GROWTH AND NUTRITIONAL QUALITY OF TOMATO IN RESPONSE TO HUMIC ACID AND SALICYLIC ACID

MD. MEHEDI HASAN

DEPARTMENT OF HORTICULTURE
SHER-E-BANGLA AGRICULTURAL UNIVERSITY
DHAKA-1207

JUNE, 2018

GROWTH AND NUTRITIONAL QUALITY OF TOMATO IN RESPONSE TO HUMIC ACID AND SALICYLIC ACID

BY

MD. MEHEDI HASAN

REG. NO. : 17-08194

A Thesis
Submitted to the Department of Horticulture
Sher-e-Bangla Agricultural University, Dhaka
in partial fulfilment of the requirements
for the degree of

MASTER OF SCIENCE (MS)
IN
HORTICULTURE

SEMESTER: JANUARY-JUNE, 2018

APPROVED BY:

Md. Dulal Sarkar
Assistant Professor
Department of Horticulture
Supervisor

Ms. Salma Ahmed
Principal Scientific Officer
BCSIR
Co-Supervisor

Prof. Dr. Mohammad Humayun Kabir
Chairman
Examination Committee

DEPARTMENT OF HORTICULTURE

Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka-1207

Memo No: SAU/HORT/…………   **Date: ……………...**

CERTIFICATE

This is to certify that the thesis entitled, ***"GROWTH AND NUTRITIONAL QUALITY OF TOMATO IN RESPONSE TO HUMIC ACID AND SALICYLIC ACID"*** *submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of* ***MASTER OF SCIENCE*** *in* ***HORTICULTURE****, embodies the result of a piece of bona fide research work carried out by* ***Md. Mehedi Hasan****, Registration number:* ***17-08194*** *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 duly been acknowledged.

Dated: June, 2018
Dhaka, Bangladesh

Md. Dulal Sarkar
Assistant Professor
Department of Horticulture
Sher-e-Bangla Agricultural University
Dhaka-1207
Supervisor

DEDICATED

TO

MY BELOVED PARENTS

ACKNOWLEDGEMENTS

*All praises are due to the **Almighty Allah**, Who has enabled me to complete the research work and to prepare this thesis for the degree of Master of Science (M.S.) in Horticulture.*

*The author expresses his heartfelt respect, deepest sense of gratitude and immense indebtedness to my esteemed Supervisor **Md. Dulal Sarkar**, Assistant Professor, Department of Horticulture, Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh for his scholastic guidance, support, encouragement, valuable suggestions and constructive criticism throughout the study period in conducting and successfully completing the research work and in the preparation of the manuscript writing including data analysis.*

*The author also expresses his profound gratitude and indebtedness to his honorable Co-supervisor **Ms. Salma Ahmed**, Principal Scientific Officer, Institute of Food Science and Technology (IFST), BCSIR, Dhaka for her scholastic guidance, constant inspiration, inestimable help, valuable suggestions throughout the research work and in preparation of the thesis.*

The author also expresses his sincere gratitude towards the sincerity of the Chairman, Prof. Dr. Mohammad Humayun Kabir, Department of Horticulture, SAU, Dhaka for his valuable suggestions and cooperation during the study period. The author sincerely expresses his gratefulness, sincere appreciation and heartiest indebtedness to all the teachers of the Department of Horticulture, SAU, for their valuable suggestions, instructions, cordial help and encouragement during the period of the study.

The author also thankful to all the field staff of Horticulture Department, SAU, Dhaka for their help and cooperation during the experimental period.

The author also expresses his sincere appreciation to his brother, sister, relatives and friends for their inspiration, help and encouragement throughout the study period.

The Author

GROWTH AND NUTRITIONAL QUALITY OF TOMATO IN RESPONSE TO HUMIC ACID AND SALICYLIC ACID

BY

MD. MEHEDI HASAN

ABSTRACT

The field experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka during October 2017 to April 2018 to find out the response of humic acid and salicylic acid on growth and nutritional quality of tomato. Four different doses of humic acid viz., H_0= 0 ppm, H_1= 20 ppm, H_2= 40 ppm, H_3= 80 ppm and four doses of salicylic acid viz., S_0= 0 ppm, S_1= 30 ppm, S_2= 70 ppm, S_3= 110 ppm were used to conduct this experiment. The experiment was laid out in Randomized Complete Block Design having two factors. Humic acid and salicylic acid showed significant variations with most of the parameters studied. The maximum number of flowers per plant (38.58), number of fruit per plant (27.42), yield of fruits per plant (2.90 kg) were found at 80 ppm humic acid treatment while the lowest result found in control. The maximum number of flowers per plant (38.12), number of fruit per plant (27.83) and yield of fruits per plant (2.95 kg) were found in 70 ppm salicylic acid treatment. The highest total sugar (4.40%), sodium (8.20%) and lycopene content (5 mg/100g) in fruit were found in 80 ppm humic acid with 30 ppm salicylic acid. The highest yield of fruits per hectare (94.07 tones) was obtained from 80 ppm humic acid with 70 ppm salicylic acid treatment. So, the application of 80 ppm humic acid with 70 ppm salicylic acid would be the best option to maintain better growth and to have better quality tomato.

LIST OF CONTENTS

LIST OF TABLES

LIST OF APPENDICES

CHAPTER I

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill) belongs to Solanaceae family and one of the most popular vegetable. It has a significant role in human nutrition because of its rich source of lycopene, minerals and vitamins such as ascorbic acid and ß-carotene which contain antioxidants and promote good health.

Humic acid is an organic fertilizer based component that improve soil fertility and increase nutrients availability, thus enhances plant growth and yield as well as decreases the harmful effect of stresses (Doran *et al*., 2003). Humic acid is believed to increase helps in nitrogen use efficiency and therefore stimulates the shoot and root growth (Adani *et al*., 1998). Humic acid constitute a stable fraction of carbon that improve some of the soil characteristics such as improve water holding capacity, pH buffering and thermal insulation (McDonnell *et al*., 2001). Humic acid assimilates minor and major elements, activates or inhibits enzyme, causes changes in membrane permeability resulting in protein synthesis and activating biomass production which stimulates plant growth (El-Ghamry *et al*., 2009).

Humic Acid (HA) is highly active and versatile component of soil organic matter. They can buffer pH, sorb organic solutes, bind metal ions and stimulate plant growth. Humic acids bind metal ions either through a simple cation exchange reaction or by forming stable complexes with ligands. (MacCarthy *et al*., 1990). Humic substances have been reported to influence plant growth both directly and indirectly. The indirect effects of humic compounds on soil fertility include. (i) Increase in the soil microbial population including beneficial microorganisms. (ii) Improved soil structure. (iii) Increase in the cation exchange capacity and the pH buffering capacity of the soil. Directly, humic acid compounds may have various biochemical effects either at cell wall, membrane level or in the cytoplasm, including increased photosynthesis and respiration rates in plants, enhanced protein synthesis and plant hormone like activity (Chen and Aviad., 1990). Humic substances may enhance the uptake of minerals through the stimulation of microbiological activity (Schnitzer, 1986).

The effect of humic substances (HS) on plants depends on the material of origin, fulvic and humic acid concentration, the dose used, the plant species and variety. The main effects of HS on the plant metabolism include induction of plasmatic membrane H^+-ATPases, root development and increased ion transportation (Façanha *et al.*, 2002); stimulus to plant growth from the release of bioactive molecules with action similar to that of auxin (Canellas *et al*., 2002) and the effect of enzymes on various metabolic pathways (Vaughan *et al*., 1985), on sugars and organic acids that improve tomato quality.

Fruit quality can be affected by several pre-harvest greenhouse cultural practices, particularly Salicylic Acid (SA) application. SA or orthohydroxylbenzonic acid and related compounds belong to a diverse group of plant phenolics. Salicylic Acid naturally occurs in plants in very low amounts and the term phytohormone can be utilized for describing this compound (Raskin, 1992). Previous studies reported a vast range of responses after SA application on plants (Raskin *et al*., 1990). An increase of yield, including in barley (El-Tayeb, 2005) maize (Gunes *et al*., 2005) and cucumber (Yildirim *et al*., 2008) have been reported. Better germination of seeds (Basra *et al*., 2007; Hamada and Al-Hakimi, 2001; Shakirova *et al*., 2003), more photosynthetic activities (Singh and Usha, 2003; Maibangsa *et al*., 2000) augmentation of antioxidants activity within plants (Landberg and Greger, 2002; Dat *et al*., 2000; Agarwal *et al*., 2005), stimulation of mineral element absorption (Metwally *et al*., 2003) protection against abiotic stresses (Leventtuna *et al*., 2007; Karlidag *et al*., 2009) and biotic stresses (Doares *et al*., 1995; Leon *et al*., 1995) are also instances of a general positive influence of SA treatment on plants. So, the main theme of this study is to investigate the physiological growth, yield and quality of tomato as influenced by humic acid and salicylic acid.

Keeping in view of above facts, a field experiment entitled, “Growth, antioxidant content and nutritional quality of tomato in response to humic acid and salicylic acid” was conducted during rabi season to fulfill the following objectives:

❖ To study the physiological response of tomato.
❖ To evaluate the antioxidant content in tomato fruit.
❖ To investigate the nutritional changes in tomato fruit.

CHAPTER II

REVIEW OF LITERATURE

Tomato is one of the most important vegetable crops grown under field and greenhouse condition, which received much attention to the researchers throughout the world. In Bangladesh little work(s) have been done in this respect. However, the available findings in this connection over the world have been reviewed in this chapter under the following headings.

2.1 Effect of humic acid

Abdell Atif *et al*. (2017) was conducted the study to evaluate the effect of humic acid (HA) applied at 4.8, 9.6 and 14.4 kg ha^{-1} on the growth and productivity of two tomato hybrids Nema 1400 and Platinium 5043 under hot continental climate. HA was applied twice to soil: the first one – three weeks from transplanting and the second one, after one week from the first application, in both seasons. Application of HA during the summer season targeted a great result on tomato plant growth and productivity. HA at 14.4 kg ha^{-1} increased the vegetative growth of tomatoes (plant height and fresh weight) and flowering parameters (number of flower clusters and flowers per plant) as well as yield characters (fruit number per plant and fruit weight, which resulted in higher early and total yield) in both seasons. HA application had the least impact on fruit number per plant, and on vitamin C and total soluble solids (TSS%) concentration as compared to control.

Adani *et al*. (1998) reported that, the effects of humic acids extracted from two commercially available products on the growth and mineral nutrition of tomato plants (*Lycopersicon esculentum* L.) in hydroponics culture were tested at concentrations of 20 and 50 mg L^{-1}. Both the humic acids tested stimulated plants growth. The CPA stimulated only root growth, especially at 20 mg L^{-1} [23% and 22% increase over the control, on fresh weight basis (f.w.b.), and dry weight basis (d.w.b.), respectively]. In contrast, CPB showed a positive effect on both shoots and roots, especially at 50 mg L^{-1} (shoots: 8% and 9% increase over the control; roots: 18% and 16% increase over the control, on f.w.b. and d.w.b., respectively). Total ion uptake by the plants was affected by the two products. In particular, CPA showed an increase in the uptake of nitrogen (N), phosphorus (P), iron (Fe), and copper (Cu), whereas, CPB showed positive effects for N, P, and Fe uptake. The change in the Fe content was the most appreciable effect on mineral nutrition (CPA: 41% and 33% increase over the control for 20 mg L^{-1} and 50 mg L^{-1} respectively; CPB: 31% and 46% increase over the control for 20 mg L^{-1} and 50 mg L^{-1}, respectively). Increases in Fe concentration in the plant roots were especially pronounced (CPA: 113% and 123% increases with respect to controls for the 20 mg $L^{-1}$and 50 mg L^{-1} treatments; CPB: 135% and 161% increases with respect to the control for 20 mg L^{-1} and 50 mg L^{-1} treatments). On the basis of the current experiments and from evidence in the literature, reduction of Fe^{3+} to Fe^{2+} by humic acid is considered as a possibility to explain a higher Fe availability for the plants.

Aman and Rab (2013) was conducted an experiment to study the response of tomato to nitrogen levels with or without Humic acid on yield and yield components of tomato `Advanta-1209` sown at New Developmental Farm (Horticulture section),The University of Agriculture, Peshawar Pakistan, during summer 2011. The experiment was laid out in Randomized Complete Block Design with spilt plot arrangements having three replications. The experiment involved two factors, Humic acid (0 and 5 kg ha^{-1}) allotted to main plot and nitrogen (0, 25, 50, 75, 100, 125 and 150 kg ha^{-1}) kept in sub plots. The results showed that leaf length (cm), plant height (cm), fruit weight (g), and yield (t ha^{-1}) were significantly affected, whereas survival percentage and blossom end rot to fruits were not significantly affected by Humic acid and nitrogen levels and interaction of both. High leaf length (6.43 cm), plant height (82.92 cm), fruit weight (75.27 gm) and yield (28.49 t ha^{-1}) were produced by Humic acid applied at the rate of 5 kg $ha^{-1}$and maximum leaf length (6.88 cm), plant height (89.16 cm), fruit weight (78.82 gm) and yield (32.43 t ha^{-1}) were recorded by nitrogen applied at the rate of 125 kg ha^{-1}. From this study it can be concluded that tomato plants should be treated with fertilizers, humic acid and nitrogen at the rate of 5 kg and 125 kg ha^{-1}, respectively to obtain maximum and quality yield.

Asri *et al*. (2013) stated that, humic acids (HA) provide formation of the organomineral in soil, thus they improve nutrient concentration of tomato leaves and agricultural production. The objective of this study was to find effects of soil HA applications on yield, fruit quality and nutrient concentration of processing tomato. Humic acid was sprayed on soil at the rate of 0, 40, 80, 120, 160 and 200 L ha-1 soil along with uniform dose of nitrogen-phosphorus-potassium (NPK) (180-60-210 kg ha-1) was applied through drip irrigation. The experiment was conducted according to randomized complete block design with 4 replicates in 2011-2012 years. The humic acid applications caused a significant increase of yield. Titratable acidity, fruit weight and fruit diameter showed increase by ascending humic acid levels. Results showed that N, P, K, Ca, Zn and Mn concentration of leaves was increased by humic acid, especially 80 L ha-1 humic acid level provided the most important progress in the first year. In the second year, N, P, K, Fe and Mn concentration of leaves was positive changed by humic acid and high levels of humic acid caused decline. Therefore, mid-levels (80 and 120 L ha-1) were found more effective.

Böhme and Thi Lua (1999) started out experiments to investigate the effect of humates in hydroponic systems on the growth of tomato plants. Investigations were carried out by using different substrates (perlite, coconut-fibre and peat-based substrates) and in small tanks as water-culture. In some experiments were compared concentrations and forms of humic acids (K-, Na- and NH_4-humates). Moreover, were investigated the influence of humates on the germination of tomato seeds. It was analysed the influence of treatments with humates on the nutrient uptake of tomatoes. Tomato test plants were cultivated in containers with different substrates or tanks with nutrient solution until the plants had three inflorescence and they produced crop. In some experiments tomato plants were cultivated until they had eleven or twelve leaves. The 'Hydrofer' computer program was used for calculating the amounts of fertilizers, salts and acids required. It was analysed fresh and dry matter of the plants, root length, sugar content in tomato fruits and the content of nutrients in fruits. The following conclusions have been drawn: Treatments with humic acid showed a positive influence on the germination of tomato seeds. Effects on the plant growth depends of the humate form and material used for the extraction (peat, coal). Humic acid improved plant growth depending on the concentration and frequency of treatments and the air-capacity in the rhizosphere. Humic acid has an influence on the length of roots and shoots. The content of nutrients as Ca and K were influenced by treatments with humic acid, but different in leafs and fruits.

De Lima *et al*. (2011) was conducted an experiment to evaluate the yield and quality of tomato fruits, hybrid "Vênus", produced on substrates and with application of nutrient solution and humic acids (AH). Four doses of AH were evaluated (0, 20, 40 and 80 L ha^{-1}) and 4 substrates: S1 (coconut fiber (CF)), S2 (FC + carbonized coffee husk (CC) in the ratio 1:3), S3 (CF + CC in the ratio 2:3) and S4 (CC), were evaluated following the randomized blocks design in factorial 4x4 scheme with four replications. The 35-day old seedlings were transplanted into plastic bags of 7 L. The humic acids were applied four times in eight-day intervals, and the first application was carried out eight days after transplanting. There was no significant effect of AH on the yield and quality of fruit, except in relation to soluble solids (SS)/titratable acidity (TA). Doses of up to 36 L ha^{-1}, increase the AT, above that amount favored increase of SS. The carbonized coffee husk in treatments S2, S3 and S4, did not alter the production of small fruits, medium, non-commercial, moisture, pH, SS, AT and SS/AT, however, significantly reduced the total production, commercial and large size fruit. The production of fruits in S1 was significantly higher compared to the other treatments, with an average of 142.6 t ha^{-1}, showing average increase in yield of 24.4%, 29.3% and 36.1% compared to plant of treatments S2, S3 and S4, respectively.

Loffredo *et al*. (1997) reported that, the morphology and length of roots and shoots of tomato (*Lycopersicon esculentum* Mill.) seedlings grown on a nutrient medium for fourteen days in a controlled environment chamber were apparently not affected, whereas the dry matter content of roots was significantly enhanced when 200 mg L^{-1} of humic acid (HA) isolated from either a non- amended soil or a sewage sludge amended soil was present in the nutrient medium. In contrast, the HA like fraction isolated directly from the sewage sludge caused, under the same conditions, extensive alterations of tomato morphology and a significant reduction of the length and dry weight of both shoots and roots. The presence in the nutrient medium of the herbicides alachlor or imazethapyr at concentrations of 1 and 0.01 mg L^{-1}, respectively, caused a marked decrease of tomato root and shoot length and dry weight. Differently, the herbicide rimsulfuron at a concentration of 0.01 mg L^{-1} produced a slight decrease in shoot and root length and a slight increase in their dry weight. A combination of 200 mg L^{-1} soil HA and each of the herbicides alachlor, rimsulfuron and imazethapyr at concentrations of 1, 0.01 and 0.01 mg L^{-1}, respectively, in the nutrient medium attenuated the growth depression of tomato shoots and roots observed in the presence of the herbicide alone. However, the simultaneous presence of sewage sludge HA and any herbicide in the nutrient solution caused negative synergistic effects on tomato growth. The volume of nutrient solution and the number of electrolytes taken up by tomato plants during the growth experiments correlated highly significantly with the total plant dry weight. Tomato seedlings induced a pH decrease in the nutrient medium in all treatments except in those where sludge HA was present, either alone or in combination with any herbicide.

Thi, L. H., and Bohme et al. (2001) were conducted greenhouse experiments to investigate the effect of humates on the growth of tomato plants in hydroponic systems. The investigations were carried out using different substrates (perlite, coconut fibre and peat-based substrates) and different concentrations and forms of humates (K-, Na- and NH4-humates). In general, treatments with humic acid increased seed germination, improved plant growth, and increased the content of Ca in shoots, leaves and fruits of tomato.

VirgineTenshia and Singram (2005) was conducted a pot culture experiment to study the influence of humic acid on nutrient availability and uptake in tomato. The data revealed that addition of humic acid @ 20 kg ha" along with 100% recommended dose of fertilizers improved the availability of major and micronutrients viz., iron and zinc and enhanced their uptake. Soil application of humic acid @ 20 kg ha"' along with 75% recommended dose of fertilizers improved the availability and uptake of nutrients than 100% recommended dose of fertilizers alone. Foliar spray of humic acid @ 0.1% showed significant increase in uptake of nutrients than the control.

2.2 Effect of salicylic acid

A field experiment was conducted by Mohammad (2013) to investigate the effect of seed presoaking of shikimic acid (30, 60 and 120 ppm) on growth parameters, fruit productivity and quality, transpiration rate, photosynthetic pigments and some mineral nutrition contents of tomato plants. Shikimic acid at all concentrations significantly increased fresh and dry weights, fruit number, average fresh and dry fruit yield, vitamin C, lycopene, carotenoid contents, total acidity and fruit total soluble sugars of tomato plants when compared to control plants. Seed pretreatment with shikimic acid at various doses induces a significant increase in total leaf conductivity, transpiration rate and photosynthetic pigments (Chl.a, chl.b and carotenoids) of tomato plants. Furthermore, shikimic acid at various doses applied significantly increased the concentration of nitrogen, phosphorus and potassium in tomato leaves as compared to control non-treated tomato plants. Among all doses of shikimic acid treatment, it was found that 60 ppm treatment caused a marked increase in growth, fruit productivity and quality and most studied parameters of tomato plants when compared to other treatments. On the other hand, no significant differences were observed in total photosynthetic pigments, concentrations of nitrogen and potassium in leaves of tomato plants treated with 30 ppm of shikimic acid and control plants. According to these results, it could be suggested that shikimic acid used for seed soaking could be used for increasing growth, fruit productivity and quality of tomato plants growing under field conditions.

Afsana *et al*. (2017) The current piece study was conducted to find out the role of exogenous foliar application of salicylic acid (SA) and calcium (Ca2+) on growth, reproductive behavior and yield of tomato. The single factor experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. At the experimental farm of Sher-e-Bangla Agricultural University, Dhaka, during the winter season of November 2013 to April 2014. BARI Tomato-15 was used as planting material. Six different treatments viz., A0=0 mM of SA and 0 mM Ca^{2+}, A1=0.25 mM SA and 0 mM Ca^{2+}, A2=0 mM SA and 5 mM Ca^{2+}, A3 =0.25 mM SA and 5 mM Ca^{2+}, A4 =0 mM of SA and 10 mM Ca^{2+} and A5 = 0.25 mM SA and 10 mM Ca^{2+} were applied in the morning at 15, 30, and 45 days after transplanting (DAT). Data of plant height, branch plant^{-1}, cluster plant^{-1}, flowers plant^{-1}, fruits plant^{-1}, fruit length (cm), fruit diameter (cm) and yield were recorded and analyzed for logical interpretation. The morphological and yield contributing characters as well as yield of tomato were positively influenced with single and combined application salicylic acid (SA) and calcium (Ca^{2+}). Significant increase of plant height and number of leaves plant^{-1} at 20, 40 and 60 DAT were observed with the application of A3 treatment. Application of A3 treatment also showed significant influence on production of cluster plant-1 (20.44), flowers plant^{-1} (168.1), and fruits plant^{-1} (99.42) as well as fruit yield (72.57 t ha^{-1}). However, application of A4 treatment failed to improve the morphological and yield contributing characters as well as yield of tomato over the A_0 treatment (control).Results suggests that combined application of SA and Ca^{2+} successfully increase the tomato fruit yield by altering the morphological and reproductive characters.

Bondok (2013) completed an experiment aimed to investigate the effect of foliar application with salicylic acid (2 mM/L) alone or combined with chitosan (0.1%) with or without TMV inoculation on improving resistance, growth, productivity and quality of tomato Hybrid Super Jackal F. as tomato (*Solanum lycopersicum*

L.) plants are considered sensitive to tomato mosaic virus especially during the reproductive growth phase. The study was conducted in the Experimental Farm, Faculty of Agriculture, Ain Shams University, Shoubra ElKheima, Egypt, during the two growing summer seasons of 2012 and 2013. All inoculated plants with TMV after 14 and 30 days from foliar application with combination of salicylic acid and chitosan, exhibited symptoms later and less severe than the plants inoculated with TMV in the other treatments. The SA plus CH foliar application without TMV inoculation gave the highest significant values of vegetative growth in both seasons. Combination treatment of SA plus CH increased significantly N, P, K, Fe and Zn concentration. This treatment was also effective in increasing tomato yield compared with treatment of infection alone. Our results showed that SA or CH alone or combined significantly increased ascorbic acid concentration compared with control treatment.

Eraslan *et al*. (2007) carried out an experiment to elucidate the effect of exogenously applied salicylic acid on growth, physiology and antioxidant activity of carrot plant. The results of their experiment revealed that salicylic acid significantly enhanced the overall growth, root dry mass, sulphur concentration, carotenoids and anthocyanin contents with a concomitant enhancement of total antioxidant activity of shoot and that of storage root. The SA application also regulated the proline accumulation both in shoot and storage root increased with the application of SA. At low concentrations, SA has no effect on the activities of these enzymes in vitro. Salicylic acid at higher concentrations (5 and 10 mM) though inhibited CAT activity; the activities of APX and POX remain unchanged. High concentration of SA increased the level of H2O2 and malondialdehyde both in root and leaf tissues. Thus, SA though has been reported to be a signal molecule for inducing various physiological and morphological attributes in plants, this study indicated the negative effect of the compound on growth and the activity of major enzymatic antioxidants.

Falcioni *et al*. (2014) reported that the salicylic acid (SA) is an inducer of systemic acquired resistance (SAR) and could be a potential candidate in the control of plant virus diseases. In this study we assayed under controlled conditions the potential effect of three doses of exogenous SA treatment on tomato plants infected with Potato virus X (PVX) and measured their effects on: different physiological parameters (gas exchange, stable isotopes, chlorophyll content), the activation of secondary metabolism, viral accumulation and induction of the expression of pathogenesis-related proteins (PRs) such as ß-1, 3-glucanase (PR2) and chitinase (PR3). SA treatment increased the expression of PR2, the activity of phenylalanine ammonia lyase (PAL) and the concentration of antioxidant compounds at 7 days post-treatment. Earlier expression of PR3 compared to PR2 was observed. SA treatment delayed the detection of PVX by ELISA in uninoculated leaves of mechanically infected tomato plants. Although the effect of PVX infection on physiological parameters was weak, moderate SA treatments showed enhanced photosynthesis, particularly for infected plants. The results obtained confirm that SA promotes major changes in the induction of resistance in tomato plants and suggest that treatment with exogenous SA could be considered to reduce the infections caused by PVX.

Hussein *et a*l. (2007) conducted a pot experiment where they sprayed salicylic acid to the foliage of wheat plants, irrigated with Mediterranean sea water and reported an enhanced productivity due to an improvement in all growth characteristics including plant height, number and area of green leaves, stem diameter and dry weight of stem, leaves and of the plant as a whole. Moreover, the plants that received treatment with SA had more proline content.

Javaheri *et al.* (2014) studied 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) in seedling stage as foliar replication. Measured characters was including (number of panicle in a bush, yield, fruit number in panicle, fruit number in bush, fruit weight and fruit diameter). 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 SA1 (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 treatment and the highest amount of fruit weight and also fruit diameter was measured in control treatment with mean of 61.50 g and 51.75 mm, respectively.

Javanmardi and Akbari (2016) reported that the most of the researches on Salicylic acid (SA) have focused on postharvest application or acquiring stress resistance, while studies on its effect on plant growth, secondary metabolites and fruit quality are limited. SA as foliar application (0, 150, 300 and 450 mg/L) at different plant growth stages on fruit yield, secondary metabolites and quality features of tomato (*Solanum lycopersicum* L. cv. Kardelen) under greenhouse conditions were evaluated. The highest fruit yield per plant (about 1.3-fold greater than control) was obtained from 300 mg/L SA when applied three weeks after fruit set. Comparing to control plants, the highest fruit firmness, 10 days prolonged storability, highest total phenolics (22.6 mg gallic acid equivalent per 100 g fw); and highest antioxidant activity (65.11) were observed when 450 mg/L SA applied at fruiting stage and 3 weeks later. An increasing pattern in ascorbic acid content was observed with increasing SA concentration irrespective to application time. The same concentration effect was observed in flavonoid content when plants treated at 3 weeks after fruiting. The highest effect of flavonoids on antioxidant activity was calculated using Pearson correlation (r=0.82). SA concentrations greater than 450 mg/L showed significantly adverse effects on all measured traits. The effect of exogenous SA on tomato plant depends on the developmental stage and SA concentrations tested. Improved fruit quality factors may happen in a certain concentration range, while over that may have negative or adverse effect.

Kazemi (2013) conducted an experiment in order to study effect of salicylic acid and calcium foliar application on growth, yield and yield components of strawberry plants as a factorial in completely randomized experimental design with four replications. These factors included of salicylic acid in 3 levels (0.25, 0.5 and 0.75 mM) and calcium in 2 levels (2.5 and 5 mM) spray on strawberry. Results showed that salicylic acid (0.25 mM) and calcium chloride (2.5 mM) spray either alone or in combination (0.25 mM SA+ 2.5 mM Ca^{2+}) affected on vegetative and reproductive growth, significantly. Mean comparisons indicated yield, and quality of strawberry plants was improved in low salicylic acid and calcium chloride concentration. In Finally, salicylic acid and calcium chloride application can be helpful for yield improvement and prevent of decreasing yield.

Kazemi (2014) conducted experiment to study the effect of salicylic acid and methyl jasmonate as pre- harvest treatments on the tomato vegetative growth, yield and fruit quality. The experiment was completely randomized experimental design with four replications. 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 $mmolL^{-1}$) and methyl jasmonate (0.25 $mmolL^{-1}$) either alone or in combination (0.5 $mmolL^{-1}$ SA + 0.25 $mmolL^{-1}$ MJ) increased vegetative and reproductive growth, yield and chlorophyll content. The application of salicylic acid (0. 5 $mmolL^{-1}$) alone significantly increased the leaves-NK content and dry weight and decreased the incidence of blossom-end rot, but methyl jasmonate application alone or in combination had not significant effect on blossom-end rot and leaves-NK content. The TSS, TA and vitamin C content of tomato fruit had significantly affected by the application of salicylic acid and methyl jasmonate either alone or in combination (0.5 $mmolL^{-1}$ SA+ 0.25 $mmolL^{-1}$ MJ). Application of salicylic acid with methyl jasmonate improved the yield contributing factors that resulted in significant increase in tomato fruit yield.

Kowalska and Smoleñ (2013) was conducted a study to evaluate the effect of an increased salt concentration in a nutrient solution and foliar application of salicylic acid and KMnO4 (the latter causing oxidative stress) on the yield, fruit quality and nutritional status of tomato plants. Salinity stress was stimulated by elevating the electrical conductivity (EC) of a nutrient solution by a proportional increase in the content of all macro- and micronutrients. In 2009- 2010, tomato plants were grown on rockwool, in a heated foil tunnel. 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: 1. control, without foliar application; 2. salicylic acid (SA); 3. SA/$KMnO_4$. In the SA/$KMnO_4$ combination, solutions of these compounds were applied alternately every 7 days. SA was applied in the concentration of 0.01%, while the concentration of $KMnO_4$ was 0.1%. Foliar treatments were conducted at 7-day intervals from the 3rd cluster flowering stage until ten days before the first harvesting of fruits. 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. Neither did it affect significantly the mineral status of plants except for an increase in the Mn level induced by SA/$KMnO_4$. A significantly higher content of ascorbic acid together with a decreased content of phenolic compounds and free amino acids resulted from the foliar application of SA and SA/$KMnO_4$. Salicylic acid counteracted the oxidative stress caused by $KMnO_4$.

Sahu *et al.* (2007) investigated the effect of various concentrations of salicylic acid (SA) on the growth, pigment content and the activity of antioxidants in the laboratory grown wheat plants. The root and shoot growth was affected at higher concentration of SA in early days of growth. The activities of catalase (CAT), ascorbate peroxidase (APX) and guaicol-specific peroxidase (POX) declined with the application of SA (50, 500 and 1000 µM), the decrease being more pronounced with the increase in SA concentrations both in the root and leaf tissues. On the other hand superoxide dismutase (SOD) activity increased with the application of SA. At low concentrations, SA has no effect on the activities of these enzymes in vitro. Salicylic acid at higher concentrations (5 and 10 mM) though inhibited CAT activity; the activities of APX and POX remain unchanged. High concentration of SA increased the level of H2O2 and malondialdehyde both in root and leaf tissues. Thus, SA though has been reported to be a signal molecule for inducing various physiological and morphological attributes in plants, this study indicated the negative effect of the compound on growth and the activity of major enzymatic antioxidants.

Salem *et al.* (2013) held three experiments (laboratory, field and pots) those were conducted at Giza Agric. Res. Station, ARC, Egypt, during the two successive summer seasons 2012 and 2013. Seed of teosinte variety (local) were primed in five concentrations of salicylic acid (0.4, 0.6, 0.8, 1.0 and 1.2 g/L) for 24 hours, as well as control with non-priming. The aims of this study was to determine the best level of salicylic acid of pre-sowing treatment for teosinte seeds to improve germination performance, germination speed, seedling characters, anti-oxidant enzyme activity and forage yield. A completely randomized design (CRD) at laboratory experiment, a randomized complete block design (RCBD) at field experiment and a split plot design at pot experiment with four replications were used. The results showed that seed priming with 0.6 g/L salicylic acid gave the highest germination speed, germination percentage, shoot and radical length and increased plant leaf area at pot experiment. And it increased fresh and dry forage yield fed, plant height, number of tillers plant, number of leaves plant and stem diameter of teosinte plants at the field experiment.

Shahba *et al.* (2010) stated that soil salinity is a serious environmental problem that has negative effect on plant growth, production and photosynthesis. Fresh and dry plant weights decrease with salinity treatments. The very important role of salicylic acid (SA) in response to different stress and modification and decline damages due to stresses has established in different studies. In this research tomato seeds planted in pots containing perlite in a growth chamber under controlled conditions of 27±2°c and 23±2°c temperature, 16h lightness and 8h 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 were used in the form of factorial experiment in a complete randomized design (CRD). 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 shoot 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.

Shakirova (2016) recorded enhanced germination and seedling growth in wheat, when the grains were subjected to pre-sowing seed-soaking treatment in salicylic acid.

Yıldırım and Dursun (2008) was conducted the study to determine the effect of foliar salicylic acid (SA) applications on fruit quality, growth and yield of tomato under greenhouse conditions in 2006 and 2007. 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-day intervals 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 our results, applications of 0.50 mM SA should be recommended in order to improve yield.

Zhang-Xin *et al.* (2004) observed the effects of SA on tolerance of tomato seedlings to cold stress were studied, with the tomato seedlings at three-leaf stage treated with a series of concentration of salicylic acid (SA) (0.5, 2.0, and 4.0 mmol/L). The results showed that SA could enhance the tolerance of tomato seedlings to cold stress, with the most effective for the concentration of SA at 2.0 mmol/L. Compared to non-treated tomato seedlings with cold stress, the rate of electrolyte leakage of tomato seedlings could be detected in the leaves of tomato seedlings treated with the concentration of SA at 2.0 mmol/L for 4 days after cold stress, which was significantly lower than other ones. While malondialdehyde (MDA) had a least increase of 73.01%. The content of soluble sugar had a highest increase of 87.35%. Chlorophyll content had a decrease of 16.47%. Therefore, the results suggested that tolerance of tomato seedlings to cold stress could be increased after a pre-treatment with SA at concentration of 2.0 mmol/L.

CHAPTER III

MATERIALS AND METHOD

This chapter deals with the materials and methods that were used to carrying out the experiment. It includes a short description of location of the experiment, characteristics of soil, climate, land preparation, manuring and fertilizing, transplanting and gap filling, stalking, harvesting and collection of data.

3.1 Experimental site

The experiment was conducted at the Horticulture farm of Sher-e-Bangla Agricultural University, Dhaka, during the period from November 2017 to April 2018. The location of the site in 23°74" N latitude and 90°35" E longitude with an elevation of 8.2 meter from sea level (Appendix-I).

3.2 Climate

The experimental site is located in subtropical region where climate is characterized by heavy rain fall during the months from April to September (Kharif season) and scanty rain fall during rest of the month (Rabi season). The maximum and minimum temperature, humidity and rainfall during the study period are collected from the Sher-e-Bangla mini weather station (Appendix-II).

3.3 Soil

The initial soil samples from 0-15 cm depth were collected from experimental field. The collected samples were analyzed at Soil Resources Development Institute (SRDI), Dhaka, Bangladesh. The physio-chemical properties of the soil are presented in Appendix-III. The soil of the experimental plots belonged to the agro-ecological zone of Madhupur Tract (AEZ-28), which is shown in Appendix-III.

3.4 Plant Materials

The tomato variety used in the experiment was BARI Tomato14. This is a high yielding determinate type variety.

3.5 Treatments of the Experiment

The experiment was designed to study the response of humic acid and salicylic acid on physiological growth, yield, antioxidant content and quality of tomato. The experiment consisted of two factors as follows:

Factor A: **Humic Acid**

a. H_0 = 0 ppm
b. H_1 = 20 ppm
c. H_2 = 40 ppm
d. H_3 = 80 ppm

Factor B: **Salicylic Acid**

a. S_0 = 0 ppm
b. S_1 = 30 ppm
c. S_2 = 70 ppm
d. S_3 = 110 ppm

3.6 Experimental design and layout

It was a two factorial experiment. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The experimental area was divided into three equal blocks. Every replication had sixteen plots where 16 treatments were allotted at randomly. The total number of plots was 48. The size of each plot was 2 m × 1.6 m. The distance between two blocks and two of plots both were l.0 m.

3.7 Land preparation

The selected land for the experiment was opened 6 October, 2017 with the help of a power tiller and kept open to sun for 4 days prior to further ploughing. The land was prepared well by ploughing and cross ploughing followed by laddering at 8 October, 2017. Weeds and stubble were removed and the basal dosed of fertilizers were applied and mixed thoroughly with the soil before final land preparation. The unit plots were prepared by keeping lm spacing in between two plots and 50cm drain was dug around the land. The space between each blocks and plots were made as drain having a depth of about 30 cm.

3.8 Seedbed preparation

Tomato seedlings were raised in the seedbed situated on a relatively high land at Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka. The size of the seedbed was 3 m x l m. The soil was well prepared with the help of spade and made into loose friable and dried mass to obtain fine tilth. All weeds and stubbles were removed and 5 kg well rotten cowdung was applied at seedbed during seedbed preparation. The seeds were sown on 20 October, 2017 and after sowing, seeds were covered with light soil. Heptachlor 40 WP was applied @ 4 kg/ha around each seedbed as precautionary measure against ants and worm. The germination of the seedlings took place within 5 to 6 days after sowing. Necessary shading by banana leaves was provided over the seed bed to protect the young seedlings from scorching sun or heavy rain. Weeding, mulching and irrigation were done from time to time as and when required and no chemical fertilizer was used in the seedbed.

3.9 Application of manures and fertilizers

Following doses of manures and fertilizers were commended for tomato production fertilizer recommendation guide (2012).

Fertilizers	**Doses ha^{-1}**
Cow dung	10 t
Urea	550 kg
TSP	450 kg
MoP	450 kg

Half of cow dung and all of TSP were applied as basal during final land preparation. Remaining cow dung was applied in pits before planting of seedlings. Urea and MoP were applied in two equal splits at 15 and 35 days after transplanting as ring method under moist soil condition and mixed thoroughly with the soil as soon as possible for better utilization.

3.10 Transplanting of seedlings

Healthy and uniform 30 days old seedlings were uprooted separately from the seed bed and were transplanted in the experimental plots in the afternoon of 19 November, 2017 maintaining a spacing of 60cm x 40cm between the rows and plants, respectively. The seedbed was watered before uprooting the seedlings from the seedbed so as to minimize damage of roots. The seedlings were watered after transplanting. Shading was provided using polythene with bamboo structure from seed sowing to harvesting to protect the seedlings from the adverse weather conditions in summer season. Seedlings were also planted around the border area of the experimental plots for gap filling.

3.11 Application of humic acid and salicylic acid

Humic acid and Salicylic acid in different concentrations were prepared and spraying at 30, 70 and 100 days after sowing (DAS) according to the treatments.

3.12 Intercultural Operations

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

3.12.1 Weeding

Weeding was done whenever necessary to keep the crop free from weeds.

3.12.2 Shoot pruning and stalking

For proper growth and development of the plants the main stems were managed upward by hand and with the help of bamboo stick. So, the rainy and stormy weather could not damage the growing stems of the plants.

3.12.3 Irrigation

The experiment was done in rabi season. So, irrigation was given when it was necessary. Sometimes rain was supplied sufficient water then irrigation was no need. When irrigation was applied then it was given through drains of the plots.

3.12.4 Plant protection

Tomato is a very sensitive plant to various insect pests and diseases. So, various protection measures were taken. Melathion 57 EC and Ripcord was applied @ 2 ml against the insect pests like beetle, fruit fly, fruit borer and other. The insecticide application was made fortnightly from 10 days after seed sowing to a week before first harvesting. During cloudy and hot weather precautionary measures against viral disease was taken by spraying. Furadan 5 G was also applied @ 6 g/pit during pit preparation as soil insecticide.

3.13 Harvesting

When the green fruits were in marketable condition then they were harvested. Fruits were also harvested when reddish color started to developing at the point where flowers are dropped.

3.14 Data collection

Data collected on the following parameters.

3.15 Data collection procedure

3.15.1 Plant height (cm)

Plant height was taken at three times during 30 DAS, 70 DAS and 100 DAS which measured in centimeter from ground level to tip of the main stem from each plant of each treatment and mean value was calculated.

3.15.2 Number of leaves per plant

Total number of leaves was counted at three times during 30 DAS, 70 DAS and 100 DAS from each plant of the treatment and mean value was calculated. The pruned leaves number was also included in counting.

3.15.3 Number of branches per plant

Total number of branches was counted at three times during 30 DAS, 70 DAS and 100 DAS from each plant of the treatment and mean value was calculated. The pruned branches number was also included in counting.

3.15.4 SPAD values of leaf

SPAD values of leaf were measured by SPAD meter (SPAD 502).

3.15.5 Total dry matter

Total dry mater of plant at harvest was calculated by aggregating the dry matter weight of leaves, stems, roots and other immature reproductive parts.

3.15.6 Days to 1st flowering

Days to 1st flowering were recorded by counting the number of days required from transplanting date to start flower initiation of tomato plant in each plot.

3.15.7 Days to 1st fruit set

Days to 1st fruit set were recorded by counting the number of days required from transplanting date to start fruit set of tomato plant in each plot.

3.15.8 Number of flower per pant

Number of flower per plant was counted from plant. Number of flower per plant was recorded for each treatment.

3.15.9 Number of fruit per plant

Number of fruit was counted from first harvest stage to last harvest. Number of fruit per plant was recorded for each treatment.

3.15.10 Fruit length and diameter (cm)

Fruit length and diameter was taken by vernier scale in centimeter. Diameter i.e. breath of fruit was measured at the middle portion of fruits from each plot and their average was taken. Average length of same fruits was also taken.

3.15.11 Weight of individual fruit (g)

Among the total number of fruits harvests during the period from first to final harvest, the fruits, except the first and last harvests, were considered for determining the individual fruit weight in gram (g).

3.15.12 Weight of fruits per plant (kg)

A per scale balance was used to take the weight of fruits per plant. It was measured by total fruit of plant separately during the period from fruit set to final harvest and was recorded in kilogram (kg).

3.15.13 Yield of fruits

To estimate yield, all the 10 plants in every plot and all the fruits in every harvest were considered. Thus, the average yield per plot was measured. The yield per hectare was calculated considering the area covered by the six plants.

3.15.14 Determination of total ash

10 gram of the sample was weighed accurately into a crucible. The crucible was placed on a clay pipe triangle and heated first over a low flame till all the material was completely charred, followed by heating in a muffle furnace for about 5-6 hours at 600°C. It was then cooled in a desiccator and weighed. To ensure completion of ashing, the crucible was then heated in the muffle furnace for 1h, cooled and weighed. This was repeated till two consecutive weights were the same and the ash was almost white or grayish white in color. Then total ash was calculated as following equation:

Ash content (g/l00 g sample) = Wt of ash × 100 / Wt of sample taken

(Raghuramulu *et al.*, 2003)

3.15.15 Determination of protein

Digestion: Turned on digestion block and heated to appropriate temperature. Accurately weighted approximately 0.5 g tomato sample. Recorded the weight. Placed tomato sample in digestion tube. Repeated for two more samples. Added one catalyst tablet and appropriate volume (e.g., 7 ml) of concentrated sulfuric acid to each tube with tomato sample. Prepared duplicate blanks: one catalyst tablet + volume of sulfuric acid used in the sample + weigh paper (if weigh paper was added with the tomato sample). Placed rack of digestion tubes on digestion block. Covered digestion block with exhaust system turned on. Let samples digest until digestion is complete. The samples were clear with no charred material remaining. Took samples off the digestion block and allow to cool with the exhaust system still turned on. Carefully diluted digest with an appropriate volume of distilled water. Swirled each tube.

Distillation: Followed appropriate procedure to start up distillation system. Dispensed appropriate volume of boric acid solution into the receiving flask. Placed receiving flask on distillation system. Make sure that the tube coming from the distillation of the sample is submerged in the boric acid solution. Put sample tube in place, making sure it is seated securely, and proceed with the distillation until completed. In this distillation process, a set volume of NaOH solution are delivered to the tube and a steam generator distilled the sample for a set period of time. Upon completing distillation of one sample, proceed with a new sample tube and receiving flask. After completing distillation of all samples, shut down the distillation unit.

Titration: Recorded the normality of the standardized HCl solution as determined. Put a magnetic stir bar in the receiver flask and place it on a stir plate. Kept the solution stirring briskly while titrating, but do not let the stir bar hit the electrode. Titrated each sample and blank to an endpoint pH of 4. Recorded volume of HCl titrant used. While using a colorimetric endpoint, put a magnetic stir bar in the receiver flask, placed it on a stir plate, and kept the solution stirring briskly while titrating. Titrated each sample and blank with the standardized HCl solution to the first faint gray color. Recorded volume of HCl titrant used.

Calculation: Moles of HCl = moles of NH3 = moles of N in the sample

A reagent blank was ran to subtract reagent nitrogen from the sample nitrogen.

% N = N HCl × Corrected acid volume g of sample ×14 g N mol ×100

A factor was used to convert percent N to percent crude protein. Most proteins contain 16% N, so the conversion factor is 6.25 (100/16 = 6.25).

% N/0.16 = % protein

3.15.16 Determination of Sugar

Reagents:

(1) Fehling A: Dissolve 69.28-g copper sulphate ($CuSO_4.5H_2O$) in distilled water. Dilute to 1000 ml. Filter and store in amber coloured bottle.

(2) Fehling B: Dissolve 346 g Rochelle salt (potassium sodium tartrate) (K Na $C_4H_4O_6$. $4H_2O$) and 100 g NaOH in distilled water. Dilute to 1000 ml. Filter and store in amber coloured bottle.

Standardization of Fehling's solution:

Prepare standard dextrose solution into a 50ml. burette. Find the titre (volume of dextrose solution required to reduce all the copper in 10 ml. of Fehling solution) corresponding to the standard dextrose solution (Refer table below).Pipette 10 ml of Fehling's solution into a 300 ml of conical flask and run in from the burette almost the whole of the standard dextrose solution required to effect reduction of all the copper, so that more than one millilitre will be required later to complete the titration. Heat the flask containing mixture over wire gauze. Gently boil the contents of the flask for 2 minutes. At the end of two minutes of boiling add without interrupting boiling, one ml. of methylene blue indicator solution. While the contents of the flask begins to boil, begin to add standard dextrose solution (one or two drops at a time) from the burette till blue color of indicator disappears [The titration should be completed within one minute so that the contents of the flask boil together for 3 minutes without interpretation. Note the titre (that is total volume in ml. of std. dextrose solution used for the reduction of all the copper in 10 ml. of Fehling's solution). Multiply the titre (obtd. by direct titration) by the number of milligrams of anhydrous dextrose in one millilitre of standard dextrose solution to obtain the dextrose factor. Compare this factor with the dextrose factor and determine correction.

Transfer test sample representing about 2- 2.5 gm sugar to 200 ml volumetric flask, dilute to about 100 ml and add excess of saturated neutral Lead acetate solution (about 2 ml is usually enough). Mix, dilute to volume and filter, discarding the first few ml filterate. Add dry Pot. or Sod. Oxalate to precipitate excess lead used in clarification, mix and filter, discarding the first few ml filterate.

Take 25 ml filterate or aliquot containing (if possible) 50 – 200 mg reducing sugars and titrate with mixed Fehling A and B solution using Lane and Eynon Volumetric method.

For inversion at room temperature, transfer 50 ml aliquot clarified and deleaded solution to a 100 ml volumetric flask, add 10 ml HCl (1+ 1) and let stand at room temperature for 24 hours. (For inversion, the sample with HCl can be heated at 70^0 C for 1 hr. This saves time and makes the whole process shorter). Neutralise exactly with conc. NaOH solution using phenolphthalein and dilute to 100 ml. Titrate against mixed Fehling A and B solution (25 ml of Fehling's Solution can be considered for the purpose) and determine total sugar as invert sugar (Calculate added sugar by deducting reducing sugars from total sugars).
Reducing and total reducing sugar can be calculated as;

$$\text{Reducing sugar (\%)} = \frac{\text{mg. of invert sugar x vol. made up x 100}}{\text{TR x Wt. of sample x 1000}}$$

$$\text{Total reducing sugar (\%)} = \frac{\text{mg. of invert sugar x final vol. made up x original volume x 100}}{\text{TR x Wt. of sample x 1000}}$$

Total sugar (as sucrose) (%)
= (Total reducing sugar – Reducing sugar) x 0.95
Added sugar = Total sugars – Reducing sugars

3.15.17 Vitamin C content

Vitamin C content of green and dry fruits were determined by 2, 6-dichlorophenol indophenols visual titration method. The following reagents were used for the estimation of vitamin C contains.

Reagents

i. **3% Metaphosphoric acid (HPO_3):** Was prepared by dissolving 30 g of HPO_3 and 80 ml glacial acetic acid in distilled water and volumes made up to one liter.

ii. **Standard ascorbic acid solution:** 10 % of L- ascorbic acid solvent was made by dissolving ascorbic acid in 3 metaphosphoric acid solution.

iii. **Dry solution:** It was prepared by dissolving 260 mg of sodium salt of 2, 6- dicholophenol indophenols in one liter of distilled water.

Procedure

Standardization of dye solution: Dilute 5 ml of standard ascorbic acid solution with 5 ml of Meta phosphoric acid. A micro burette was loaded with dye solution and the mixed solution was titrated with dye solution using phenolphthalein as indicator to the pink colored end point which insisted for at least 15 sec.

Dye factor was enumerated using the following formula:

$$\text{Dye factor} = \frac{0.5}{\text{Titre}}$$

Titration

5 ml of the aliquot was taken in conical flask and titrated with 2, 6- dicholophenol indophenols dye, phenolphthalein was used as indicator to a ping colored end point, which persisted at least 15 seconds. The ascorbic acid content (Vitamin C) of the sample was calculated by using the following formula:

$$\text{Ascorbic acid (mg/100g)} = \frac{T \times d \times V_1}{V_2 \times W} \times 100$$

Where,

T = Titre value (ml)

D = Dye factor

V_1 = Volume to be made (ml)

V_2 = Volume of extract taken for titration (ml)

W = Weight of sample taken for estimation (g)

3.15.18 Lycopene content

Procedure

I. Started with well homogenized tomato juice (prepared under vacuum to minimize the introduction of air bubbles), used a 100 µL Drummond micropipettor to take the sample. Dispensed the sample into a screw cap tube. Also prepared several blank samples with 100 µL water instead of tomato pulp.

II. Added 8.0 ml of hexane:ethanol:acetone (2:1:1) using a repipetter. Capped and vortex the tube immediately, then incubated out of bright light.

III. After at least 10 minutes, or as long as several hours later, added 1.0 ml water to each sample and vortex again.

IV. Let samples stand 10 minutes to allowed phases to separate and all air bubbles to disappear.

V. Rinsed the cuvette with the upper layer from one of the blank samples. Discard, then used a fresh blank to zero the spectrophotometer at 503 nm. Determined the A503 of the upper layers of the lycopene samples.

Calculation of lycopene levels

Lycopene levels in the hexane extracts were calculated according to:

$$\text{Lycopene (mg/kg fresh wt.)} = (A_{503} \times 537 \times 8 \times 0.55) / (0.10 \times 172) \quad (1)$$

$$= A_{503} \times 137.4 \quad (2)$$

where 537 g/mole is the molecular weight of lycopene, 8 mL is the volume of mixed solvent, 0.55 is the volume ratio of the upper layer to the mixed solvents, 0.10 g is the weight of tomato added, and 172 mM-1 is the extinction coefficient for lycopene in hexane.

3.16 Statistical analysis

Analysis of variance was performed in order to assess growth, antioxidant content and nutritional quality of tomato in response to humic acid and salicylic acid. Tukey's HSD tests were used to determine variances between each treatment where $P<0.05$ was considered as significant. Statistical analyses were carried out using IBM SPSS Statistics version 20.

CHAPTER IV

RESULTS AND DISCUSSION

This chapter comprises the presentation and discussion of the results from the experiment. The experiment was conducted to determine the response of humic acid and salicylic acid on growth and nutritional quality of tomato. Some of the data have been presented and expressed in table (s) and others in figures for ease of discussion, comparison and understanding. A summary of all the parameters have been shown in possible interpretation wherever necessary have given under the following headings.

4.1 Plant height (cm)

The effect of humic acid was significant on plant height at 30, 70 and 100 day after sowing (DAS). The tallest plant (10.72, 5.9.23, and 134.10cm at 30, 70 and 100 DAS, respectively) was produced by H_2 (40ppm humic acid) and the shortest plant (8.29, 48.73 and 118.88 cm at 30, 70 and 100DAS, respectively) was produced by H_0 (control) treatment (Table 1 and Appendix iv). The plant height was increased with increasing in humic acid significantly up to a certain level.

Plant height was recorded at 30, 70 and 100 DAS. Plant height at 30, 70 and 100 DAS due to the influence of different level of salicylic acid fertilizer was significant. The highest plant height (8.71, 51.38, and 122.20 cm at 30, 70 and 100 DAS, respectively) was produced from S_3 (110 ppm salicylic acid) treatment. However, the lowest plant height (8.29, 48.73 and 118.88 cm at 30, 70 and 100 DAS, respectively) was obtained from S_0 (control) treatment (Table 2 and Appendix iv). It was found that plant height increase with increasing salicylic acid. These findings are in agreement with those of Javaheri et al. (2012), Salem (2013), Kazemi (2013) who reported that SA independently increased the plant height of tomato.

Table 1. Effect of humic acid on plant height of tomato at different days after sowing (DAS)

Treatments	Plant height (cm)		
	30 DAS	70 DAS	100 DAS
H_0	6.73±0.09^{d}	41.28±0.50^{d}	105.10±0.58^{d}
H_1	7.63±0.04^{c}	46.50±0.49^{c}	116.83±0.57^{c}
H_2	10.72±0.07^{a}	59.23±0.32^{a}	134.10±0.63^{a}
H_3	9.08±0.12^{b}	53.77±0.48^{b}	126.10±0.55^{b}
$LSD_{(0.05)}$	0.24	1.39	1.80
P-value	0.00	0.00	0.00
CV(%)	2.50	2.50	1.35

Means with the same letter did not significantly differ from each other at $p<0.05$. Abbreviations are as follows H_0 = 0, H_1 = 20 ppm, H_2 = 40 ppm, H_3 = 80 ppm of humic acid. DAS = days after sowing. Values are mean ± SE.

Table 2. Effect of salicylic acid on the plant height of tomato at different days after sowing (DAS)

Treatments	Plant height(cm)		
	30 DAS	70 DAS	100 DAS
S_0	8.29±0.48^{b}	48.73±2.16^{b}	118.88±3.32^{c}
S_1	8.53±0.46ab	50.05±2.17^{ab}	120.05±3.15^{bc}
S_2	8.63±0.48^{a}	50.62±2.08^{a}	121.00±3.22^{ab}
S_3	8.71±0.43^{a}	51.38±1.95^{a}	122.20±3.46a
$LSD_{(0.05)}$	0.24	1.39	1.80
P-value	0.00	0.00	0.00
CV(%)	2.50	2.50	1.35

Means with the same letter did not significantly differ from each other at $p<0.05$. Abbreviations are as follows S_0 = 0, S_1 = 30 ppm, S_2 = 70 ppm, S_3 = 110 ppm of salicylic acid. DAS = days after sowing. Values are mean ± SE.

Table 3. Combined effect of humic acid and salicylic acid on the plant height of tomato at different days after sowing (DAS)

Treatments	Plant height(cm)		
	30 DAS	**70 DAS**	**100 DAS**
H_0S_0	6.40±.06^{f}	39.67±.18^{g}	103.00±.87^{e}
H_0S_1	6.60±.03^{ef}	40.73±.85^{g}	104.93±1.22^{e}
H_0S_2	6.70±.10^{ef}	41.33±.47^{fg}	105.07±.53^{e}
H_0S_3	7.20±.06de	43.40±.92^{efg}	107.40±.33^{e}
H_1S_0	7.60±.03^{d}	44.93±1.04^{def}	115.47±1.07^{d}
H_1S_1	7.57±.18^{d}	46.07±.59de	118.47±1.14^{d}
H_1S_2	7.70±.06^{d}	47.73±.1.09^{d}	116.87±1.44^{d}
H_1S_3	7.63±.03^{d}	47.27±.59^{d}	116.53±.64^{d}
H_2S_0	10.90±.10^{a}	58.53±.77^{ab}	133.93±2.03^{a}
H_2S_1	10.47±.10^{a}	59.33±.58^{a}	135.00±.53^{a}
H_2S_2	10.73±.13^{a}	59.47±.60^{a}	131.93±.27^{ab}
H_2S_3	10.77±.09^{a}	59.60±.81^{a}	135.53±.58^{a}
H_3S_0	8.90±.06^{bc}	51.80±.58^{c}	125.73±.79^{c}
H_3S_1	8.73±.03^{c}	54.07±.37^{c}	127.93±.44^{bc}
H_3S_2	9.47±.29^{b}	53.80±.83^{c}	123.73±.68^{c}
H_3S_3	9.23±.23^{bc}	55.40±.70^{bc}	127.00±.64^{c}
$LSD_{(0.05)}$	0.65	3.80	4.91
P-value	0.01	0.50	0.45
CV(%)	2.50	2.50	1.35

Means with the same letter did not significantly differ from each other at $p<0.05$. Abbreviations are as follows H_0 = 0, H_1 = 20 ppm, H_2 = 40 ppm, H_3 = 80 ppm of humic acid and S_0 = 0, S_1 = 30 ppm, S_2 = 70 ppm, S_3 = 110 ppm of salicylic acid. DAS = days after sowing. Values are mean ± SE.

The effect of humic acid and salicylic acid indicated a significant variation in plant height at (Table 3 and Appendix iv). The tallest plant height (10.77, 59.60, 135.53 cm at 30, 70 and 100 DAS, respectively) was found in H_2S_3 (40 ppm humic acid with 110 ppm salicylic acid) and the smallest plant height (6.40, 39.67 and 103.0 cm at 30, 70 and 100 DAS, respectively) was found in H_0S_0 (control) treatment.

4.2 Number of leaves per plant

A good number of leaves indicated better growth and development of crop. It is also possibly related to the yield of tomato. The greater number of leaf, the greater the photosynthetic area which may result higher fruit yield. The humic acid showed significant variation in the number of leaves per plant at 30, 70 and 100 DAS. The maximum number of leaves per plant (15.67, 22.92 and 49.23 at 30, 70 and 100 DAS, respectively) was produced by H_2 treatment, which was statistically identically with other and H_0 treatment produced the lowest number of leaves per plant (7.83, 13.68, and 33.35 at 30, 70 and 100 DAS, respectively) (Table 4 and Appendix v). Number of leaves per plant increased with increasing humic acid.

Number of leaves per plant due to the influence of salicylic acid was not significant at 30, 70 and 100 DAS. The S_3 treatment had the highest number of leaves per plant (11.67, 17.87, 42.28 and 65.01 at 30, 70 and 100 DAS, respectively). However, the lowest number of leaves per plant (11.17, 17.47 and 40.58 at 30, 70 and 100 DAS, respectively) was obtained from the S_0 treatment (Table 5 and Appendix v). Thus these result suggest that simultaneous application of SA produced higher number of tomato leaves. This fact was supported by many authors like Kazemi (2013), Salem (2013), Zamaninejad *et al*. (2013).

Table 4. Effect of humic acid on the number of leaves per plant at different days after sowing (DAS)

Treatments	Number of leaves per plant		
	30 DAS	70 DAS	100 DAS
H_0	7.83±.27[d]	13.68±.16[d]	33.35±.68[d]
H_1	10.17±.24[c]	15.88±.15[c]	38.82±.49[c]
H_2	15.67±.45[a]	22.92±.22[a]	49.23±.53[a]
H_3	11.83±.24[b]	18.20±.19[b]	43.45±.64[b]
$LSD_{(0.05)}$	1.23	0.64	1.93
P-value	0.00	0.00	0.00
CV(%)	9.75	3.28	4.23

Means with the same letter did not significantly differ from each other at $p<0.05$. Abbreviations are as follows H_0 = 0, H_1 = 20 ppm, H_2 = 40 ppm, H_3 = 80 ppm of humic acid. DAS = days after sowing. Values are mean ± SE.

Table 5. Effect of salicylic acid on the number of leaves per plant at different days after sowing (DAS)

Treatments	Number of leaves per plant		
	30 DAS	70 DAS	100 DAS
S_0	11.17±.92[a]	17.47±.95[a]	40.63±1.91[a]
S_1	11.33±.82[a]	17.52±1.08[a]	40.58±1.35[a]
S_2	11.33±1.09[a]	17.83±1.09[a]	41.35±2.14[a]
S_3	11.67±.80[a]	17.87±1.05[a]	42.28±1.91[a]
$LSD_{(0.05)}$	1.23	0.64	1.93
P-value	0.73	0.22	0.08
CV(%)	9.75	3.28	4.23

Means with the same letter did not significantly differ from each other at $p<0.05$. Abbreviations are as follows S_0 = 0, S_1 = 30 ppm, S_2 = 70 ppm, S_3 = 110 ppm of salicylic acid. DAS = days after sowing. Values are mean ± SE.

A significant variation in the number of leaves per plant was found between the humic acid and salicylic acid (Table 6 and Appendix v). The maximum number of leaves per plant (16.67, 23.47 and 50.80 at 30, 70 and 100 DAS, respectively) was found in H_2S_3 treatment, whereas the lowest number of leaves per plant (7.00, 13.27 and 31.20 at 30, 40 and 100 DAS, respectively) was found in H_0S_0.

Table 6. Combined effect of humic acid and salicylic acid on the number of leaves per plant of tomato at different days after sowing (DAS)

Treatments	**Number of leaves per plant**		
	30 DAS	**70 DAS**	**100 DAS**
H_0S_0	7.00±.67^{f}	13.27±.24^{f}	31.20±1.50^{i}
H_0S_1	7.67±.67^{f}	13.73±.18^{ef}	32.60±.35^{hi}
H_0S_2	8.33±.00^{ef}	13.87±.47^{ef}	34.80±.72^{ghi}
H_0S_3	8.33±.33^{ef}	13.87±.37^{ef}	34.80±1.63^{ghi}
H_1S_0	10.00±.58^{def}	16.27±.18^{cd}	37.40±.50^{fgh}
H_1S_1	10.33±.67^{def}	15.33±.24de	38.93±.18^{efg}
H_1S_2	10.00±.58^{def}	15.87±.24^{cd}	40.20±.2^{def}
H_1S_3	10.33±.33^{def}	16.07±.33^{cd}	38.73±1.79^{efg}
H_2S_0	16.00±1.15^{a}	22.40±.23^{a}	48.53±.52^{ab}
H_2S_1	15.33±.88^{ab}	22.67±.18^{a}	47.07±.24^{abc}
H_2S_2	16.67±.88^{a}	23.47±.57^{a}	50.80±.61^{a}
H_2S_3	14.67±.67^{abc}	23.13±.59^{a}	50.53±.88^{a}
H_3S_0	12.33±.33^{bcd}	17.47±.07^{bc}	44.00±1.86^{bcde}
H_3S_1	11.33±.33^{cde}	18.80±.50^{b}	41.53±.29^{def}
H_3S_2	11.67±.67^{cde}	18.13±.19^{b}	43.20±1.03^{cde}
H_3S_3	12.00±.58^{bcd}	18.40±.20^{b}	45.07±1.03^{bcd}
$LSD_{(0.05)}$	3.36	1.76	5.28
P-value	0.48	0.11	0.03
CV(%)	9.75	3.28	4.23

Means with the same letter did not significantly differ from each other at $p<0.05$. Abbreviations are as follows $H_0 = 0$, $H_1 = 20$ ppm, $H_2 = 40$ ppm, $H_3 = 80$ ppm of humic acid and $S_0 = 0$, $S_1 = 30$ ppm, $S_2 = 70$ ppm, $S_3 = 110$ ppm of salicylic acid. DAS = days after sowing. Values are mean ± SE.

4.3 Number of branches per plant

The humic acid showed significant variation in the number of branches per plant at 70 and 100 DAS. The maximum number of branches per plant (3.95 and 4.52, at 70 and 100 DAS) was produced by H_2 treatment. H_0 treatment produced the minimum number of branches per plant (2.08 and 3.17) (Table 7 and Appendix vi). These results indicate that humic acid increases the growth of tomato plant, which ensured the maximum number of branch than control.

The effect of salicylic acid was no significantly influenced on number of branch per plant. The S_3 had the highest number of branches per plant (3.13 and 3.85 at 70 and 100 DAS, respectively) and the lowest number of branches per plant (2.87, 3.77 at 70, and 100 DAS, respectively) was obtained from the S_0 treatment (Table 8 and Appendix vi). In contrast, Kazemi (2013) and Yildirim et al. (2009) observed significant effect of SA in increasing the number of branches in plant. Therefore, variety and environmental factors may have some influence of considerable branches production.

The interaction between different doses of humic acid and salicylic acid was found significant on the number of branches per plant (Table 9 and Appendix vi). The maximum number of branches per plant (4.67 and 4.67 at 70 and 100 DAS, respectively) was found in H_2S_3 treatment, whereas the lowest number of branches per plant (1.93 and 3.13 at 20, 30, 40 and 50 DAS, respectively) was found in H_0S_0 (control) treatment.

Table 7. Effect of humic acid on the number of branch per plant, SPAD value and total dry weight of plant

Treatments	Number of branches per plant		SPAD value		Plant total dry weight (g)
	70 DAS	100 DAS	70 DAS	100 DAS	
H_0	2.08±.07^{d}	3.17±.03^{d}	42.18±.26^{d}	51.00±.78^{d}	40.80±.34^{d}
H_1	2.72±.04^{c}	3.62±.03^{c}	45.59±.39^{c}	58.00±.42^{c}	45.16±.40^{c}
H_2	3.95±.04^{a}	4.52±.06^{a}	54.38±.58^{a}	74.82±.38^{a}	61.58±.30^{a}
H_3	3.30±.07^{b}	3.90±.04^{b}	49.67±.41^{b}	64.40±.44^{b}	52.00±.63^{b}
$LSD_{(0.05)}$	0.15	0.16	1.36	1.34	1.03
P-value	0.00	0.00	0.00	0.00	0.00
CV(%)	4.37	3.72	2.56	1.95	1.87

Means with the same letter did not significantly differ from each other at $p<0.05$. Abbreviations are as follows $H_0 = 0$, $H_1 = 20$ ppm, $H_2 = 40$ ppm, $H_3 = 80$ ppm of humic acid. DAS = days after sowing. Values are mean ± SE.

Table 8. Effect of salicylic acid on the number of branch per plant, SPAD value and total dry weight of plant

Treatments	Number of branches per plant		SPAD value		Plant total dry weight (g)
	70 DAS	100 DAS	70 DAS	100 DAS	
S_0	2.87±.23^{b}	3.77±.16^{a}	47.45±1.28^{a}	61.53±2.87^{a}	49.44±2.55^{b}
S_1	3.10±.22^{a}	3.82±.17^{a}	47.65±1.69^{a}	61.68±2.75^{ab}	49.99±2.29^{ab}
S_2	2.95±.18^{b}	3.77±.13^{a}	48.41±1.40^{a}	62.98±2.43^{a}	50.59±2.49^{a}
S_3	3.13±.22^{a}	3.85±.15^{a}	48.31±1.33^{a}	62.04±2.69^{ab}	49.52±2.26^{b}
$LSD_{(0.05)}$	0.15	0.16	1.36	1.34	1.03
P-value	0.00	0.41	0.17	0.03	0.02
CV(%)	4.37	3.72	2.56	1.95	1.87

Means with the same letter did not significantly differ from each other at $p<0.05$. Abbreviations are as follows $S_0 = 0$, $S_1 = 30$ ppm, $S_2 = 70$ ppm, $S_3 = 110$ ppm of salicylic acid. DAS = days after sowing. Values are mean ± SE.

Table 9. Combined effect of humic acid and salicylic acid on the number of branch per plant, SPAD value and total dry weight of plant

Treatments	Number of branches per plant		SPAD value		Plant total dry weight (g)
	70 DAS	100 DAS	70 DAS	100 DAS	
H_0S_0	$1.93 \pm .03^{h}$	$3.13 \pm .06^{f}$	$42.33 \pm .43^{hi}$	49.87 ± 1.39^{f}	$39.10 \pm .38^{f}$
H_0S_1	$2.13 \pm .07^{gh}$	$3.20 \pm .07^{ef}$	$41.07 \pm .20^{i}$	$48.70 \pm .85^{f}$	$41.13 \pm .33^{f}$
H_0S_2	$2.40 \pm .06^{fg}$	$3.20 \pm .06^{ef}$	$42.63 \pm .38^{ghi}$	$54.67 \pm .88^{e}$	$41.47 \pm .29^{ef}$
H_0S_3	$1.87 \pm .13^{h}$	$3.13 \pm .03^{f}$	$42.67 \pm .52^{ghi}$	$50.80 \pm .25^{f}$	$41.50 \pm .43^{ef}$
H_1S_0	$2.60 \pm .12^{ef}$	$3.60 \pm .06^{cde}$	44.83 ± 1.05^{fgh}	$57.17 \pm .47^{de}$	$46.57 \pm .96^{d}$
H_1S_1	$2.73 \pm .03^{ef}$	$3.53 \pm .07^{def}$	$45.40 \pm .75^{fgh}$	$58.73 \pm .78^{d}$	$44.33 \pm .57^{d}$
H_1S_2	$2.73 \pm .03^{ef}$	$3.73 \pm .03^{cd}$	$46.13 \pm .48^{fg}$	$56.77 \pm .41^{de}$	$44.07 \pm .07^{de}$
H_1S_3	$2.80 \pm .1^{e}$	$3.60 \pm .06^{cde}$	$46.00 \pm .98^{fgh}$	$59.37 \pm .71^{cd}$	$45.67 \pm .43^{d}$
H_2S_0	$4.00 \pm .06^{a}$	$4.47 \pm .03^{a}$	$52.60 \pm .80^{bcd}$	$75.47 \pm .46^{a}$	$62.07 \pm .81^{a}$
H_2S_1	$4.00 \pm .12^{a}$	$4.60 \pm .2^{a}$	$56.33 \pm .79^{a}$	$75.53 \pm .78^{a}$	$60.83 \pm .37^{a}$
H_2S_2	$3.87 \pm .07^{ab}$	$4.33 \pm .09^{ab}$	$55.00 \pm .83^{ab}$	$74.87 \pm .78^{a}$	$61.93 \pm .48^{a}$
H_2S_3	$3.93 \pm .07^{ab}$	$4.67 \pm .07^{a}$	53.60 ± 1.25^{abc}	$73.40 \pm .43^{a}$	$61.47 \pm .74^{a}$
H_3S_0	$3.27 \pm .07^{cd}$	$3.93 \pm .07^{bcd}$	$50.03 \pm .88^{cde}$	$64.23 \pm .55^{b}$	$52.23 \pm .60^{bc}$
H_3S_1	$3.53 \pm .07^{bc}$	$4.00 \pm .1^{bc}$	$47.80 \pm .12^{ef}$	$65.27 \pm .72^{b}$	$51.47 \pm .19^{c}$
H_3S_2	$3.47 \pm .03^{c}$	$3.80 \pm .1^{cd}$	$49.87 \pm .43^{de}$	$65.63 \pm .39^{b}$	$54.90 \pm .10^{b}$
H_3S_3	$2.93 \pm .07^{de}$	$3.87 \pm .07^{cd}$	$50.97 \pm .24^{cde}$	$62.47 \pm .42^{bc}$	$49.43 \pm .81^{c}$
$LSD_{(0.05)}$	0.40	0.43	3.72	3.66	2.83
P-value	0.00	0.17	0.01	0.00	0.01
CV(%)	4.37	3.72	2.56	1.95	1.87

Means with the same letter did not significantly differ from each other at $p<0.05$. Abbreviations are as follows H_0 = 0, H_1 = 20 ppm, H_2 = 40 ppm, H_3 = 80 ppm of humic acid and S_0 = 0, S_1 = 30 ppm, S_2 = 70 ppm, S_3 = 110 ppm of salicylic acid. DAS = days after sowing. Values are mean ± SE.

4.4 SPAD value

The humic acid showed significant variation in the SPAD value at 70 and 100 DAS. The maximum SPAD value (54.38 and 74.82, at 70 and 100 DAS, respectively) was produced by H_2 treatment. H_0 treatment produced the minimum SPAD value (42.18 and 51.00) (Table 7 and Appendix vi).

The effect of salicylic acid was no significantly influenced on SPAD value. The S_3 had the highest SPAD value (48.41 and 62.98 at 70 and 100 DAS, respectively) and the lowest SPAD value (47.45, 61.53 at 70, and 100 DAS, respectively) was obtained from the S_0 treatment (Table 8 and Appendix vi).

The interaction between different doses of humic acid and salicylic acid was found significant on the SPAD value (Table 9 and Appendix vi). The maximum SPAD value (56.33 and 75.53 at 70 and 100 DAS, respectively) was found in H_2S_1 treatment, whereas the lowest SPAD value (41.07 and 48.70 at 20, 30, 40 and 50 DAS, respectively) was found in H_0S_1 (control) treatment.

4.5 Total dry weight of plant (gm)

Humic acid had a significant influence on the total dry weight of plant. The highest total dry weight per plant (61.58 g) was recorded in H_2, which was statistically identical to that recorded in H_1 and H_3 (Table 7 and Appendix vi). The lowest total dry weight per plant (40.80 g) was recorded in H_0. Differences in morpho-physiological behaviors due to variety might influence the photosynthetic characters and hence influenced the total dry matter production.

There was significant variation in total dry weight per plant due to SA. The maximum total dry weight per plant (50.59 g) was obtained from S_2 and the minimum (40.44 g) from S_0 (Table 8 and Appendix vi).

Interaction of humic acid and SA had a significant effect on total dry weight per plant. The highest total dry weight per plant (61.93 g) was obtained from H_2S_2, which was statistically similar with H_2S_0, H_2S_1 and H_2S_3 while the lowest (39.10 g) from H_0S_0 (Table 9 and Appendix vi).

4.6 Days to first flowering

An insignificant variation was observed in days to first flowering due to humic acid (Table 10 and Appendix vii). The H_2 treatment required the earliest of days to first flowering (55.56 days). H_0 treatment was the longest time of first flowering (57.67days).

An insignificant difference was observed among the salicylic acid in the days to first flowering (Table 11 and Appendix vii). Delayed first flowering (57.22 days) was found in S_0 treatment and first flowering was earliest (56.42 days) in S_3 treatment.

The combined effect of humic acid and salicylic acid on days of first flowering was found to be significant. In table 12 and appendix vii shows that, the days of first flowering was minimum (53.50 days) in H_2S_3, while it was maximum (58.67 days) in H_0S_0 and H_3S_3 treatment.

4.7 Days to first fruit set

The different humic acid shows significant variation in the days to first fruit set. The H_1 treatment required the maximum time of days to first fruit set (64.22 days). H_2 treatment was the earliest in first fruit set (64.11 days) (Table 10 and Appendix vii).

There was a marked difference among the salicylic acid in the days to first fruit set. Delayed first fruit set (66.53 days) was found in S_0 treatment and first fruit set was earliest (65.30 days) in S_2 treatment (Table 11 and Appendix vii).

The combined effect of different humic acid and salicylic acid on days to first fruit set was found to be significant (Table 12 and Appendix vii). The minimum days to first fruit set (62.97 days) was found in H_2S_2 treatment. The maximum days to first fruit set (68.40 days) was found in H_0S_0 treatment.

Table 10. Effect of humic acid on days to first flowering and first fruit set, number of flowers per plant and number of fruits per plant of tomato

Treatments	Days to first flowering	Days to first fruit set	Number of flowers per plant	Number of fruits per plant
H_0	57.67±.67[a]	66.81±.30[ab]	37.17±.41[b]	26.50±.44[a]
H_1	57.04±.14[b]	67.22±.25[a]	37.50±.45[b]	27.33±.26[a]
H_2	55.56±.31[b]	64.11±.31[c]	37.25±.30[b]	27.25±.28[a]
H_3	57.17±.40[a]	66.08±.24[b]	38.58±.34[a]	27.42±.26[a]
$LSD_{(0.05)}$	1.05	0.84	0.9	0.94
P-value	0.00	0.00	0.00	0.04
CV(%)	1.67	1.14	2.17	3.15

Means with the same letter did not significantly differ from each other at $p<0.05$. Abbreviations are as follows H_0 = 0, H_1 = 20 ppm, H_2 = 40 ppm, H_3 = 80 ppm of humic acid. Values are mean ± SE.

Table 11. Effect of salicylic acid on days to first flowering and first fruit set, number of flowers per plant and number of fruits per plant of tomato

Treatments	Days to first flowering	Days to first fruit set	Number of flowers per plant	Number of fruits per plant
S_0	57.22±.41[a]	66.53±.48[a]	36.833±.36[b]	27.00±.37[ab]
S_1	57.09±.45[a]	66.15±.39[a]	37.833±.46[a]	26.83±.30[b]
S_2	57.04±.37[a]	65.30±.44[b]	38.167±.46[a]	27.83±.27[a]
S_3	56.42±.67[a]	66.23±.43[a]	37.67±.24[ab]	26.83±.30[b]
$LSD_{(0.05)}$	1.05	0.84	0.9033	0.94
P-value	0.19	0.00	0.00	0.02
CV(%)	1.67	1.14	2.17	3.15

Means with the same letter did not significantly differ from each other at $p<0.05$. Abbreviations are as follows S_0 = 0, S_1 = 30 ppm, S_2 = 70 ppm, S_3 = 110 ppm of salicylic acid. Values are mean ± SE.

Table 12. Combined effect of humic acid and salicylic acid on days to first flowering and first fruit set, number of flowers per plant and fruits per plant of tomato

Treatments	Days to first flowering	Days to first fruit set	Number of flowers per plant	Number of fruits per plant
H_0S_0	58.67±.17^{a}	68.40±.21^{a}	36.00±.33^{e}	25.33±.33^{c}
H_0S_1	58.00±.56^{abc}	66.33±.33^{abcd}	36.33±.33de	26.00±.58^{bc}
H_0S_2	58.00±1^{abc}	66.13±.13^{abcd}	39.33±.33^{ab}	28.00±.33^{ab}
H_0S_3	53.50±.29^{d}	66.37±.37^{abcd}	36.33±.33de	26.00±.58^{bc}
H_1S_0	55.56±.24^{bcd}	66.73±.27^{abc}	39.00±.58^{abc}	27.00±.58^{abc}
H_1S_1	56.33±.33^{cd}	67.50±.29^{ab}	38.67±.33^{abcd}	28.00±.58^{ab}
H_1S_2	56.00±.29^{abcd}	66.50±.29^{abcd}	36.67±.58^{cde}	27.67±.33^{abc}
H_1S_3	55.33±.17^{cd}	68.13±.59^{a}	36.33±.33de	27.00±.58^{abc}
H_2S_0	58.33±.17^{ab}	64.67±.88^{cde}	37.00±.58^{bcde}	27.67±.33^{abc}
H_2S_1	57.00±.58^{abc}	64.23±.39de	36.67±.67^{cde}	26.67±.33^{abc}
H_2S_2	56.53±.53^{abc}	62.97±.43^{e}	38.00±.58^{abcde}	28.67±.58^{a}
H_2S_3	53.50±.6^{d}	64.57±.30^{cde}	37.33±.67^{abcde}	26.67±.67^{abc}
H_3S_0	56.33±.33^{abcd}	66.33±.75^{abcd}	38.00±.58^{abcde}	28.00±.58^{ab}
H_3S_1	57.83±1.17^{abc}	66.53±.29^{abc}	39.33±.33^{ab}	26.67±.33^{abc}
H_3S_2	57.83±.44^{abc}	65.60±.31^{bcd}	39.67±.33^{a}	27.00±.58^{abc}
H_3S_3	58.67±.67^{a}	65.83±.44^{bcd}	37.33±.33^{abcde}	27.67±.33^{abc}
$LSD_{(0.05)}$	2.88	2.29	2.47	2.58
P-value	0.00	0.03	0.00	0.01
CV(%)	1.67	1.14	2.17	3.15

Means with the same letter did not significantly differ from each other at $p<0.05$. Abbreviations are as follows H_0 = 0, H_1 = 20 ppm, H_2 = 40 ppm, H_3 = 80 ppm of humic acid and S_0 = 0, S_1 = 30 ppm, S_2 = 70 ppm, S_3 = 110 ppm of salicylic acid. Values are mean ± SE.

4.8 Number of flowers per plant

The humic acid showed significant variation in the number of flowers per plant (Table 10 and Appendix vii). The maximum number of flowers per plant (38.58) was produced by H_3 treatment and H_0 produced the minimum number of flowers per plant (37.17), which was statistically similar with H_1 and H_2 treatment.

There was a significant difference among the salicylic acid fertilizer in the number of flowers per plant (Table 11 and Appendix vii). The maximum number of flowers per plant (38.17) was produced in S_2 treatment. The minimum number of flowers per cluster (36.83) was produced in S_0 treatment. Salicylic acid has effect on many functions of the plant such as hormone movement, active salt absorption, flowering and fruiting process, pollen germination that leads to maximum flowering with optimum doses (Bose and Tripathi, 1996).

The analysis of variance (Table 12 and Appendix vii) indicated a significant variation among the treatment combinations of humic acid and salicylic acid in number of flowers per plant. The maximum number of flowers per plant (28.67) was found in H_3S_2, whereas the minimum number of flowers per plant (36.00) was found in H_0S_0 treatment.

4.9 Number of fruits per plant

The humic acid showed insignificant variation in the number of fruit per plant (Table 10 and Appendix vii). The maximum number of fruit per plant (27.42) was produced by H_3treatment and H_0 produced the minimum number of fruit per plant (26.50).

Number of fruit per plant due to the influence of salicylic acid was significant (Table 11 and Appendix vii). The S_2 treatment had the highest number of fruit per plant (27.83), and the lowest number of fruit per plant (26.83) was obtained from the S_1 and S_3 treatment. Salicylic acid effects on the vascular cambium of fruits which are capable for meristematic activities. Muhal and Solanki (2014) reported that 100 ppm SA foliar spray registered significantly higher number of siliqua per plant compared to water spray. The spraying of concentrations of SA had a growth regulatory effect on number of fruit per plant and increased the fruit yield as suggested by Javaheri et al. (2012).

The interaction between humic acid and salicylic acid was found significant on the number of fruits per plant (Table 12 and Appendix vii). The maximum number of fruits per plant (28.67) was found in H_2S_2, whereas the lowest number of fruits per plant (25.33) was found in H_0S_0.

4.10 Length of fruit (cm)

The humic acid was exhibited significant variation in the length of fruit (Table 13 and Appendix viii). However, the longest fruit length (5.61 cm) was produced by H_2 and H_0 produced the shortest fruit length (4.69 cm). It was found that fruit length increase with increasing humic acid up to a certain level. Similar findings also reported by Gelmesa *et al.* (2010).

Insignificant variation in the length of fruit was found among the salicylic acid (Table 14 and Appendix viii). The longest fruit length (5.15 cm) was obtained from S_2 and the shortest fruit length (5.12 cm) was obtained from S_0, S_1, and S_3. Here result showed that SA increased fruit length as reported by Javaheri et al. (2012), Salem (2013) that application of SA increased the fruit length of tomato.

The variation in fruit length due to combined effect of humic acid and salicylic acid was found statistically significant (Table 15 and Appendix viii). The longest fruit length (5.70 cm) was found in H_2S_2, which was statistically similar with H_2S_0 whereas the shortest fruit length (4.60 cm) was found from H_0S_0.

4.11 Diameter of fruit (cm)

The variation in the diameter of fruit humic acid was exhibited significant (Table 13 and Appendix viii). The largest fruit diameter (5.48 cm) was produced by H_2 and H_0 produced the shortest fruit breath (4.28 cm). Similar findings also reported by Gelmesa *et al.* (2010).

A significant variation in the diameter of fruit was found among the salicylic acid (Table 14 and Appendix viii). The largest fruit diameter (5.26 cm) was obtained from S_2 and the shortest fruit diameter (4.91 cm) was obtained from S_0. Earlier many authors reported that SA played an important role on the fruit development and fruit setting in many crops. All together at present many researcher suggested that SA has positive functions on fruit diameter as well as fruit yield of tomato as supported by Javaheri et al. (2012).

The variation of fruit diameter due to combined effect of humic acid and salicylic acid was found statistically significant (Table 15 and Appendix viii). The largest fruit diameter (5.70 cm) was found in H_2S_0. The shortest fruit diameter (3.90 cm) was found in H_0S_0 treatment.

Table 13. Effect of humic acid on yield and yield contributing characters of tomato

Treatments	Fruit diameter (cm)	Fruit length (cm)	Individual fruit weight (g)	Yield per plant (kg)	Total yield per hectare (ton)
H_0	4.28±.11^{c}	4.69±.03^{d}	104.02±.42^{b}	2.76±.05^{b}	86.17±1.61^{b}
H_1	5.17±.08^{b}	4.99±.02^{c}	105.50±.41^{a}	2.89±.03^{a}	90.38±.80^{a}
H_2	5.48±.09^{a}	5.61±.03^{a}	105.04±.59^{ab}	2.86±.03^{a}	89.44±1.03^{a}
H_3	5.41±.08^{ab}	5.21±.03^{b}	105.93±.33^{a}	2.90±.02^{a}	90.48±.95^{a}
$LSD_{(0.05)}$	0.29	0.10	1.1174	0.10	3.25
P-value	0.00	0.00	0.00	0.00	0.00
CV(%)	5.08	1.78	0.96	3.28	3.29

Means with the same letter did not significantly differ from each other at $p<0.05$. Abbreviations are as follows H_0 = 0, H_1 = 20 ppm, H_2 = 40 ppm, H_3 = 80 ppm of humic acid. Values are mean ± SE.

Table 14. Effect of salicylic acid on yield and yield contributing characters of tomato

Treatments	Fruit diameter (cm)	Fruit length (cm)	Individual fruit weight (g)	Yield per plant (kg)	Total yield per hectare (ton)
S_0	4.91±.22^{b}	5.12±.11^{a}	104.58±.56^{b}	2.82±.05^{b}	87.97±1.49^{b}
S_1	5.06±.15^{ab}	5.12±.11^{a}	105.21±.54^{ab}	2.83±.03^{b}	88.21±.97^{b}
S_2	5.26±.12^{a}	5.15±.1^{a}	105.80±.23^{a}	2.95±.03^{a}	92.02±.83^{a}
S_3	5.11±.15^{ab}	5.12±.09^{a}	104.89±.49^{ab}	2.83±.04^{b}	88.28±1.2^{b}
$LSD_{(0.05)}$	0.29	0.10	1.1174	0.10	3.25
P-value	0.02	0.75	0.04	0.01	0.01
CV(%)	5.08	1.78	0.96	3.28	3.29

Means with the same letter did not significantly differ from each other at $p<0.05$. Abbreviations are as follows S_0 = 0, S_1 = 30 ppm, S_2 = 70 ppm, S_3 = 110 ppm of salicylic acid. Values are mean ± SE.

Table 15. Combined effect of humic acid and salicylic acid on yield and yield contributing characters of tomato

Treat ments	Fruit length(cm)	Fruit diameter (cm)	Individual fruit weight (g)	Yield per plant (kg)	Total yield per hectare (ton)
H_0S_0	4.60±.06[h]	3.90±0.0[e]	102.19±.50[d]	2.59±.04[c]	80.90±1.16[c]
H_0S_1	4.70±.1[gh]	4.10±.06[de]	105.18±.32[abcd]	2.74±.07[abc]	85.47±2.12[abc]
H_0S_2	4.73±.1[fgh]	4.70±.07[bcd]	105.02±.68[abcd]	2.87±.03[abc]	89.58±.94[abc]
H_0S_3	4.73±.21[fgh]	4.40±.07[cde]	103.70±.30[bcd]	2.70±.05[bc]	84.25±1.69[bc]
H_1S_0	4.97±.03[efg]	5.03±.03[abc]	106.64±.34[ab]	2.88±.06[ab]	89.97±1.69[ab]
H_1S_1	5.00±.06[def]	5.10±.06[abc]	103.37±.51[cd]	2.90±.07[ab]	90.46±2.30[ab]
H_1S_2	5.00±.1[def]	5.10±.06[ac]	106.05±.29[abc]	2.94±.03[ab]	91.69±.89[ab]
H_1S_3	5.00±.28[def]	5.43±.06[ab]	105.94±.38[abc]	2.86±.06[abc]	89.39±1.95[abc]
H_2S_0	5.60±.15[a]	5.70±.06[a]	103.61±.56[bcd]	2.87±.04[abc]	89.58±1.41[abc]
H_2S_1	5.57±.2[ab]	5.20±.03[ab]	106.16±1.33[abc]	2.86±.05[abc]	89.37±1.63[abc]
H_2S_2	5.70±.09[a]	5.67±.06[a]	105.98±.11[abc]	2.97±.06[ab]	92.74±1.96[ab]
H_2S_3	5.57±.19[ab]	5.37±.07[ab]	103.31±.29[cd]	2.76±.06[abc]	86.08±1.94[abc]
H_3S_0	5.10±.21[cde]	5.60±0.0[a]	105.89±.13[abc]	2.96±.06[ab]	92.65±1.82[ab]
H_3S_1	5.30±.12[bc]	5.23±0.0[ab]	105.04±.75[abcd]	2.80±.03[abc]	87.53±1.1[abc]
H_3S_2	5.27±.12[cd]	5.57±.09[a]	107.25±.48[a]	3.01±.06[a]	94.07±2.05[a]
H_3S_3	5.17±.13[cde]	5.25±.03[ab]	106.61±.97[ab]	2.95±.05[ab]	92.18±1.61[ab]
$LSD_{(0.05)}$	0.28	0.78	3.06	0.28	8.88
P-value	0.09	0.03	0.00	0.00	0.00
CV(%)	1.78	5.08	0.96	3.28	3.29

Means with the same letter did not significantly differ from each other at $p<0.05$. Abbreviations are as follows H_0 = 0, H_1 = 20 ppm, H_2 = 40 ppm, H_3 = 80 ppm of humic acid and S_0 = 0, S_1 = 30 ppm, S_2 = 70 ppm, S_3 = 110 ppm of salicylic acid. Values are mean ± SE.

4.12 Individual fruit weight (g)

Humic acid did influence significantly on the average weight of individual fruit weight (Table 13 and Appendix viii). The largest individual fruit weight (105.93 g) was produced by H_3, which was statistically similar with H_1 treatment and H_0 produced the lowest individual fruit weight (104.02 g).

The weight of individual fruit weight was significantly influenced by salicylic acid (Table 14 and Appendix viii). The largest individual fruit weight 105.80 g) was obtained from S_2 treatment. The lowest fruit weight (104.58 g) was obtained from S_0. These results indicate that salicylic acid increases the growth of tomato, which ensured the maximum weight of fruits/plant than control.

Individual fruit weight was significantly affected by both humic acid and salicylic acid (Table 15 and Appendix viii). The highest individual fruit weight (107.25 g) was found in H_3S_2. Whereas the lowest individual fruit weight (102.19 g) was found in H_0S_0 treatment.

4.13 Yield of fruits (kg) per plant

Humic acid had significant effect on the yield of fruits per plant (Table 13 and Appendix viii). The maximum yield of fruits per plant (2.90 kg) was produced by H_3 treatment, which was statistically similar with H_1 and H_2 and the minimum yield of fruits per plant (2.76 kg) was produced from H_0. Similar result was found by Anuja and Shakila (2006)

Salicylic Acid in tomato significantly influenced on the yield of fruits per plant (Table 14 and Appendix viii). The maximum yield of fruits per plant (2.95 kg) was obtained from S_2 treatment and the minimum yield of fruits per plant (2.82 kg) was obtained from $S_{0,}$ which was statistically similar with S_1 and S_3. Similar findings also reported by Meena (2010).

The combined effect of humic acid and salicylic acid was significant on yield of fruit per plant (Table 15 and Appendix viii). The highest yield of fruits per plant (3.01 kg) was obtained from H_3S_2.The lowest yield of fruits per plant (2.59 kg) was obtained from H_0S_0.

4.14 Total fruit yield per hectare (t/ha)

The yield of tomato per plot was converted into per hectare, and has been expressed in metric tons (Table 13 and Appendix viii). The different humic acid had significant effect on the yield of fruits per hectare. The maximum yield of fruits per hectare (90.48 tones) was obtained H_3 (80 ppm) treatment, which was statistically similar with H_1 and H_2 and the minimum yield of fruits per hectare (86.17 tones) was obtained from H_0 treatment. At 80 ppm humic acid, the yield of fruits was maximum due to the combination of number of fruits per plant, weight of individual fruit, low flower dropping. Fruit yield was gradually increased with increasing humic acid. Similar result was found by Anuja and Shakila (2006).

The total yield of tomato varied significantly due to the application of different levels of salicylic acid fertilizer (Table 14 and Appendix viii). The highest yield of fruit (92.02 t/ha) was obtained from S_2, while (S_0) gave the lowest (87.97 t/ha) yield, which was statistically similar with S_1 and S_3. This result showed that the yield of tomato increased gradually with the increased doses of salicylic acid fertilizer. This result showed that the yield of tomato increased gradually with the increased doses of salicylic acid fertilizer. Similarly Meena (2010) reported that 6 kg B/ha gave the highest fruit yield while the lowest was obtained from control. These results are consistent with the present morpho-physilogical and yield contributing characters such as plant height, leaf number per plant, branch number per plant number of flower per plant, fruit number and fruit length. Kazemi (2013) reported that SA increases the yield of tomato. The result in conformity of the present study of profound influence of salicylic acid levels to increase yield of tomato has been reported by many authors Salem et *al.* (2013).

The combined effect of humic acid and salicylic acid fertilizer was significant on yield of fruits per hectare (Table 15 and Appendix viii). The highest yield of fruits per hectare (94.07 tones) was obtained from H_3S_2 treatment. The lowest yield of fruits per hectare (80.90 tones) was obtained from H_0S_0 treatment. These is significant differences were observed among the all treatments. Therefore, the present results of this study indicate that yield increased with combined use of humic acid and salicylic acid.

4.15 Shelf-life of fruit

A significant variation was observed in fruit shelf-life due to humic acid (Table 16 and Appendix ix). The H_2 treatment required the maximum shelf-life of fruit (20.65 days). H_0 treatment was the minimum time of fruit shelf-life (12.74 days).

A significant difference was observed among the salicylic acid in the fruit shelf-life (Table 17 and Appendix ix). The maximum shelf-life of fruit (16.92 days) was found in S_3 treatment and first flowering was earliest (15.98 days) in S_0 treatment, which was statistically similar with S_1 and S_2.

The combined effect of humic acid and salicylic acid on days of fruit shelf-life was found to be significant. The days of fruit shelf-life was maximum (21.58 days) in H_2S_3, while it was minimum (12.47 days) in H_0S_1 treatment. (Table 18 and Appendix ix)

4.16 Ash percentage on fruit

Ash percentage on fruit was influenced by humic acid. The highest ash percentage on fruit (0.51) was obtained from H_2 and whereas the lowest (0.40) was observed in H_0 (control) treatment. (Table 16 and Appendix ix)

Different doses of SA was not significantly influenced on ash percentage on fruit. It was evident from the highest ash percentage on fruit (0.46) was recorded from S_0 and S_1 and the lowest ash percentage on fruit was (0.44) from S_3 treatment (Table 17 and Appendix ix)

Combination effect of humic acid and SA showed statistically significant variation on ash percentage on fruit. The highest ash percentage on fruit (0.52) was found from H_2S_0, while the lowest ash percentage on fruit (0.38) was recorded from H_0S_3, which was statistically similar with H_0S_1 (Table18 and Appendix ix).

Table 16. Effect of humic acid on Shelf-life, Ash, Protein, Brix and Sodium content on fruit of tomato

Treatments	Shelf-life (day)	Ash (%)	Protein (%)	ºBrix	Sodium (mg/100g)
H_0	12.74±.11[d]	0.40±.01[d]	2.1483±.03[c]	4.36±.05[a]	5.95±.14[d]
H_1	14.77±.2[c]	0.43±0[c]	2.2733±.06[b]	4.30±.02[ab]	6.64±.31[b]
H_2	20.65±.2[a]	0.51±.01[a]	2.3258±.03[a]	4.29±.02[ab]	6.21±.09[c]
H_3	16.98±.23[b]	0.46±0[b]	2.2433±.04[b]	4.25±.03[b]	7.22±.26[a]
$LSD_{(0.05)}$	0.54	0.02	0.05	0.09	0.25
P-value	0.00	0.00	0.00	0.03	0.00
CV(%)	2.97	3.9	1.88	1.91	3.43

Means with the same letter did not significantly differ from each other at $p<0.05$. Abbreviations are as follows $H_0 = 0$, $H_1 = 20$ ppm, $H_2 = 40$ ppm, $H_3 = 80$ ppm of humic acid. Values are mean ± SE.

Table 17. Effect of salicylic acid on Shelf-life, Ash, Protein, Brix and Sodium content on fruit of tomato

Treatments	Shelf-life (day)	Ash (%)	Protein (%)	ºBrix	Sodium (mg/100g)
S_0	15.98±.9[b]	0.46±.01[a]	2.27±.06[b]	4.24±.03[b]	6.14±.19[c]
S_1	16.06±.84[b]	0.46±.01[a]	2.33±.05[a]	4.28±.02[ab]	6.61±.28[ab]
S_2	16.18±.87[b]	0.45±.01[a]	2.18±.03[c]	4.36±.04[a]	6.82±.24[a]
S_3	16.92±.97[a]	0.44±.01[a]	2.22±.01[bc]	4.32±.03[ab]	6.46±.27[b]
$LSD_{(0.05)}$	0.54	0.02	0.05	0.09	0.25
P-value	0.00	0.04	0.00	0.01	0.00
CV(%)	2.97	3.9	1.88	1.91	3.43

Means with the same letter did not significantly differ from each other at $p<0.05$. Abbreviations are as follows $S_0 = 0$, $S_1 = 30$ ppm, $S_2 = 70$ ppm, $S_3 = 110$ ppm of salicylic acid. Values are mean ± SE.

Table 18. Combined effect of humic acid and salicylic acid on Shelf-life of fruit, Ash, Protein, Brix and Sodium content on fruit of tomato

Treatments	Shelf-life (day)	Ash (%)	Protein (%)	ºBrix	Sodium (mg/100g)
H_0S_0	12.83±.22[hi]	0.46±0[cde]	2.38±.02[abc]	4.13±.03[c]	6.61±.25[bcd]
H_0S_1	12.67±.22[i]	0.44±.01[de]	2.34±.03[abcd]	4.33±.03[abc]	5.91±.14[ef]
H_0S_2	12.47±.14[i]	0.42±.02[def]	2.20±.01[ef]	4.53±.07[a]	5.68±.13[fg]
H_0S_3	13.00±.25[hi]	0.38±.01[f]	2.18±.01[ef]	4.43±.03[ab]	5.60±.05[fg]
H_1S_0	14.16±.30[gh]	0.39±0[f]	1.94±.05[h]	4.30±.06[abc]	5.19±.19[g]
H_1S_1	14.83±.22[fg]	0.41±.01[ef]	2.44±.01[a]	4.27±.03[bc]	6.38±.03[cde]
H_1S_2	14.75±.52[g]	0.41±.01[ef]	2.02±.01[gh]	4.37±.03[abc]	7.08±.1[b]
H_1S_3	15.33±.30[efg]	0.41±.01[ef]	2.19±.01[ef]	4.28±.06[bc]	7.90±.2[a]
H_2S_0	20.67±.30[ab]	0.52±.01[a]	2.34±.02[abcd]	4.23±.03[bc]	6.11±.06[cdef]
H_2S_1	20.25±.25[ab]	0.51±.01[ab]	2.45±.05[a]	4.33±.03[abc]	5.94±.07[def]
H_2S_2	20.08±.17[b]	0.50±.03[abc]	2.27±.01[cde]	4.31±.01[abc]	6.65±.1[bc]
H_2S_3	21.58±.22[a]	0.50±.01[abc]	2.24±.01[de]	4.28±.02[bc]	6.14±.03[cdef]
H_3S_0	16.25±.25[def]	0.46±.01[abcd]	2.40±.01[ab]	4.30±.06[abc]	6.64±.06[bc]
H_3S_1	16.50±.14[cde]	0.46±.01[bcd]	2.08±.04[fg]	4.20±.06[bc]	8.20±.01[a]
H_3S_2	17.42±.08[cd]	0.46±0[abcd]	2.21±.02[e]	4.23±.09[bc]	7.86±.17[a]
H_3S_3	17.75±.50[c]	0.45±0[cde]	2.28±.01[bcde]	4.28±.04[bc]	6.19±.19[cdef]
$LSD_{(0.05)}$	1.46	0.05	0.13	0.25	0.68
P-value	0.05	0.01	0.00	0.00	0.00
CV(%)	2.97	3.9	1.88	1.91	3.43

Means with the same letter did not significantly differ from each other at $p<0.05$. Abbreviations are as follows H_0 = 0, H_1 = 20 ppm, H_2 = 40 ppm, H_3 = 80 ppm of humic acid and S_0 = 0, S_1 = 30 ppm, S_2 = 70 ppm, S_3 = 110 ppm of salicylic acid. Values are mean ± SE.

4.17 Protein percentage on fruit

Protein percentage on fruit was influenced by humic acid. The highest Protein percentage on fruit (2.33) was obtained from H_2 and whereas the lowest (2.15) was observed in H_0 (control) treatment. (Table 16 and Appendix ix)

Different doses of SA significantly influenced on Protein percentage on fruit. It was evident from the highest Protein percentage on fruit (2.33) was recorded from S_1 and the lowest Protein percentage on fruit (2.18) was obtained from S_2 treatment (Table 17 and Appendix ix)

Combination effect of humic acid and SA showed statistically significant variation on Protein percentage on fruit. The highest Protein percentage on fruit (2.45) was found from H_2S_1, while the lowest Protein percentage on fruit (1.94) was recorded from H_1S_0 (Table 18 and Appendix ix).

4.18 ^{o}Brix on fruit

^{o}Brix on fruit was influenced by humic acid. The highest ^{o}Brix on fruit (4.36) was obtained from H_0 treatment and whereas the lowest (4.25) was observed in H_3 treatment. (Table 16 and Appendix ix)

Different doses of SA significantly influenced on ^{o}Brix on fruit. The highest ^{o}Brix on fruit (4.36) was recorded from S_2, which was statistically identical with other and the lowest ^{o}Brix on fruit (4.24) was obtained from S_0 treatment (Table 17 and Appendix ix).

Combination effect of humic acid and SA showed statistically significant variation on ^{o}Brix on fruit. The highest ^{o}Brix on fruit (4.53) was found from H_0S_2, while the lowest ^{o}Brix on fruit (4.13) was recorded from H_0S_0 (Table 18 and Appendix ix).

4.19 Sodium percentage (mg/100g) on fruit

Sodium percentage on fruit was significantly influenced by humic acid. The highest Sodium percentage on fruit (7.22) was obtained from H_3 treatment, which was statistically identical from other and whereas the lowest (5.95) was observed in H_0 treatment. (Table 16 and Appendix ix)

Different doses of SA significantly influenced on Sodium percentage on fruit. The highest total Sodium percentage on fruit (6.82) was recorded from S_2 treatment, and the lowest Sodium percentage on fruit (6.14) was obtained from S_0 treatment, which was statistically identical with other (Table 17 and Appendix ix).

Combination effect of humic acid and SA showed statistically significant variation on Sodium percentage on fruit. The highest Sodium percentage on fruit (8.20) was found from H_3S_1, which was statistically similar with H_1S_3 and H_3S_2 while the lowest Sodium percentage on fruit (5.19) was recorded from H_1S_0 (Table 18 and Appendix ix).

4.20 Total sugar percentage on fruit

Total sugar percentage on fruit was influenced by humic acid. The highest total sugar percentage on fruit (4.26) was obtained from H_2 treatment, which was statistically identical from other and whereas the lowest (4.22) was observed in H_0 treatment. (Table 19 and Appendix x)

Different doses of SA significantly influenced on total sugar percentage on fruit. The highest total sugar percentage on fruit (4.28) was recorded from S_2, and the lowest total sugar percentage on fruit (4.22) was obtained from S_0 treatment, which was statistically similar with S_1 and S_3 (Table 20 and Appendix x).

Combination effect of humic acid and SA showed statistically significant variation on total sugar percentage on fruit. The highest total sugar percentage on fruit (4.40) was found from H_3S_1, while the lowest total sugar percentage on fruit (4.12) was recorded from H_0S_0 and H_3S_3 (Table 21 and Appendix x).

Table 19. Effect of humic acid on sugar percentage of tomato

Treatments	Total sugar percentage on fruit	Reducing sugar percentage on fruit	Non-reducing sugar percentage on fruit
H_0	4.22±.03^{b}	3.09±.02^{b}	1.13±.01^{a}
H_1	4.25±.02^{ab}	3.13±.04^{a}	1.12±.02^{a}
H_2	4.26±.02^{a}	3.13±.01^{a}	1.13±.01^{a}
H_3	4.24±.04^{ab}	3.14±.04^{a}	1.10±.01^{b}
$LSD_{(0.05)}$	0.03	0.02	0.01
P-value	0.01	0.00	0.00
CV(%)	0.6	0.65	1

Means with the same letter did not significantly differ from each other at $p<0.05$. Abbreviations are as follows H_0 = 0, H_1 = 20 ppm, H_2 = 40 ppm, H_3 = 80 ppm of humic acid. Values are mean ± SE.

Table 20. Effect of salicylic acid on sugar percentage of tomato

Treatments	Total sugar percentage on fruit	Reducing sugar percentage on fruit	Non-reducing sugar percentage on fruit
S_0	4.24±.02^{b}	3.10±.02^{c}	1.14±.01^{a}
S_1	4.24±.03^{b}	3.13±.04^{b}	1.11±0^{b}
S_2	4.27±.03^{a}	3.16±.04^{a}	1.11±.02^{b}
S_3	4.24±.03^{b}	3.10±.02^{c}	1.14±.01^{a}
$LSD_{(0.05)}$	0.03	0.02	0.01
P-value	0.00	0.00	0.00
CV(%)	0.6	0.65	1

Means with the same letter did not significantly differ from each other at $p<0.05$. Abbreviations are as follows S_0 = 0, S_1 = 30 ppm, S_2 = 70 ppm, S_3 = 110 ppm of salicylic acid. Values are mean ± SE.

Table 21. Combined effect of humic acid and salicylic acid on sugar percentage of tomato

Treatments	**Total sugar percentage on fruit**	**Reducing sugar percentage on fruit**	**Non-reducing sugar percentage on fruit**
H_0S_0	4.13±0[g]	3.03±0[e]	1.10±0[fg]
H_0S_1	4.19±.01[efg]	3.08±0[de]	1.11±.01[fg]
H_0S_2	4.23±.01[cdef]	3.08±.01[de]	1.15±.01[bcde]
H_0S_3	4.36±.01[ab]	3.18±.01[bc]	1.18±.01[ab]
H_1S_0	4.23±0[cdef]	3.07±.01[de]	1.16±.01[abc]
H_1S_1	4.17±.01[efg]	3.05±.01[e]	1.12±.01[def]
H_1S_2	4.37±.03[ab]	3.34±.02[a]	1.03±.01[h]
H_1S_3	4.24±.01[cde]	3.06±.01[de]	1.18±0[a]
H_2S_0	4.30±.01[bc]	3.14±.01[bc]	1.16±.01[abcd]
H_2S_1	4.18±.02[efg]	3.07±.01[de]	1.11±.01[fg]
H_2S_2	4.36±.01[ab]	3.20±.01[b]	1.16±.01[abc]
H_2S_3	4.22±.01[def]	3.12±.01[cd]	1.10±0[fg]
H_3S_0	4.29±0[bcd]	3.16±0[bc]	1.13±.01[cdef]
H_3S_1	4.42±0[a]	3.33±0[a]	1.09±0[g]
H_3S_2	4.15±0[fg]	3.04±.01[e]	1.11±.01[efg]
H_3S_3	4.12±.04[g]	3.03±.04[e]	1.09±.01[g]
$LSD_{(0.05)}$	0.08	0.06	0.03
P-value	0.00	0.00	0.00
CV(%)	0.6	0.65	1

Means with the same letter did not significantly differ from each other at $p<0.05$. Abbreviations are as follows H_0 = 0, H_1 = 20 ppm, H_2 = 40 ppm, H_3 = 80 ppm of humic acid and S_0 = 0, S_1 = 30 ppm, S_2 = 70 ppm, S_3 = 110 ppm of salicylic acid. Values are mean ± SE.

4.21 Reducing sugar percentage on fruit

Reducing sugar percentage on fruit was influenced by humic acid. The highest reducing sugar percentage on fruit (3.14) was obtained from H_3 treatment, which was statistically similar from H_1 and H_2 and whereas the lowest (3.09) was observed in H_0 treatment. (Table 19 and Appendix x)

Different doses of SA significantly influenced on reducing sugar percentage on fruit. The highest reducing sugar percentage on fruit (3.16) was recorded from S_2, and the lowest reducing sugar percentage on fruit (3.10) was obtained from S_0 and S_3 treatment (Table 20 and Appendix x).

Combination effect of humic acid and SA showed statistically significant variation on reducing sugar percentage on fruit. The highest reducing sugar percentage on fruit (3.34) was found from H_1S_2, while the lowest reducing sugar percentage on fruit (3.03) was recorded from H_0S_0 and H_3S_3 (Table 21 and Appendix x).

4.22 Non-reducing sugar percentage on fruit

Non-reducing sugar percentage on fruit was influenced by humic acid. The highest non-reducing sugar percentage on fruit (1.13) was obtained from H_0 and H_2 treatment, which was statistically with H_1 and whereas the lowest (1.10) was observed in H_3 treatment. (Table 19 and Appendix x)

Different doses of SA significantly influenced on non-reducing sugar percentage on fruit. The highest non-reducing sugar percentage on fruit (1.14) was recorded from S_0 and S_3, and the lowest non-reducing sugar percentage on fruit (1.11) was obtained from S_1 and S_2 treatment (Table 20 and Appendix x).

Combination effect of humic acid and SA showed statistically significant variation on non-reducing sugar percentage on fruit. The highest non-reducing sugar percentage on fruit (1.18) was found from H_1S_3, while the lowest total sugar percentage on fruit (1.09) was recorded from H_3S_3 (Table 21 and Appendix x).

4.23 Vitamin C content

The humic acid show significant variation in case of vit-C content in tomato fruit which is examined by sampling it in proper way. The higher amount vit-C (24.75 mg/100 g) found in H_0 treatment and lower amount vit-C (24.18 mg/100 g) found in H_2 treatment, which was statistically similar with H_3 (Table 22 and Appendix x)

The variation in vit-C content of tomato fruit due to different doses of SA is significant. The higher amount vit-C (24.94 mg/100 g) found in S_3 treatment which is statistically similar with S_1 treatments. The lower amount vit-C (23.86 mg/100 g) found in S_3 treatment. (Table 23 and Appendix x)

Due to combined effect of humic acid and different doses of SA performed significant effect on vit-C content. The treatment combination of H_0S_3 gave the maximum vit-C content (27.29 mg/100 g) and the minimum vit-C content (23.29 mg/100 g) was found from the treatment combination on H_1S_2 treatment (Table 24 and Appendix x).

4.24 Lycopene content on fruit

The humic acid show significant variation in case of lycopene content in tomato fruit which is examined by sampling in proper way. The higher amount lycopene content in fruit (4.82mg/100 g) found in H_1 and H_3 treatment and lower amount lycopene content in fruit (4.69 mg/100 g) found in H_2 treatment, which was statistically identical with H_0 (Table 22 and Appendix x).

The variation in lycopene content in fruit due to different doses of SA is significant. The higher amount lycopene content in fruit (4.84 mg/100 g) found in S_1 treatment which is statistically identically with all other treatments. The lower amount lycopene content in fruit (4.71 mg/100 g) found in S_3 treatment. (Table 23 and Appendix x).

Combined effect of humic acid and salicylic acid has no statistical difference on lycopene content in tomato among the treatments. The treatment combination of H_3S_1 gave the maximum lycopene content in fruit (5.00 mg/100 g) and the minimum lycopene content in fruit (4.56 mg/100 g) was found from the treatment combination on H_2S_0 treatment (Table 24 and Appendix x).

Table 22. Effect of humic acid on vit-C and lycopene content in tomato

Treatments	Vit-C content on fruit (mg/100 gm)	Lycopene content on fruit (mg/100 gm)
H_0	24.75±.47[a]	4.73±.03[b]
H_1	24.39±.28[ab]	4.82±.02[a]
H_2	24.18±.14[b]	4.69±.03[b]
H_3	24.21±.17[b]	4.82±.03[a]
$LSD_{(0.05)}$	0.5	0.06
P-value	0.01	0.00
CV(%)	1.87	1.06

Means with the same letter did not significantly differ from each other at $p<0.05$. Abbreviations are as follows H_0 = 0, H_1 = 20 ppm, H_2 = 40 ppm, H_3 = 80 ppm of humic acid. Values are mean ± SE.

Table 23. Effect of salicylic acid on vit-C and lycopene content in tomato

Treatments	Vit-C content on fruit (mg/100 gm)	Lycopene content on fruit (mg/100 gm)
S_0	24.23±.24[bc]	4.74±.03[bc]
S_1	24.50±.17[ab]	4.84±.04[a]
S_2	23.86±.18[c]	4.78±.02[ab]
S_3	24.94±.44[a]	4.71±.02[c]
$LSD_{(0.05)}$	0.5	0.06
P-value	0.00	0.00
CV(%)	1.87	1.06

Means with the same letter did not significantly differ from each other at $p<0.05$. Abbreviations are as follows S_0 = 0, S_1 = 30 ppm, S_2 = 70 ppm, S_3 = 110 ppm of salicylic acid. Values are mean ± SE.

Table 24. Combined effect of humic acid and salicylic acid on vit-C and lycopene content in tomato

Treatments	**Vit-C content on fruit (mg/100 gm)**	**Lycopene content on fruit (mg/100 gm)**
H_0S_0	23.63±.01[cd]	4.79±.01[bcd]
H_0S_1	24.72±.13[bc]	4.65±.02[def]
H_0S_2	23.38±.04[cd]	4.72±.09[bcde]
H_0S_3	27.29±.24[a]	4.78±.01[bcd]
H_1S_0	25.14±.34[b]	4.85±.01[abc]
H_1S_1	25.14±.35[b]	4.86±.03[ab]
H_1S_2	23.29±.20[d]	4.83±.02[bc]
H_1S_3	24.01±.41[bcd]	4.73±.02[bcde]
H_2S_0	24.47±.24[bcd]	4.56±.01[f]
H_2S_1	23.95±.17[bcd]	4.84±.02[bc]
H_2S_2	24.54±.34[bcd]	4.76±.01[bcde]
H_2S_3	23.74±.12[cd]	4.62±.02[ef]
H_3S_0	23.68±.56[cd]	4.77±.01[bcde]
H_3S_1	24.17±.18[bcd]	5.00±0[a]
H_3S_2	24.24±.05[bcd]	4.82±.01[bc]
H_3S_3	24.73±.1[bc]	4.70±.05[cdef]
$LSD_{(0.05)}$	1.38	0.15
P-value	0.00	0.00
CV(%)	1.87	1.06

Means with the same letter did not significantly differ from each other at $p<0.05$. Abbreviations are as follows H_0 = 0, H_1 = 20 ppm, H_2 = 40 ppm, H_3 = 80 ppm of humic acid and S_0 = 0, S_1 = 30 ppm, S_2 = 70 ppm, S_3 = 110 ppm of salicylic acid. Values are mean ± SE.

CHAPTER V

SUMMARY AND CONCLUSION

The field experiment was conducted at Sher-e-Bangla Agricultural University Farm, Dhaka, Bangladesh during October 2017 to April 2019 to find the response of humic acid and salicylic acid on growth, yield and nutritional quality of tomato. Four different doses of humic acid, viz., H_0= 0 ppm, H_1= 20 ppm, H_2= 40 ppm, H_3= 80 ppm and four doses of salicylic acid viz. S_0= 0 ppm, S_1= 30 ppm, S_2= 70 ppm, S_3= 110 ppm were used to conduct this experiment. The experiment was laid out in Randomized Complete Block Design (RCBD) having two factors and replicated three times. Data were taken on growth; yield contributing characters, yield and the collected data were statistically analyzed for evaluation of the treatment effects. The summary of the results has been described in this chapter.

The effect of humic acid was significant on plant height and number of leaves per plant at 30, 70 and 100 day after sowing (DAS). The tallest plant (10.72, 5.9.23, and 134.10cm at 30, 70 and 100 DAS, respectively) was produced by H_2 (40 ppm humic acid). The maximum number of leaves per plant (15.67, 22.92 and 49.23 at 30, 70 and 100 DAS, respectively) was produced by H_2 treatment. The humic acid showed significant variation in the number of branches per plant at 70 and 100 DAS. The maximum number of branches per plant (3.95 and 4.52, at 70 and 100 DAS) was produced by H_2 treatment. The highest total dry weight per plant (61.58 g) was recorded in H_2. The H_2 treatment required the earliest of days of first flowering (55.56 days). H_2 treatment was the earliest in first fruit set (64.11 days). The maximum number of flowers per plant (38.58), number of fruit per plant (27.42) was produced by H_3 treatment. The highest fruit thickness (5.61 cm), diameter (5.48 cm) was produced by H_2. The largest individual fruit weight (105.93 g) was produced by H_3. The humic acid had significant effect on the yield of fruits per plant. The maximum yield of fruits per plant (2.90 kg) was produced by H_3 treatment. The different humic acid had significant effect on the yield of fruits per hectare. The maximum yield of fruits per hectare (90.48 tones) was obtained H_3 (80 ppm) treatment and the minimum yield of fruits per hectare (86.17 tones) was obtained from H_0 treatment.

Ash percentage in tomato was influenced by humic acid. The highest ash percentage in tomato (0.51), protein percentage in tomato (2.33) was obtained from H_2. The highest brix percentage in tomato (4.36) was obtained from H_0 treatment. The highest total sugar percentage in tomato (4.26) was obtained from H_2 treatment. The highest sodium percentage in tomato (7.22) was obtained from H_3 treatment. The humic acid show significant variation in case of vit C content in tomato fruit which is examined by sampling it in proper way. The higher amount vit C (24.75 mg/100 g) found in H_0 treatment. The higher amount lycopene content in fruit (4.82 mg/100 g) found in H_1.

Plant height was recorded at 30, 70 and 100 DAS. Plant height at 30, 70 and 100 DAS was influenced due to different level of salicylic acid fertilizer was significant. The highest plant height (8.71, 51.38, and 122.20 cm at 30, 70 and 100 DAS, respectively) and number of leaves per plant (11.67, 17.87, 42.28 and 65.01 at 30, 70 and 100 DAS, respectively) was produced from S_3 (110 ppm salicylic acid) treatment. The S_3 had the highest number of branches per plant (3.13 and 3.85 at 70 and 100 DAS, respectively). The maximum total dry mater per plant (50.59 g) was obtained from S_2. Delayed first flowering (57.22 days) was found in S_0 treatment and first flowering was earliest (56.42 days) in S_3 treatment. The earliest (65.30 days) fruit set was in S_2 treatment. There was a significant difference among the salicylic acid fertilizer in the number of flowers per plant and number of fruit per plant. The maximum number of flowers per plant (38.17), number of fruit per plant (27.83) was produced in S_2 treatment. The longest fruit length (5.15 cm), fruit diameter (5.26 cm) was obtained from S_2. The largest individual fruit weight 105.80 g) was obtained from S_2 treatment. The maximum yield of fruits per plant (2.95 kg) was obtained from S_2 treatment. The highest yield of fruit (92.02 t/ha) was obtained from S_2, while (S_0) gave the lowest (87.97 t/ha) yield.

Different doses of SA was not significantly influenced on ash percentage on fruit. It was evident from the highest ash percentage on fruit (0.46) was recorded from S_0 and S_1. The highest protein percentage on fruit (2.33) was recorded from S_1. The highest brix percentage on fruit (4.36), total sugar percentage on fruit (4.28), total sodium percentage on fruit (6.82) was recorded from S_2. The variation in vit C content of tomato fruit was due to different doses of salicylic acid. The higher amount vit C (24.94 mg/100 g) found in S_3 treatment. The higher amount lycopene content in fruit (4.84 mg/100 g) found in S_1 treatment.

The effect of different doses of humic acid and different doses of salicylic acid indicated a significant variation in all parameter. The tallest plant height (10.77, 59.60, 135.53 cm at 30, 70 and 100 DAS, respectively) and maximum number of leaves per plant (16.67, 23.47 and 50.80 at 30, 70 and 100 DAS, respectively) was found in H_2S_3 (40 ppm humic acid with 110 ppm salicylic acid). The maximum number of branches per plant (4.67 and 4.67 at 70 and 100 DAS, respectively) was found in H_2S_3 treatment. The maximum SPAD value (56.33 and 75.53 at 70 and 100 DAS, respectively) was found in H_2S_1 treatment. The highest total dry mater per plant (61.93 g) was obtained from H_2S_2, the days of first flowering was minimum (53.50 days) in H_2S_3, The minimum days to first fruit set (62.97 days) was found in H_2S_2 treatment. The maximum number of flowers per plant (28.67) was found in H_3S_2. The maximum number of fruits per plant (28.67) was found in H_2S_2. The longest fruit length (5.70 cm) and fruit diameter (5.67 cm) was found in H_2S_2. The highest individual fruit weight (107.25 g) was found in H_3S_2. The highest yield of fruits per plant (3.01 kg) was obtained from H_3S_2. The highest yield of fruits per hectare (94.07 tones) was obtained from H_3S_2 treatment. The lowest yield of fruits per hectare (80.90 tones) was obtained from H_0S_0 treatment.

The highest ash percentage on fruit (0.52) was found from H_2S_0, The highest protein percentage on fruit (2.45) was found from H_2S_1. The highest brix percentage on fruit (4.53) was found from H_0S_2. The highest total sugar percentage on fruit (4.40) was found from H_3S_1. The highest sodium percentage on fruit (8.20) was found from H_3S_1. The treatment combination of H_0S_3 gave the maximum vit

C content (27.29 mg/100 g). The treatment combination of H_3S_1 gave the maximum lycopene content (5.00 mg/100 g) in fruit.

Further investigation may carry out in different agro ecological zones of Bangladesh before giving any recommendation.

REFERENCES

Abdellatif, I. M. Y., Abdel-Ati, Y. Y., Abdel-Mageed, Y. T., Hassan, M. A. M. M. (2017). Effect of humic acid on growth and productivity of tomato plants under heat stress. Journal of Horticultural Research, 25(2): 59-66.

Adani, F., Genevini, P., Zaccheo, P., Zocchi, G. (1998). The effect of commercial humic acid on tomato plant growth and mineral nutrition. Journal of plant nutrition, 21(3): 561-575.

Afsana, N., Islam, M. M., Hossain, E., Nizam, R., Monalesa, N., Hussain, A., Parvin, S. (2017) Response of Tomato (*Solanum lycopersicum* L.) to Salicylic Acid and Calcium.J. Appl. Life Sci. Intl., 15(2):1-7.

Agarwal, Palma and Francisco. (2005). Combined effect of salicylic acid and salinity on some antioxidant activities, oxidative stress and metabolite accumulation in Phaseolus vulgaris. Plant Growth Regulation (58.3): 307-316.

Anuja, S., and Shakila, A. (2006). Effect of bioregulators on yield and quality of tomato. Advances in Plant Sciences, 19(1): 53.

Aman, S. and Rab, A. (2013). Response of tomato to nitrogen levels with or without humic acid.Sarhad J. Agric. 29 (2): 181-186.

Asri, F. O., Demirtas, E. I., Ari, N. (2015). Changes in fruit yield, quality and nutrient concentrations in response to soil humic acid applications in processing tomato. Bulgarian Journal of Agricultural Science, 21(3): 585-591.

Basra, Wahid, Abdul, M., Perveen and S., Gelani. (2007). Pretreatment of seed with H_2O_2 improves salt tolerance of wheat seedlings by alleviation of oxidative damage and expression of stress proteins. Journal of Plant Physiology 164: 283-294.

Böhme, M., Thi Lua, H. (1999, August). Influence of humic acid on the growth of tomato in hydroponic systems. In International Symposium on Growing Media and Hydroponics 548, pp. 451-458.

Bondok, H., El-Mohamedy, R. S., Abdel-Kareem, F., Abdallah, R. A., Gueddes-Chahed, M., and Daami-Remadi, M. (2013). Variation in chitosan and salicylic acid efficacy towards soil-borne and air-borne fungi and their suppressive effect of tomato wilt severity. J Plant Pathol Microbiol, *6*(325), 2.

Bose, U. S., and Tripathi, S. K. (1996). Effect of micronutrients on growth, yield and quality of tomato cv. Pusa Ruby in MP. Crop Research-Hisar, 12: 61-64.

Canellas, L. P., Olivares, F. L., Façanha, A. L. O. and Façanha, A. R. (2002). Humic acids isolated from earthworm compost enhance root elongation, lateral root emergence, and plasma membrane H^+-ATPase activity in maize roots. Plant Physiology 130: 1951-1957.

Chen, Y., and T. Aviad. (1990). Effects of humic substances on plant growth. In: MacCarthy, P., Clapp, C.E., Malcom, R.L., Bloom, P.R. (Eds.), In Humic Substances in Soils and Crop Science: Selected Readings, soil science society of America, Madison, pp. 161–186.

De Lima, A. A., Alvarenga, M. A. R., Rodrigues, L., and Chitarra, A. B. (2011). Yield and quality of tomato produced on substrates and with application of humic acids. Horticultura Brasileira, 29(3): 269-274.

Doares, Steven H. (1995). Salicylic acid inhibits synthesis of proteinase inhibitors in tomato leaves induced by systemin and jasmonic acid. Plant physiology 108(4): 1741-1746.

Doran, I., C. Akinci and M. Yildirim. (2003). Effects of delta humate applied with different doses and methods on yield and yield components of diyarbakir-81 wheat cultivar. 5th Field Crops Congress. Diyarbakir. Turkey. 2: 530-534 (in Turkish with English abstracts).

El-Ghamry, A.M., K.M.A., E. Hai and K.M. Ghoneem. (2009). Amino and Humic acids promote growth, yield and disease resistance of faba bean cultivated in clayey soil. Aust. J. Basic Applied Sci. 3: 731-739.

El-Tayeb, M. A. (2005). Response of barley grains to the interactive effect of salinity and salicylic acid. Journal of Plant Growth Regulation. 45: 215–224.

Eraslan, F., Inal, A., Gunes, A., and Alpaslan, M. (2007). Impact of exogenous salicylic acid on the growth, antioxidant activity and physiology of carrot plants subjected to combined salinity and boron toxicity. Scientia horticulturae, 113(2): 120-128.

Façanha, A.R., Façanha, A. L. O., Olivares, F. L., Guridi, F. G. A., Velloso, A. C. X.,Rumjanek, V. M. R.,Brasil, F.,Schripsema, J.,Braz-filho, R., Oliveira M. A., and Canellas, L. P. C. (2002). Bioatividade de ácidoshúmicos: efeitossobre o desenvolvimento radicular e sobre a bomba de prótons da membranaplasmática. *Pesquisa Agropecuária Brasileira* 37: 1301-1310.

Falcioni, T., Ferrio, J. P., Del Cueto, A. I., Giné, J., Achón, M. Á., and Medina, V. (2014). Effect of salicylic acid treatment on tomato plant physiology and tolerance to potato virus X infection. European journal of plant pathology, 138(2): 331-345.

Gelmesa, D., Abebie, B., and Desalegn, L. (2010). Effects of Gibberellic acid and 2, 4-dichlorophenoxyacetic acid spray on fruit yield and quality of tomato (Lycopersicon esculentum Mill.). Journal of Plant Breeding and Crop Science, 2(10): 316-324.

Gunes, A., M. Alpaslan, N. Cicek, E. Guneri, and T. Guzelordu. (2005). Effects of exogenously applied salicylic acid on the induction of multiple stress tolerance and mineral nutrition in maize. International Journal of Agriculture and Biology 51: 678–695.

Hamada, A. M., and A. M. A. Al-Hakimi. (2001). Concentration of salinity stress on wheat plants by grain soaking in ascorbic acid, thiamin or sodium salicylate. J. Plant Biology. 44: 253–261.

Hussein, M. M., Balbaa, L. K., and Gaballah, M. S. (2007). Salicylic acid and salinity effects on growth of maize plants. Research Journal of Agriculture and Biological Sciences, 3(4): 321-328.

Javaheri, M., Mashayekhi, K., Dadkhah, A., and Tavallaee, F. Z. (2012). Effects of salicylic acid on yield and quality characters of tomato fruit (Lycopersicum esculentum Mill.). Int. J. Agric. Crop Sci, 4(16): 1184-1187.

Javanmardi, J. and Akbari, N. (2016). Salicylic acid at different plant growth stages affects secondary metabolites and phisico-chemical parameters of greenhouse tomato. Adv. Hort. Sci., 30(3): 151-157.

Karlidag, H., E. Yildirim, and M. Turan. (2009). Salicylic acid ameliorates the adverse effect of salt stress on strawberry. Journal of Agriculture Science 66: 180–187.

Kazemi, M. (2013). Foliar application of salicylic acid and calcium on yield, yield component and chemical properties of strawberry. Bull. Env. Pharmacol. Life Sci, 2(11): 19-23.

Kazemi, M. (2014). Effect of foliar application with salicylic acid and methyl jasmonate on growth, flowering, yield and fruit quality of tomato. Bulletin of Environment, Pharmacology and Life Sciences, 3(2): 154-158.

Kowalska, I., and Smoleñ, S. (2013). Effect of foliar application of salicylic acid on the response of tomato plants to oxidative stress and salinity. Journal of Elementology, 18(2): 216-221.

Landberg, T., and M. Greger. (2002). Differences in oxidative stress in heavy metal resistance and sensitive clones of Salix viminalis. Journa of Plant Physiology 156: 69–75.

Leon, J., L. A. Lawton, and I. Raskin. (1995). Hydrogene peroxide stimulate salicylic acid biosynthesis in tobacco. Journal of Plant Physiology 108: 1673–1678.

Leventtuna, A., C. Kaya, M. Dikilitas, I. Yokas, B. Burun, and H. Altunlu. (2007). Comparative effects of various salicylic acid derivatives on key growth parameters and some enzyme activities in salinity stressed maize plants. Pakistan Journal of Botany 39: 787–798.

Loffredo, E., Senesi, N., and D'Orazio, V. (1997). Effects of humic acids and herbicides, and their combinations on the growth of tomato seedlings in hydroponics. Zeitschriftfür Pflanzenernährung und Bodenkunde, 160(4): 455-461.

MacCarthy, P., R. Malcolm, C. Clapp, and P. Bloom. (1990).An introduction to soil humic substances. In humic substances in soil and crop sciences, eds. P. MacCarthy, C. Clapp, R. Malcolm, and P. Bloom, 1–12. Madison, WI: ASA-CSSA.

Maibangsa, S., M. Thangaraj, and R. Stephen. (2000). Effect of brassinosteriod and SA on rice grown under low irradiance condition. Indian J. Agril. Sci. 34: 258–260.

McDonnell, R., N.M. Holden, S.M. Ward, J.F. Collins, E.P. Farrell and M.H.B. Hayes. (2001). Characteristics of Humic substances in health, land and forested peat soils of the Wicklow mountains. Bio. Environ. 101: 187-197.

Meena, A. K., AND Rao, M. M. (2010). Folk herbal medicines used by the Meena community in Rajasthan. Trends in Food Science and Technology, 21(10): 502-509.

Metwally, A., I. Finkmeier, M. George, and K. Dietz. (2003). Salicylic acid alleviates the cadmium toxicity in barley seedlings. J. Plant Physiology 1321: 272–281.

Mohammad, Yusuf, M., Hayat, S., Alyemeni, M. N., Fariduddin, Q., and Ahmad, A. (2013). Salicylic acid: physiological roles in plants. In Salicylic acid, pp. 15-30.

Muhal, S., Solanki, N. S., Singh, P., and Shukla, K. B. (2014). Effect of salicylic acid on productivity and nutrient uptake of Brassica species under different planting durations. African Journal of Agricultural Research, 9(13): 1101-1106.

Raskin, I., J. Malamy, J. P. Carr, and D. F. Klessing. (1990). Salicylic acid: A likely endogenous signal in the resistance response of tobacco to viral infection. Science 250: 1002–1004.

Raskin, I. (1992). Salicylate, a new plant hormone. Plant Physiology 99: 799–803.

Sahu, G. K., and Sabat, S. C. (2011). Changes in growth, pigment content and antioxidants in the root and leaf tissues of wheat plants under the influence of exogenous salicylic acid. Brazilian Journal of Plant Physiology, 23(3): 209-218.

Salem, M. Z. M., and Böhm, M. (2013). Understanding of formaldehyde emissions from solid wood: an overview. BioResources, 8(3): 4775-4790.

Salman, S. R., S. D. Abou-Hussein, A. M. R. Abdel-Mawgoud, and M. A. El-Nemr. (2005). Fruit yield and quality of watermelon as affected by hybrids and humic acid application. J. Applied Sci. Res. 1:51-58.

Schnitzer, M. (1986). Binding of humic substances by soil mineral colloids. In Interactions of soil minerals with natural organics and microbes, SSSA Special Publication No. 17, eds. P. M. Huang and M. Schnitzer, 87. Madison, WI: SSSA.

Shahba, Z., Baghizadeh, A., and Yosefi, M. (2010). The salicylic acid effect on the tomato (*Lycopersicum esculentum* Mill.) germination, growth and photosynthetic pigment under salinity stress (NaCl). J. Stress Physiology and Biochemistry, 6(3).

Shakirova, F. M., A. R. Shakhabutdinova, M. V. Bezrukova, R. A. Fathkutdinov, and D. R. Fathkhutdinova. (2003). Changes in the hormonal status of wheat seedlings induced by salicylic acid and salinity. J. Plant Science. 164: 317-322.

Shakirova, F. M., Allagulova, C. R., Maslennikova, D. R., Klyuchnikova, E. O., Avalbaev, A. M., and Bezrukova, M. V. (2016). Salicylic acid-induced protection against cadmium toxicity in wheat plants. Environmental and experimental botany, 122: 19-28.

Shehata, S., A. Gharib, A. A. Mohamed, M. El-Mogy, K.F. Abdel Gawad, and E.A. Shalaby. (2011). Influence of compost, amino and humic acids on the growth, and yield and chemical parameters of strawberries. J. Medicinal Plants Research. 5:2304-2308.

Singh, B., and K. Usha. (2003). Salicylic acid induced physiological and biochemical changes in wheat seedlings under water stress. J. Plant Growth Regulation 23: 366–370.

Thi, L. H., and Bohme, M. (2001). Influence of humic acid on the growth of tomato in hydroponic systems. Acta Horticulturae, 548: 451-458.

Vaughan, D., Malcolm, R. E. and Ord, B. G. (1985). Influence of humic substances on biochemical processes in plants. In: VAUGHAN D; MALCOLM RE. (eds). Soil organic matter and biological activity. Dordrecht: Kluwer Academic. p. 77-108.

Virgine, Tenshia, J. S. and Singram, P. (2005). Influence of humic acid application on yield, nutrient availability and iron uptake in tomatoes. The Madras Agricultural Journal, 92: 670-676.

Yildirim, E. 2007. Foliar and soil fertilization of humic acid affect productivity and quality of tomato. J Plant Sci., 57: 182-186.

Yıldırım, E., and Dursun, A. (2008, April). Effect of foliar salicylic acid applications on plant growth and yield of tomato under greenhouse conditions. In International Symposium on Strategies towards Sustainability of Protected Cultivation in Mild Winter Climate 807 pp. 395-400.

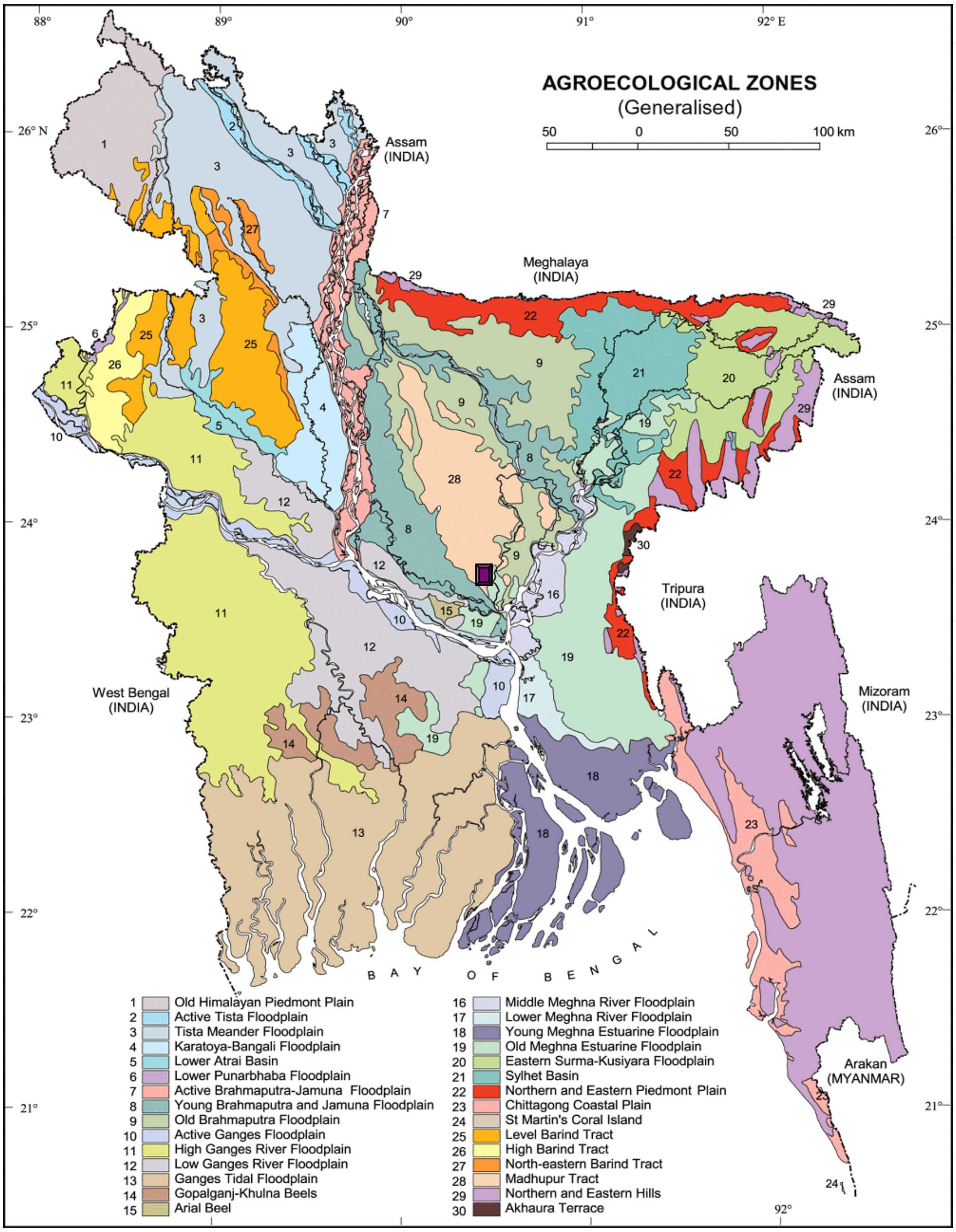
Yildirim, E., and Dursun, A. (2009). Effect of foliar salicylic acid applications on plant growth and yield of tomato under greenhouse conditions. J. Acta Horticulturea. 807: 395-400.

Zhang-Xin, X., Fowler, S. G., Cheng, H., Lou, Y., Rhee, S. Y., Stockinger, E. J., and Thomashow, M. F. (2004). Freezing-sensitive tomato has a functional CBF cold response pathway, but a CBF regulon that differs from that of freezing-tolerant Arabidopsis. The Plant Journal, 39(6): 905-919.

Zamaninejad, M., Khorasani, S. K., Moeini, M. J., and Heidarian, A. R. (2013). Effect of salicylic acid on morphological characteristics, yield and yield components of corn (Zea mays L.) under drought condition. European Journal of Experimental Biology, 3(2): 153-161.

APPENDICES

Appendix i. Map showing the experimental site under study



The experimental site under study

Appendix ii. Monthly average air temperature, total rainfall, relative humidity and sunshine hours of the experimental site during the period from October 2017 to March 2018

Year	Month	Average Air temperature (^{0}C)			Total rainfall (mm)	Average RH (%)	Total Sun shine hours
		Maximum	Minimum	Mean			
2017	October	30.5	24.3	27.4	417	80	142
	November	29.7	20.1	24.9	5	65	192.20
	December	26.9	15.8	21.35	0	68	217.03
2018	January	24.6	12.5	18.7	0	66	171.01
	February	27.1	15.8	21.05	09	66	168.60
	March	30.2	18.4	24.3	12	68	165.02

Source: Dhaka Metrological Centre (Climate Division)

Appendix iii: Soil characteristics of Horticulture Farm of Sher-e-Bangla Agricultural University are analysed by Soil Resources Development Institute (SRDI), Farmgate, Dhaka

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Horticulture garden, SAU, Dhaka
AEZ	Modhupur tract (28)
General soil type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained

Source: SRDI

B. Physical and chemical properties of the initial soil

Characteristics	Value
Practical size analysis	
Sand (%)	16
Silt (%)	56
Clay (%)	28
Silt + Clay (%)	84
Textural class	Silty clay loam
pH	5.56
Organic matter (%)	0.25
Total N (%)	0.02
Available P (µgm/gm soil)	53.64
Available K (me/100g soil)	0.13
Available S (µgm/gm soil)	9.40
Available B (µgm/gm soil)	0.13
Available Zn (µgm/gm soil)	0.94
Available Cu (µgm/gm soil)	1.93
Available Fe (µgm/gm soil)	240.9
Available Mn (µgm/gm soil)	50.6

Source: SRDI

Appendix iv: Analysis of variance on data with the effect of humic acid and salicylic acid on plant height (cm) at different days after sowing (DAS)

Source of variation	Degrees of freedom	Mean square of		
		Plant height at 30 DAS	Plant height at 70 DAS	Plant height at 100 DAS
Factor A	3	36.687**	750.076**	1867.68**
Factor B	3	0.387**	14.990**	23.81**
AB	9	0.131*	1.492ns	2.68ns
Error	32	0.046	1.577	2.63

**: at <0.01 level of probability, ns: non-significant, *: at <0.05 level of probability

Appendix v: Analysis of variance on data with the effect of humic acid and salicylic acid on the number of leaves per plant at different days after sowing (DAS)

Source of variation	Degrees of freedom	Mean square of		
		Number of leaves per plant at 30 DAS	Number of leaves per plant at 70 DAS	Number of leaves per plant at 100 DAS
Factor A	3	130.528**	187.576**	547.596**
Factor B	3	0.528ns	0.521ns	7.587ns
AB	9	1.194ns	0.609ns	7.242*
Error	32	1.229	0.336	3.041

**: at <0.01 level of probability, ns: non-significant, *: at <0.05 level of probability

Appendix vi: Analysis of variance on data with the effect of humic acid and salicylic acid on the number of branches per plant, SPAD value and total dry weight at different days after sowing (DAS)

Source of variation	Degrees of freedom	Mean square of				
		Number of branches per plant at 70 DAS	Number of branches per plant at 100 DAS	SPAD value at 70 DAS	SPAD value at 100 DAS	Plant total dry weight (g)
Factor A	3	7.649**	3.833**	332.988**	1227.05**	984.173**
Factor B	3	0.189**	0.020ns	2.714ns	5.12*	3.372*
AB	9	0.078**	0.031ns	4.463*	9.51**	6.982*
Error	32	0.017	0.020	1.512	1.46	0.873

**: at <0.01 level of probability, ns: non-significant, *: at <0.05 level of probability

Appendix vii: Analysis of variance on data with the effect of humic acid and salicylic acid on days to first flowering, days to first fruit set, number of flowers per plant and number of fruits per plant

Source of variation	Degrees of freedom	Mean square of			
		Days to first flowering	Days to first fruit set	Number of flowers per plant	Number of fruits per plant
Factor A	3	11.109**	22.827**	5.139**	2.139*
Factor B	3	1.548ns	3.347**	3.861**	2.750*
AB	9	6.975**	1.377*	4.769**	2.361*
Error	32	0.908	0.570	0.667	0.729

**: at <0.01 level of probability, ns: non-significant, *: at <0.05 level of probability

Appendix viii: Analysis of variance on data with the effect of humic acid and salicylic acid on yield and yield contributing characters of tomato

Source of variation	Degrees of freedom	Mean square of				
		Fruit diameter (cm)	Fruit thickness (cm)	Individual fruit weight (g)	Yield per plant (kg)	Total yield per hectare (ton)
Factor A	3	3.715**	1.784**	8.012**	0.049**	48.923**
Factor B	3	0.251*	0.003^{ns}	3.272*	0.046*	45.028*
AB	9	0.169*	0.016^{ns}	6.985**	0.031**	30.505**
Error	32	0.067	0.008	1.020	0.009	8.611

**: at <0.01 level of probability, ns: non-significant, *: at <0.05 level of probability

Appendix ix: Analysis of variance on data with the effect of humic acid and salicylic acid on shelf-life of fruits, ash, protein, brix and sodium percentage of tomato

Source of variation	Degrees of freedom	Mean square of				
		Shelf-life of fruit (day)	Ash (%)	Protein (%)	Brix (%)	Sodium (%)
Factor A	3	137.373**	0.025**	0.067**	0.022*	3.718**
Factor B	3	2.214**	0.001*	0.051**	0.032*	0.984**
AB	9	0.510^{ns}	0.001*	0.069**	0.025**	2.211**
Error	32	0.234	0.00	0.002	0.007	0.049

**: at <0.01 level of probability, ns: non-significant, *: at <0.05 level of probability

Appendix x: Analysis of variance on data with the effect of humic acid and salicylic acid on sugar percentage on fruit of tomato

Source of variation	Degrees of freedom	Mean square of		
		Total sugar percentage on fruit	Reducing sugar percentage on fruit	Non-reducing sugar percentage on fruit
Factor A	3	0.003*	0.001**	2.092**
Factor B	3	0.005**	0.013**	2.881**
AB	9	0.04**	0.042**	6.712**
Error	32	0.001	0.00	1.271

**: at <0.01 level of probability, ns: non-significant, *: at <0.05 level of probability

Appendix xi: Analysis of variance on data with the effect of humic acid and salicylic acid on vit-C and lycopene content on fruit of tomato

Source of variation	Degrees of freedom	Mean square of	
		Vit-C content on fruit (mg/100 gm)	Lycopene content on fruit (mg/100 gm)
Factor A	3	0.849*	0.049**
Factor B	3	2.476**	0.037**
AB	9	3.539**	0.028**
Error	32	0.207	0.003

**: at <0.01 level of probability, ns: non-significant, *: at <0.05 level of probability

Appendix xii: Pictorial view of research work

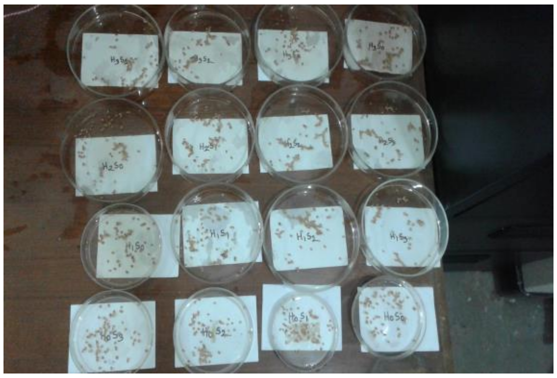


Plate 1. Seed soaked on different treatment combinations

Plate 2. Germinated seedlings on seedbed

Plate 5. Land preparation for transplanting

Plate 4. Transplanted seedlings on experimental plot

Plate 6. Vegetative stage of tomato plant

Plate 7. Flowering stage of tomato plant

Plate 8. Fruiting stage of tomato plant

Plate 9. Fruit cluster on tomato plant

Plate 10. Ripening stage of tomato

Plate 11. Determination of antioxidant content and nutritional attributes of tomato in BCSIR laboratory

Appendix xiii: Pictorial view of shelf-life of tomato

Plate 1. Harvested fresh tomato

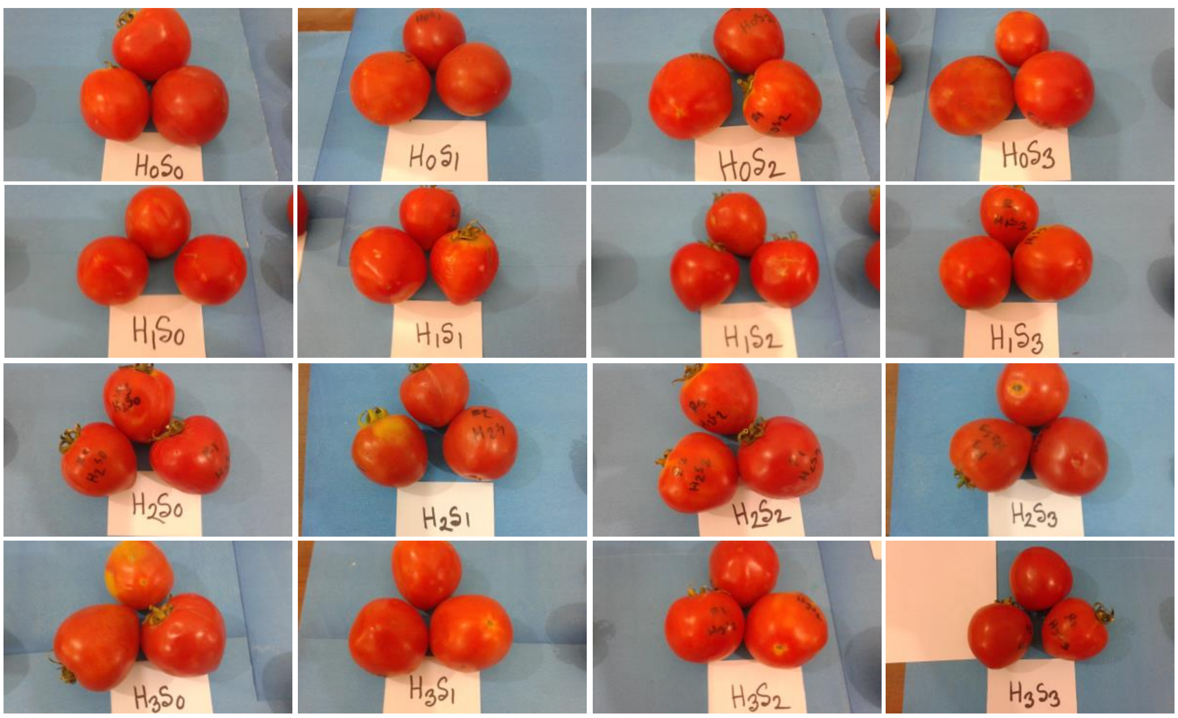


Plate 2. Color changes of tomato at 7 days after harvesting

Plate 3. Color changes of tomato at 14 days after harvesting

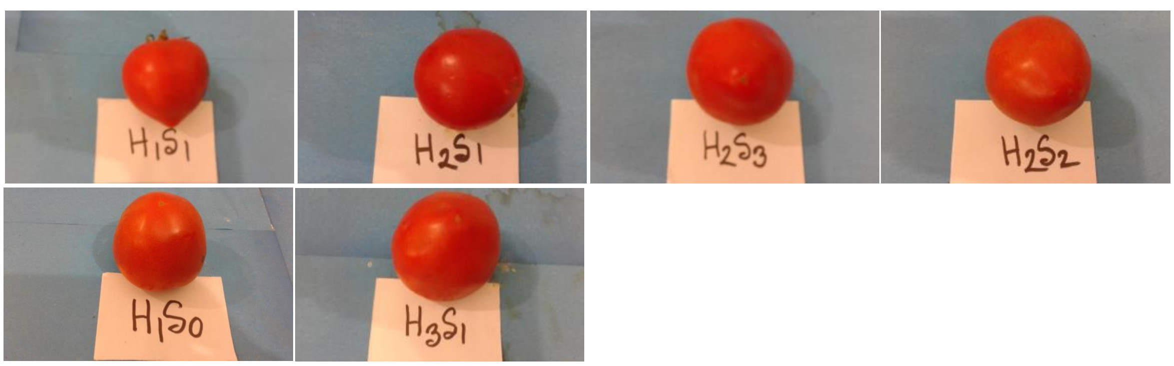


Plate 4. Color changes of tomato at 21 days after harvesting

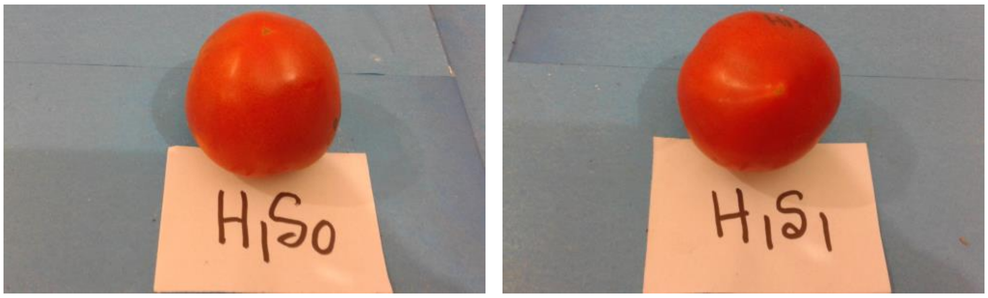


Plate 5. Color changes of tomato at 28 days after harvesting

Plate 6. Color changes of tomato at 35 days after harvesting