ratan

V_2: Mintoo hybrid

SA_0: 0 mM SA (control)

SA_1: 0.1 mM SA

SA_2: 0.2 mM SA

SA_3: 0.3 mM SA

Statistically significant variation was recorded due to the interaction effect of different varieties and levels of salicylic acid in terms of length of fruit (Appendix VII). The highest (7.88 cm) length of fruit was recorded from V_2SA_3, while the lowest (5.93 cm) length of fruit was found from V_1SA_0 treatment combination (Table 9).

4.12 Diameter of fruit

Diameter of fruit of tomato varied significantly due to different varieties (Appendix VII). The highest (4.31 cm) diameter of fruit was observed from V_2 and the lowest (3.74 cm) diameter of fruit was recorded from V_1 (Table 8).

Different levels of salicylic acid showed statistically significant variation in terms of diameter of fruit of tomato (Appendix VII). The highest (4.35 cm) diameter of fruit was found from SA_3 which was statistically similar (4.27 cm) to SA_2 and closely followed (3.96 cm) by SA_1, while the lowest (3.53 cm) diameter of fruit was recorded from SA_0 (Table 8). Javaheri *et al*. (2014) reported the highest fruit diameter in SA_1 (SA at 10-2 M) with mean of 51.75 mm.

Statistically significant variation was recorded due to the interaction effect of different varieties and levels of salicylic acid in terms of diameter of fruit (Appendix VII). The highest (4.84 cm) diameter of fruit was recorded from V_2SA_3, whereas the lowest (3.36 cm) diameter of fruit was found from V_1SA_0 treatment combination (Table 9).

4.13 Dry matter content in plant

Dry matter content in plant of tomato varied significantly due to different varieties (Appendix VII). The highest (9.41%) dry matter content in plant was found from V_2, while the lowest (9.00%) dry matter content in plant was observed from V_1 (Table 8).

Different levels of salicylic acid showed statistically significant variation in terms of dry matter content in plant of tomato (Appendix VII). The highest (9.53%) dry matter content in plant was observed from SA_3 which was

Table 9. Interaction effect of different varieties and levels of salicylic acid on yield contributing characters and yield of tomato

Treatment	Length of fruit (cm)	Diameter of fruit (cm)	Dry matter content in plant (%)	Dry matter content in fruit (%)	Weight of individual fruit (g)	Fruit yield per hectare (ton)
V_1SA_0	5.93 d	3.36 d	8.69 e	6.77 d	64.21 c	62.18 f
V_1SA_1	6.59 c	3.73 c	8.87 de	7.08 cd	66.74 bc	71.45 de
V_1SA_2	7.05 b	3.99 bc	9.29 bc	7.63 b	65.24 c	77.08 cd
V_1SA_3	6.87 b	3.86 bc	9.16 bcd	7.45 bc	64.94 c	73.29 de
V_2SA_0	6.50 c	3.69 c	8.94 cde	6.91 d	63.49 c	67.09 ef
V_2SA_1	7.08 b	4.19 b	9.40 b	7.67 b	66.10 bc	84.20 bc
V_2SA_2	7.61 a	4.54 a	9.39 b	8.18 a	71.12 ab	89.96 b
V_2SA_3	7.88 a	4.84 a	9.90 a	8.56 a	72.93 a	99.26 a
$LSD_{(0.05)}$	**0.279**	**0.315**	**0.348**	**0.463**	**5.231**	**8.070**
Level of significance	*	*	*	*	*	**
CV(%)	**6.75**	**5.34**	**5.58**	**4.19**	**5.32**	**7.03**

In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 5% level of probability

** Significant at 0.01 level of probability; * Significant at 0.05 level of probability

V_1: Ratan
V_2: Mintoo hybrid

SA_0: 0 mM SA (control)
SA_1: 0.1 mM SA
SA_2: 0.2 mM SA
SA_3: 0.3 mM SA

statistically similar (9.34%) to SA_2 and closely followed (9.13%) by SA_1, whereas the lowest (8.82%) dry matter content in plant was recorded from SA_0 (Table 8). Kazemi (2014a) reported that the application of salicylic acid (0. 5 $mmolL^{-1}$) alone significantly increased dry weight.

Statistically significant variation was recorded due to the interaction effect of different varieties and levels of salicylic acid in terms of dry matter content in plant (Appendix VII). The highest (9.90%) dry matter content in plant was recorded from V_2SA_3 and the lowest (8.69%) dry matter content in plant was observed from V_1SA_0 treatment combination (Table 9).

4.14 Dry matter content in fruit

Dry matter content in fruit of tomato varied significantly due to different varieties (Appendix VII). The highest (7.83%) dry matter content in fruit was found from V_2 and the lowest (7.23%) dry matter content in fruit was recorded from V_1 (Table 8).

Different levels of salicylic acid showed statistically significant variation in terms of dry matter content in fruit of tomato (Appendix VII). The highest (8.00%) dry matter content in fruit was observed from SA_3 which was statistically similar (7.90%) to SA_2 and closely followed (7.38%) by SA_1, while the lowest (6.84%) dry matter content in fruit was found from SA_0 (Table 8). Kazemi (2014a) reported that the application of salicylic acid (0. 5 $mmolL^{-1}$) alone significantly increased dry weight.

Statistically significant variation was recorded due to the interaction effect of different varieties and levels of salicylic acid in terms of dry matter content in fruit (Appendix VII). The highest (8.56%) dry matter content in fruit was observed from V_2SA_3, whereas the lowest (6.77%) dry matter content in fruit was recorded from V_1SA_0 treatment combination (Table 9).

4.15 Weight of individual fruit

Weight of individual fruit of tomato varied significantly due to different varieties (Appendix VII). The highest (68.41 g) weight of individual fruit was recorded from V_2, while the lowest (65.28 g) weight of individual fruit from V_1 (Table 8). Weight of individual fruit varied due to different varieties as well as genetical and environmental influences, management practices also influenced it. Biswas *et al*. (2015) reported highest fruit weight (115.9 g) from BARI Tomato-7.

Different levels of salicylic acid showed statistically significant variation in terms of weight of individual fruit of tomato (Appendix VII). The highest (68.94 g) weight of individual fruit was found from SA_3 which was statistically similar (68.18 g and 66.42 g) to SA_2 and SA_1, whereas the lowest (63.85 g) weight of individual fruit was recorded from SA_0 (Table 8). Javaheri *et al*. (2014) reported the highest amount of fruit weight in SA_1 (SA at 10-2 M) with mean of 61.50 g.

Statistically significant variation was recorded due to the interaction effect of different varieties and levels of salicylic acid in terms of weight of individual fruit (Appendix VII). The highest (72.93 g) weight of individual fruit was recorded from V_2SA_3 and the lowest (64.21 g) weight of individual fruit was found from V_1SA_0 treatment combination (Table 9).

4.16 Fruit yield per plant

Fruit yield per plant of tomato varied significantly due to different varieties (Appendix VII). The highest (2.04 kg) fruit yield per plant was observed from V_2, whereas the lowest (1.70 kg) fruit yield per plant from V_1 (Figure 9).

Different levels of salicylic acid showed statistically significant variation in terms of fruit yield per plant of tomato (Appendix VII). The highest (2.07 kg) fruit yield per plant was observed from SA_3 which was statistically similar (2.00 kg) to SA_2 and closely followed (1.87 kg) by SA_1, while the lowest (1.55 kg) fruit yield per plant was found from SA_0 (Figure 10). Singh and Singh (2016) reported that the exogenous applications of salicylic acid improved the yield contributing factors that resulted in significant increases in tomato fruit yield.

Statistically significant variation was recorded due to the interaction effect of different varieties and levels of salicylic acid in terms of fruit yield per plant (Appendix VII). The highest (2.38 kg) fruit yield per plant was found from V_2SA_3 and the lowest (1.49 kg) fruit yield per plant was observed from V_1SA_0 treatment combination (Figure 11).

4.17 Fruit yield per hectare

Fruit yield per hectare of tomato varied significantly due to different varieties (Appendix VII). The highest (85.13 ton) fruit yield per hectare was recorded from V_2 and the lowest (71.00 ton) fruit yield per hectare from V_1 (Table 8). Yield varied for different varieties might be due to genetical and environmental influences as well as management practices. Hossain *et al*., 2013 reported that yield of tomato varied significantly due to different variety. Kayum *et al*. (2008) reported that variety Ratan produced the highest (73.74 t/ha) fruit yield. Biswas *et al*. (2015) reported maximum yield (95.9 t/ha) from BARI Tomato-7 which is similar to the present findings.

Different levels of salicylic acid showed statistically significant variation in terms of fruit yield per hectare of tomato (Appendix VII). The highest (86.27 ton) fruit yield per hectare was found from SA_3 which was statistically similar (83.52 ton) to SA_2 and followed (77.82 ton) by SA_1, while the lowest (64.63 ton) fruit yield per hectare was recorded from SA_0 (Table 8). Yildirim and Dursun (2009) earlier reported that the yield of tomato was significantly influenced by foliar SA applications and the highest fruit yield occurred in 0.50 mM SA treatment.

Statistically significant variation was recorded due to the interaction effect of different varieties and levels of salicylic acid in terms of fruit yield per hectare (Appendix VII). The highest (99.26 ton) fruit yield per hectare was recorded from V_2SA_3, whereas the lowest (62.18 ton) fruit yield per hectare was found from V_1SA_0 treatment combination (Table 9).

4.18 Total soluble solid

Total soluble solid of tomato varied significantly due to different varieties (Appendix VIII). The highest (4.34%) total soluble solid was found from V_2 and the lowest (4.22%) total soluble solid was observed from V_1 (Table 10).

Different levels of salicylic acid showed statistically significant variation in terms of total soluble solid of tomato (Appendix VIII). The highest (4.41%) total soluble solid was found from SA_3 which was statistically similar (4.37%) to SA_2 and closely followed (4.26%) by SA_1, while the lowest (4.09%) total soluble solid was observed from SA_0 (Table 10). Kazemi (2014a) reported that the TSS of tomato fruit had significantly affected by the application of salicylic acid.

Statistically significant variation was recorded due to the interaction effect of different varieties and levels of salicylic acid in terms of total soluble solid (Appendix VIII). The highest (4.58%) total soluble solid was found from V_2SA_3, whereas the lowest (4.08%) from V_1SA_0 treatment combination (Table 11).

4.19 β-carotene

β-carotene content of tomato showed statistically non-significant difference due to different varieties (Appendix VIII). The highest (1671.16 µg/100 g) β-carotene was recorded from V_1 and the lowest (1669.42 µg/100 g) β-carotene was observed from V_1 (Table 10).

Different levels of salicylic acid showed statistically non-significant variation in terms of β-carotene of tomato (Appendix VIII). The highest (1679.87 µg/100 g) β-carotene was observed from SA_3, whereas the lowest (1655.46 µg/100 g) β-carotene was recorded from SA_0 (Table 10).

Statistically non-significant variation was recorded due to the interaction effect of different varieties and levels of salicylic acid in terms of β-carotene (Appendix VIII). The highest (1708.37 µg/100 g) β-carotene was recorded from V_2SA_3, while the lowest (1642.72 µg/100 g) β-carotene was observed from V_2SA_0 treatment combination (Table 11).

Table 10. Effect of different varieties and levels of salicylic acid on total soluble solid, β-carotene and sugar content of tomato

Treatment	Total Soluble Solid-TSS (%)	β-carotene (µg/100 g)	Reducing sugar (%)	Non reducing sugar (%)	Total sugar (%)
Different tomato varieties					
V_1	4.22 b	1671.16	3.37 b	1.39 a	4.76 b
V_2	4.34 a	1669.42	3.59 a	1.52 b	5.10 a
$LSD_{(0.05)}$	**0.093**	**--**	**0.123**	**0.023**	**0.127**
Level of significance	*	**NS**	**	**	**
CV(%)	**3.93**	**5.27**	**4.78**	**5.60**	**6.52**
Different levels of salicylic acid					
SA_0	4.09 c	1655.46	3.26 b	1.36 d	4.63 c
SA_1	4.26 b	1668.93	3.47 a	1.41 c	4.88 b
SA_2	4.37 ab	1676.90	3.56 a	1.49 b	5.05 ab
SA_3	4.41 a	1679.87	3.62 a	1.56 a	5.18 a
$LSD_{(0.05)}$	**0.132**	**--**	**0.174**	**0.033**	**0.180**
Level of significance	**	**NS**	**	**	**
CV(%)	**3.93**	**5.27**	**4.78**	**5.60**	**6.52**

In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 5% level of probability

V_1: Ratan

V_2: Mintoo hybrid

SA_0: 0 mM SA (control)

SA_1: 0.1 mM SA

SA_2: 0.2 mM SA

SA_3: 0.3 mM SA

Table 11. Interaction effect of different varieties and levels of salicylic acid on total soluble solid, β-carotene and sugar content of tomato

Treatment	Total Soluble Solid-TSS (%)	β-carotene (µg/100 g)	Reducing sugar (%)	Non reducing sugar (%)	Total sugar (%)
V_1SA_0	4.08 d	1668.20	3.23 d	1.33 f	4.56 e
V_1SA_1	4.22 bcd	1657.45	3.38 cd	1.37 ef	4.75 cde
V_1SA_2	4.37 b	1707.61	3.45 bcd	1.43 cd	4.88 cd
V_1SA_3	4.23 bcd	1651.38	3.41 bcd	1.45 c	4.86 cd
V_2SA_0	4.11 cd	1642.72	3.30 cd	1.39 de	4.69 de
V_2SA_1	4.30 bc	1680.42	3.55 bc	1.45 c	5.01 bc
V_2SA_2	4.36 b	1646.18	3.67 ab	1.56 b	5.23 b
V_2SA_3	4.58 a	1708.37	3.82 a	1.67 a	5.49 a
$LSD_{(0.05)}$	**0.186**	**--**	**0.246**	**0.047**	**0.255**
Level of significance	*	**NS**	*	**	*
CV(%)	**3.93**	**5.27**	**4.78**	**5.60**	**6.52**

In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 5% level of probability

V_1: Ratan

V_2: Mintoo hybrid

SA_0: 0 mM SA (control)

SA_1: 0.1 mM SA

SA_2: 0.2 mM SA

SA_3: 0.3 mM SA

4.20 Reducing sugar

Reducing sugar of tomato varied significantly due to different varieties (Appendix VIII). The highest (3.59%) reducing sugar was recorded from V_2, while the lowest (3.37%) reducing sugar was observed from V_1 (Table 10).

Different levels of salicylic acid showed statistically significant variation in terms of reducing sugar of tomato (Appendix VIII). The highest (3.62%) reducing sugar was found from SA_3 which was statistically similar (3.56% and 3.47%) to SA_2 and SA_1, whereas the lowest (3.26%) reducing sugar was recorded from SA_0 (Table 10).

Statistically significant variation was recorded due to the interaction effect of different varieties and levels of salicylic acid in terms of reducing sugar (Appendix VIII). The highest (3.82%) reducing sugar was recorded from V_2SA_3 and the lowest (3.23%) reducing sugar was found from V_1SA_0 treatment combination (Table 11).

4.21 Non-reducing sugar

Non-reducing sugar of tomato varied significantly due to different varieties (Appendix VIII). The highest (1.52%) non-reducing sugar was found from V_2 and the lowest (1.39%) non- reducing sugar was observed from V_1 (Table 10).

Different levels of salicylic acid showed statistically significant variation in terms of non- reducing sugar of tomato (Appendix VIII). The highest (1.56%) non-reducing sugar was observed from SA_3 which was closely followed (1.49%) by SA_2. On the other hand, the lowest (1.36%) non-reducing sugar was recorded from SA_0 which was closely followed (1.41%) by SA_1 (Table 10).

Statistically significant variation was recorded due to the interaction effect of different varieties and levels of salicylic acid in terms of non-reducing sugar (Appendix VIII). The highest (1.67%) non-reducing sugar was found from V_2SA_3 and the lowest (1.33%) non-reducing sugar was found from V_1SA_0 treatment combination (Table 11).

4.22 Total sugar

Total sugar of tomato varied significantly due to different varieties (Appendix VIII). The highest (5.10%) total sugar was obtained from V_2, whereas the lowest (4.76%) total sugar was found from V_1 (Table 10). Tigist *et al*. (2012) reported that tomato varieties had significant effects on quality of fruits as well as sugar content.

Different levels of salicylic acid showed statistically significant variation in terms of total sugar of tomato (Appendix VIII). The highest (5.18%) total sugar was found from SA_3 which was statistically similar (5.05%) to SA_2 and closely followed (4.88%) by SA_1, while the lowest (4.63%) total sugar was observed from SA_0 (Table 10).

Statistically significant variation was recorded due to the interaction effect of different varieties and levels of salicylic acid in terms of total sugar (Appendix VIII). The highest (5.49%) total sugar was observed from V_2SA_3, whereas the lowest (4.56%) total sugar was recorded from V_1SA_0 treatment combination (Table 11).

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh during the period from November 2014 to March 2015 to find out the effect of salicylic acid on growth, yield and quality of tomato. The experiment comprised of two factors as Factor A: Different tomato varieties (2 varieties)- V_1: Ratan, V_2: Mintoo hybrid; and Factors B: Different levels of salicylic acid -SA (4 levels)- SA_0: 0 mM SA (control), SA_1: 0.1 mM SA, SA_2: 0.2 mM SA and SA_3: 0.3 mM SA. The two factors experiment was laid out in a Randomized Complete Block Design (RCBD) with four replications. Data on different growth characters, yield attributes, yield and quality of tomato was recorded and statistical differences were found for different treatment.

In consideration of varieties, the taller plants (18.13, 43.24, 64.01, 78.71, 87.01 and 89.68 cm, respectively) was found from V_2, whereas the shorter plants (17.13, 40.00, 59.97, 74.38, 82.55 and 86.25 cm, respectively) was recorded from V_1. At 20, 30, 40, 50, 60 DAT and final harvest, the maximum number of branches per plant (3.10, 7.92, 13.88, 15.48, 16.38 and 17.17, respectively) was recorded from V_2, whereas the minimum number (2.73, 6.65, 12.24, 13.65, 14.65 and 15.65, respectively) was observed from V_1 at 20, 30, 40, 50, 60 DAT and final harvest, respectively. At 20, 30, 40, 50 and 60 DAT, the maximum leaf area (55.80, 83.76, 131.48, 160.14 and 162.83 cm^2, respectively) was found from V_2 and the minimum leaf area (50.75, 79.99, 118.08, 150.03 and 153.70 cm^2, respectively) was recorded from V_1 at 20, 30, 40, 50 and 60 DAT, respectively.

The lowest (42.88) days from transplanting to 1^{st} flowering was recorded from V_2, whereas the highest (46.31) days from V_1. The highest (6.30) number of flower clusters per plant was recorded from V_2, while the lowest (5.82) number from V_1. The highest (7.33) number of flowers per cluster was found from V_2 and the lowest (7.03) number from V_1. The highest (46.26) number of flowers per plant was recorded from V_2, while the lowest (40.94) number from V_1. The highest

(4.71) number of fruits per cluster was found from V_2 and the lowest (4.47) number of fruits per cluster was observed from V_1. The highest (29.75) number of fruits per plant was observed from V_2, while the lowest (26.09) number from V_1. The highest (64.36%) fruit setting was recorded from V_2, whereas the lowest (63.81%) from V_1. The highest (7.27 cm) length of fruit was found from V_2, while the lowest (6.61 cm) from V_1. The highest (4.31 cm) diameter of fruit was observed from V_2 and the lowest (3.74 cm) from V_1. The highest (9.41%) dry matter content in plant was found from V_2, while the lowest (9.00%) from V_1. The highest (7.83%) dry matter content in fruit was found from V_2 and the lowest (7.23%) from V_1. The highest (68.41 g) weight of individual fruit was recorded from V_2, while the lowest (65.28 g) from V_1. The highest (2.04 kg) fruit yield per plant was observed from V_2, whereas the lowest (1.70 kg) from V_1. The highest (85.13 ton) fruit yield per hectare was recorded from V_2 and the lowest (71.00 ton) from V_1.

The highest (4.34%) total soluble solid was found from V_2 and the lowest (4.22%) total soluble solid was observed from V_1. The highest (1671.16 µg/100 g) β-carotene was recorded from V_1 and the lowest (1669.42 µg/100 g) β from V_1. The highest (3.59%) reducing sugar was recorded from V_2, while the lowest (3.37%) reducing sugar was observed from V_1. The highest (1.52%) non-reducing sugar was found from V_2 and the lowest (1.39%) non-reducing sugar was observed from V_1. The highest (5.10%) total sugar was obtained from V_2, whereas the lowest (4.76%) total sugar was found from V_1.

In case of different levels of salicylic acid, at 20, 30, 40, 50, 60 DAT and final harvest, the tallest plant (18.51, 43.54, 64.44, 80.59, 87.78 and 90.99 cm, respectively) was recorded from SA_3, while the shortest plant (16.56, 38.74, 57.28, 69.24, 79.17 and 83.04 cm, respectively) was found from SA_0. At 20, 30, 40, 50, 60 DAT and final harvest, the maximum number of branches per plant (3.28, 7.78, 13.85, 15.63, 16.38 and 17.30, respectively) was found from SA_3, while the minimum number (2.25, 6.63, 11.38, 12.83, 13.95 and 15.05, respectively) from SA_0. At 20, 30, 40, 50 and 60 DAT, the maximum leaf area (55.48, 85.84, 133.34, 170.39 and 173.34 cm^2, respectively) was observed from

SA_3, while the minimum leaf area (49.41, 75.77, 108.12, 126.54 and 129.54 cm^2, respectively) from SA_0 at 20, 30, 40, 50 and 60 DAT, respectively.

The lowest (43.25) days from transplanting to 1st flowering was recorded from SA_3, while the highest (46.75) from SA_0. The highest (6.28) number of flower clusters per plant was found from SA_3, whereas the lowest (5.65) from SA_0. The highest (7.30) number of flowers per cluster was observed from SA_3, while the lowest (6.95) number from SA_0. The highest (45.93) number of flowers per plant was found from SA_3, whereas the lowest (39.27) number from SA_0. The highest (4.75) number from SA_3, while the lowest (4.30) number of fruits per cluster was recorded from SA_0. The highest (29.88) number of fruits per plant was found from SA_3, whereas the lowest (24.32) number from SA_0. The highest (65.10%) fruit setting was recorded from SA_3, while the lowest (61.89%) from SA_0. The highest (7.37 cm) length of fruit was found from SA_3, whereas the lowest (6.22 cm) from SA_0. The highest (4.35 cm) diameter of fruit was found from SA_3, while the lowest (3.53 cm) from SA_0. The highest (9.53%) dry matter content in plant was observed from SA_3, whereas the lowest (8.82%) from SA_0. The highest (8.00%) dry matter content in fruit was observed from SA_3, while the lowest (6.84%) from SA_0. The highest (68.94 g) weight of individual fruit was found from SA_3, whereas the lowest (63.85 g) from SA_0. The highest (2.07 kg) fruit yield per plant was observed from SA_3, while the lowest (1.55 kg) from SA_0. The highest (86.27 ton) fruit yield per hectare was found from SA_3, while the lowest (64.63 ton) from SA_0.

The highest (4.41%) total soluble solid was found from SA_3, while the lowest (4.09%) was observed from SA_0. The highest (1679.87 µg/100 g) β-carotene was observed from SA_3, whereas the lowest (1655.46 µg/100 g) was recorded from SA_0. The highest (3.62%) reducing sugar was found from SA_3, whereas the lowest (3.26%) from SA_0. The highest (1.56%) non-reducing sugar was observed from SA_3 and the lowest (1.36%) was recorded from SA_0. The highest (5.18%) total sugar was found from SA_3, while the lowest (4.63%) from SA_0.

For the interaction effect of different varieties and levels of salicylic acid at 20, 30, 40, 50, 60 DAT and final harvest, the tallest plant (20.05, 46.38, 67.86, 85.09, 92.27 and 94.82 cm, respectively) was observed from and the shortest plant (15.92, 36.26, 55.04, 68.24, 78.49 and 83.96 cm, respectively) was recorded from V_1SA_0. At 20, 30, 40, 50, 60 DAT and final harvest, the maximum number of branches per plant (3.50, 8.35, 15.05, 17.30, 18.05 and 18.90, respectively) was recorded from V_2SA_3, whereas the minimum number (2.20, 6.10, 10.95, 12.50, 14.10 and 15.25, respectively) was found from V_1SA_0. At 20, 30, 40, 50 and 60 DAT, the maximum leaf area (59.83, 90.11, 150.54, 181.77 and 184.39 cm^2, respectively) was observed from V_2SA_3, whereas the minimum leaf area (48.39, 75.05, 106.40, 123.69 and 126.36 cm^2, respectively) from V_1SA_0 treatment combination.

The lowest (40.25) days from transplanting to 1st flowering was found from V_2SA_3 and the highest (48.00) from V_1SA_0. The highest (6.60) number of flower clusters per plant was recorded from V_2SA_3 and the lowest (5.60) number from V_1SA_0. The highest (7.65) number of flowers per cluster was recorded from V_2SA_3, whereas the lowest (6.90) number from V_2SA_0. The highest (50.49) number of flowers per plant was observed from V_2SA_3, while the lowest (39.19) from V_1SA_0. The highest (4.95) number of fruits per cluster was recorded from V_2SA_3, whereas the lowest (4.15) number from V_1SA_0. The highest (32.67) number of fruits per plant was recorded from V_2SA_3 and the lowest (23.24) number from V_1SA_0. The highest (64.71%) fruit setting was observed from V_2SA_3 and the lowest (59.31%) from V_1SA_0. The highest (7.88 cm) length of fruit was recorded from V_2SA_3, while the lowest (5.93 cm) from V_1SA_0. The highest (4.84 cm) diameter of fruit was recorded from V_2SA_3, whereas the lowest (3.36 cm) from V_1SA_0. The highest (9.90%) dry matter content in plant was recorded from V_2SA_3 and the lowest (8.69%) from V_1SA_0. The highest (8.56%) dry matter content in fruit was observed from V_2SA_3, whereas the lowest (6.77%) from V_1SA_0. The highest (72.93 g) weight of individual fruit was recorded from V_2SA_3 and the lowest (64.21 g) from V_1SA_0. The highest (2.38 kg) fruit yield per plant was found from V_2SA_3 and the lowest (1.49 kg) from V_1SA_0. The highest (99.26

ton) fruit yield per hectare was recorded from V_2SA_3, whereas the lowest (62.18 ton) from V_1SA_0 treatment combination.

The highest (4.58%) total soluble solid was found from V_2SA_3, whereas the lowest (4.08%) total soluble solid was recorded from V_1SA_0. The highest (1708.37 µg/100 g) β-carotene was recorded from V_2SA_3, while the lowest (1642.72 µg/100 g) from V_2SA_0 treatment combination. The highest (3.82%) reducing sugar was recorded from V_2SA_3 and the lowest (3.23%) from V_1SA_0. The highest (1.67%) non-reducing sugar was found from V_2SA_3 and the lowest (1.33%) was found from V_1SA_0. The highest (5.49%) total sugar was observed from V_2SA_3, whereas the lowest (4.56%) from V_1SA_0 treatment combination.

Conclusion

- Mintoo hybrid shows better yield and quality characters than Raton variety of tomato;
- Among the different concentration of salicylic acid, tomato shows better response with 0.3 mM concentration of salicylic acid and
- Finally, Mintoo hybrid with 0.3 mM SA encouraged superior growth, yield contributing characters, yield and quality of tomato.

Recommendation

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

1. Another varieties, other management practices and cropping season may be used in future study.
2. Another higher level of salicylic acid need to be considered in different agro-ecological zones of Bangladesh for regional trial before final recommendation.

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APPENDICES

Appendix I. Characteristics of soil of experimental field

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Agricultural Botany 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 and chemical properties of the initial soil

Characteristics	Value
% Sand	27
% Silt	43
% clay	30
Textural class	Silty-clay
pH	6.1
Organic matter (%)	1.13
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	23

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

Appendix II. Monthly record of air temperature, relative humidity, rainfall and sunshine hour of the experimental site during the period from November 2014 to March 2015

Month	*Air temperature (°c)		*Relative humidity (%)	Total Rainfall (mm)	*Sunshine (hr)
	Maximum	Minimum			
November, 2014	25.8	16.0	78	00	6.8
December, 2014	22.4	13.5	74	00	6.3
January, 2015	24.5	12.4	68	00	5.7
February, 2015	27.1	16.7	67	30	6.7
March, 2015	28.1	19.5	68	00	6.8

* Monthly average,

* Source: Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka – 1207

Appendix III. Analysis of variance of the data on plant height of tomato at different days after transplanting (DAT) and at final harvest as influenced by different varieties and levels of salicylic acid

Source of variation	Degrees of freedom	Mean square					
		Plant height (cm) at					
		20 DAT	30 DAT	40 DAT	50 DAT	60 DAT	Final harvest
Replication	3	0.352	1.068	1.196	6.757	6.577	3.040
Tomato varieties (A)	1	8.100*	83.625**	130.169**	149.645**	159.311**	94.154**
Levels of salicylic acid (B)	3	6.233*	42.324**	87.332**	220.166**	130.797**	104.751**
Interaction (A×B)	3	4.940*	12.110*	12.797*	20.446*	21.605*	31.366*
Error	21	1.575	4.545	5.134	7.721	7.730	8.760

** Significant at 0.01 level of probability; * Significant at 0.05 level of probability

Appendix IV. Analysis of variance of the data on number of branches per plant of tomato at different days after transplanting (DAT) and at final harvest as influenced by different varieties and levels of salicylic acid

Source of variation	Degrees of freedom	Mean square					
		Number of branches per plant at					
		20 DAT	30 DAT	40 DAT	50 DAT	60 DAT	Final harvest
Replication	3	0.005	0.048	0.115	0.188	0.608	0.262
Tomato varieties (A)	1	1.125**	13.005**	21.451**	26.645**	23.805**	18.605**
Levels of salicylic acid (B)	3	1.742**	2.115**	10.748**	12.072**	9.515**	7.832**
Interaction (A×B)	3	0.148*	0.355*	0.831*	2.525*	4.615*	4.632*
Error	21	0.037	0.133	0.227	0.739	0.585	0.965

** Significant at 0.01 level of probability; * Significant at 0.05 level of probability

Appendix V. Analysis of variance of the data on leaf area of tomato at different days after transplanting (DAT) as influenced by different varieties and levels of salicylic acid

Source of variation	Degrees of freedom	Mean square				
		Leaf area (cm^2)				
		20 DAT	30 DAT	40 DAT	50 DAT	60 DAT
Replication	3	1.051	2.066	33.249	21.501	24.051
Tomato varieties (A)	1	203.869**	113.701**	1436.480**	817.596**	667.586**
Levels of salicylic acid (B)	3	62.769**	158.380**	1068.802**	3147.797**	3175.881**
Interaction (A×B)	3	19.055*	20.998*	418.946*	283.158*	279.048*
Error	21	7.757	11.018	73.528	66.584	68.854

** Significant at 0.01 level of probability; * Significant at 0.05 level of probability

Appendix VI. Analysis of variance of the data on yield contributing characters of tomato as influenced by different varieties and levels of salicylic acid

Source of variation	Degrees of freedom	Mean square						
		Days required to flowering	Number of flower clusters per plant	Number of flowers per cluster	Number of flowers per plant	Number of fruits per cluster	Number of fruits per plant	Fruit setting (%)
Replication	3	2.031	0.008	0.050	1.987	0.001	0.391	0.107
Tomato varieties (A)	1	94.531**	1.805**	0.720**	225.994**	0.451**	107.018**	2.508**
Levels of salicylic acid (B)	3	19.115**	0.668**	0.203**	74.160**	0.328**	50.543**	17.410**
Interaction (A×B)	3	9.365*	0.228*	0.217*	34.618*	0.038*	6.736*	19.002*
Error	21	2.746	0.065	0.050	6.962	0.035	2.733	4.793

** Significant at 0.01 level of probability; * Significant at 0.05 level of probability

Appendix VII. Analysis of variance of the data on yield contributing characters and yield of tomato as influenced by different varieties and levels of salicylic acid

Source of variation	Degrees of freedom	Mean square						
		Length of fruit (cm)	Diameter of fruit (cm)	Dry matter content in plant (%)	Dry matter content in fruit (%)	Weight of individual fruit (g)	Fruit yield per plant (kg)	Fruit yield per hectare (ton)
Replication	3	0.030	0.008	0.064	0.100	2.303	0.006	9.925
Tomato varieties (A)	1	3.472**	2.662**	1.300**	2.856**	78.250**	0.920**	1597.283**
Levels of salicylic acid (B)	3	2.313**	1.119**	0.745**	2.290**	40.853**	0.426**	740.444**
Interaction (A×B)	3	0.110*	0.160*	0.160*	0.310*	40.145*	0.088*	152.598*
Error	21	0.036	0.046	0.056	0.099	12.655	0.017	30.119

** Significant at 0.01 level of probability; * Significant at 0.05 level of probability

Appendix VIII. Analysis of variance of the data on TSS, β-carotene and sugar content as influenced by different varieties and levels of salicylic acid

Source of variation	Degrees of freedom	Mean square				
		Total Soluble Solid-TSS (%)	β-carotene (µg/100 g)	Reducing sugar (%)	Non reducing sugar (%)	Total sugar (%)
Replication	3	0.007	907.793	0.013	0.000	0.016
Tomato varieties (A)	1	0.107**	24.082	0.378**	0.123**	0.932**
Levels of salicylic acid (B)	3	0.158**	952.482	0.191**	0.064**	0.459**
Interaction (A×B)	3	0.051*	5458.073	0.040*	0.010*	0.090*
Error	21	0.016	2991.299	0.028	0.001	0.030

** Significant at 0.01 level of probability; * Significant at 0.05 level of probability

Appendix IX. List of different plates

Plate 1. Photograph showing tomato seedlings; A: Mintoo hybrid and B: Ratan

Plate 2. Photograph showing experimental plot

Plate 3. Photograph showing green tomato

Plate 4. Photograph showing mature tomato; A: Ratan and B: Mintoo hybrid