GROWTH, YIELD AND FRUIT QUALITY IMPROVEMENT OF TOMATO AS INFLUENCED BY HUMIC ACID AND SALICYLIC ACID

RUBYATH SHARMIN RIDE

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

DECEMBER, 2021

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BY

RUBYATH SHARMIN RIDE

REG. NO.: 19-10248

Email Address: riderubyathsharmin@gmail.com

Mobile No. 01783046548

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: JULY-DECEMBER, 2021

APPROVED BY:

Md. Dulal Sarkar
Assistant Professor
Department of Horticulture
SAU, Dhaka-1207
Supervisor

Salma Ahmed
Principal Scientific Officer
Institute of Food Science and Technology
BCSIR, Dhaka-1205
Co-Supervisor

Prof. Dr. Khaleda Khatun
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, YIELD AND FRUIT QUALITY IMPROVEMENT OF TOMATO AS INFLUENCED BY 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* ***RUBYATH SHARMIN RIDE****, Registration number:* ***19-10248*** *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: December, 2021
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 her 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 her profound gratitude and indebtedness to her honorable Co-supervisor ***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 her sincere gratitude towards the sincerity of the Chairman, Prof. Dr. Khaleda Khatun, Department of Horticulture, SAU, Dhaka for her valuable suggestions and cooperation during the study period. The author sincerely expresses her 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 her sincere appreciation to her brother, sister, relatives and friends for their inspiration, help and encouragement throughout the study period.

The Author

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ABSTRUCT

A field study was carried out at Sher-e-Bangla Agricultural University in Dhaka from October 2020 to April 2021 to examine how humic acid and salicylic acid influenced tomato growth, yield and fruit quality. In this experiment, four distinct dosages of humic acid H_0= 0 ppm, H_1= 30 ppm, H_2= 60 ppm, and H_3= 90 ppm as well as four doses of salicylic acid S_0= 0 ppm, S_1= 40 ppm, S_2= 80 ppm, and S_3= 120 ppm were utilized. The experiment was set up using a two-factor Randomized Complete Block Design. The maximum number of flowers per plant (53.67), number of fruits per plant (34.58), yield of fruits per plant (2.97 kg) were found at H_3 (90 ppm) humic acid treatment while the lowest result found in control. The maximum number of flowers per plant (54.43), number of fruits per plant (34.20) and yield of fruits per plant (2.90 kg) were found in S_2 (80 ppm) salicylic acid treatment. The highest vitamin – C content (16.93 mg/100g), sodium (7.28%), ^{0}brix content (4.75) and lycopene content (4.72 mg/100g) in fruit were found in 90 ppm humic acid with 80 ppm salicylic acid. The highest yield of fruits per hectare (137.06 tones) was obtained from 90 ppm humic acid with 80 ppm salicylic acid treatment. In order to sustain better development and improve tomato yield and fruit quality, the treatment of 90 ppm humic acid with 80 ppm salicylic acid would be the ideal choice.

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CHAPTER I

INTRODUCTION

Tomato (*Lycopersicon esculentum*), as one of the world's most frequently produced and consumed vegetables, have high levels of antioxidant active components such as vitamin C, polyphenols, and carotenoids. (Tommonaro *et al.*, 2012)

To enhance the quality of vegetable products, current developments include the use of natural biostimulants (Mahmood *et al.,* 2017), foliar feeding and plant growth regulators. Foliar fertilization is a typical crop-management technique to increase yield and fruit quality and assist plants in making up for low soil fertility, nutrient absorption restrictions, and nutrient fixation problems. Humic compounds, which contain humic acid, are typical organic-mineral utilizers utilized in plant fertilization (Manas *et al.,* 2014)

Humic acid, which possesses hormone-like function, promotes stress tolerance as well as plant growth and nutrient uptake. Humic acids are important for more than just their role as a storage for mineral plant nutrients and a regulator of their release. Humic acid may be utilized as a growth regulator to regulate hormone levels, boost plant growth, and improve stress tolerance, (Serenella *et al.*, 2002)

Humic acid (HA) suspensions based on potassium humates have been used successfully in many areas of plant production as a plant growth stimulant or soil conditioner for enhancing natural resistance to plant diseases, stimulating plant growth through increased cell division, optimizing nutrient and water uptake, and stimulating soil microorganisms. HA has been shown to be effective in lowering the incidence of a variety of plant diseases in several studies (Chen *et al.,* 2004)

Humic acid (HA) is a promising natural resource that can be used to boost crop yields instead of manufactured fertilizers. It has a direct effect on enzyme activity and membrane permeability, as well as an indirect effect, primarily on soil structure. During the full bloom period, humic acid treatment, berry weight, titratable acidity, and maturity index values of Italy grape cultivar increased dramatically (Ferrara and Brunetti, 2010). Humic acid applied at a medium rate (250 g/m^2) enhanced spinach output and nutritious content. They came to the conclusion that humic acid administration resulted in increased nitrogen uptake, which was the primary cause of spinach vegetation development. According to (Zaky *et al.*, 2006) the number of shoots per plant, average leaf area, total yield, and average pod fresh weight are all important factors. The use of medium doses (250 g/m^2) boosted spinach output and nutritious content. They came to the conclusion that humic acid administration resulted in increased nitrogen uptake, which was the primary cause of spinach vegetation development. (Zaky *et al*., 2006) discovered that using humic acid as a foliar fertilizer at a rate of 1 g/L enhanced the number of shoots per plant, average leaf area, total yield, average pod fresh weight, and P content.

Salicylic acid is a natural growth regulator in vascular plants that affects a variety of physiological and metabolic activities (Jayakannan *et al.,* 2015; Rivas-San Vicente and Plasencia, 2011), including photosynthesis, transpiration, ion uptake, and transportation (Sahu, 2013). By lowering stress-induced growth inhibition, foliar application of salicylic acid may boost vegetable yields (Khan *et al.*, 2015)

SA is a plant phenol that is utilized to increase plant resistance to the negative impacts of biotic and abiotic stressors, as well as contribute in plant physiological stage control. SA has a substantial impact on plant growth and development, photosynthesis, evaporation, ion transmission, and absorption, as well as causing unique alterations in leaf anatomy and chloroplast structure (Sakhabutdinova *et al*., 2003)

SA is a naturally occurring plant hormone with a variety of impacts on the ability to withstand biotic and abiotic stress. Because of lowered plant Na, Cl, and H_2O_2 concentrations, decreased electrolyte leakage, higher N and Ca contents, and increased antioxidant enzyme activity, low SA concentrations typically improve plant development under salinity (Khan *et al.*, 2010)

The majority of SA research has been on mediating local and systemic plant defense and resistance to biotic and abiotic stressors, but studies on its impact on physiological, biochemical, and qualitative aspects of fruit are scarce (Atkinson and Urwin, 2012). The purpose of this study was to investigate the effects of SA on tomato growth, fruit quality attributes including fruit firmness and storability, vitamin C, antioxidant activity, total phenolic, flavonoids, and yield under greenhouse conditions. This was done because plant growth, development, and the level of bioactive compounds, particularly antioxidant active substances, depend on the cultivar and on agronomic and environmental conditions (Tommonaro *et al.*, 2012)

SA is easily spread from the treatment site (leaves and roots) to other sites (Alaey *et al.*, 2011).SA functions as a potential non-enzymatic antioxidant that affects the regulation of numerous physiological processes in plants, including stomatal closure, ion uptake, inhibition of ethylene biosynthesis, transpiration, cell elongation, cell division, and cell differentiation. It also helps plants tolerate stress better and boosts their antioxidant capacity. Therefore, the main focus of this study is to explore how humic acid and salicylic acid affect the physiological growth, yield, and quality of tomato.

Given the foregoing, the following goals were pursued throughout the rabi season in a field experiment named "Growth, yield and fruit quality improvement of tomato as influenced by humic acid and salicylic acid."

- To find out the effect of different levels of humic acid on tomato growth, yield and fruit quality.

- To evaluate the effect of different levels of salicylic acid in tomato regarding to growth, yield and nutritional quality.

- To assess the combined impact of humic acid and salicylic acid on tomato growth, yield and fruit quality.

CHAPTER II

REVIEW OF LITERATURE

One of the most significant vegetable crops farmed in fields and greenhouses, the tomato has drawn significant attention from academics around the world. There hasn't been much study done in Bangladesh in this area. However, this chapter has evaluated the findings that are now available globally in this context within the following areas.

2.1 Effect of humic acid

Galambos *et al.* (2020) stated that PGPBs, or plant growth-promoting bacteria, provide intriguing alternatives to conventional fertilizers. The growth of plants and/or the establishment of endophytic PGPB can both be aided by humic acid (HA). Although the effects of PGPB colonization or HA treatment have been researched independently, there is limited data on how plants react to PGPB and HA applications when combined. Understanding the physiological effects, bacterial colonization, and transcriptional responses triggered by endophytic bacterial strains in tomato roots and shoots in the absence (control condition) and presence of HA was the purpose of this study (HA condition). It appears that the effects of PGPB and HA may complement each other because tomato shoot length was increased by seed inoculation with Paraburkholderia phytofirmans PsJN, Pantoea agglomerans D7G, or Enterobacter sp. 32A in the presence of HA. In both the control and HA conditions, tomato colonization by endophytic bacterial strains was comparable. The bulk of differentially expressed genes (DEGs) were elevated by endophytic bacterial strains in the HA condition, and the main transcriptional controls took place in tomato roots. As potential common responses to endophytic bacterial strains, two or three strains altered half of the DEGs. These reactions involved protein metabolism, transcription, transport, signal transduction, and defense. Additionally, tomato strain-specific responses included the increase of hormone metabolism, secondary metabolism, hormone metabolism, transcription, hormone metabolism. This study reports the optimal dosages, complementation properties, and gene markers for the further development of effective PGPB- and HA-based biostimulants. It also provides detailed information on the HA-dependent enhancement of growth-related processes stimulated by endophytic bacterial strains in tomato plants.

Kumar *et al.* (2017) done an experiment at the Rajasthan College of Agriculture in Udaipur, to determine how the combination of humic acid and nutrients affected the growth and yield parameters of tomatoes (Lycopersicon esculentum Mill). (Raj.). Following a completely randomized design, statistical analysis of the data was performed. In order to improve the analysis of leaf nutrients, treatment T7 [RDF + humic acid 10 kg/ha soil application + humic acid 0.1% foliar spray + nutrient mixture foliar spray (0.2% Ca + 0.5% Mg + 0.2% B + 0.5% Zn)] was found to be more effective. Fruit nutritional analysis shows Ca (1.656%), Mg (0.763%), Zn (25.07ppm) and B (61.94ppm) as well as total soluble solids (TSS) (6.020%), ascorbic acid content (39.85mg/100g), lycopene content (3.75 mg/100g), and cost-benefit ratio (4.81).

Asri (2015) stated that humic acids (HA) facilitate the development of organominerals in the soil, which enhances the nutritional content of tomato leaves and agricultural output. The goal of this study was to determine how the application of soil HA affected tomato processing plant production, fruit quality, and nutrient content. At rates of 0, 40, 80, 120, 160, and 200 L, humic acid was sprayed on the ground.Through drip irrigation, 180-60-210 kg of nitrogen, phosphorus, and potassium (NPK)/ha of soil were added. In the years 2011–2012, the experiment was carried out using a randomized complete block design with four repetitions. Applications of humic acid resulted in a notable increase in yield. As humic acid levels rose, it was evident that treatable acidity, fruit weight, and fruit diameter all increased. Results revealed that humic acid raised the content of N, P, K, Ca, Zn, and Mn in leaves, with humic acid levels of 80 L/ha providing the most significant progress in the first year. Humic acid positively influenced the N, P, K, Fe, and Mn concentration of leaves in the second year, and excessive amounts of humic acid led to decline. Mid-levels (80 and 120 L/ha) were discovered to be more efficient as a result.

Alenazi (2021) was conducted an experiment under greenhouse circumstances between 2011–12 and 2012–13, the responses of three tomato (*Lycopersicon esculentum* Mill.) hybrids, 'Luanova', 'Savarona', and 'Tessera', to various dosages of humic acid (HA) soil application were assessed in terms of plant growth, productivity, and fruit quality. In addition to having better quality traits, tomato fruits picked from plants of the 'Tessera' cultivar had higher yield and yield component values than tomatoes picked from other hybrids examined, regardless of the growing season. However, 'Luanova' cultivar plants ripened earlier and produced more fruits per plant. Regardless of the amount of HA and the cultivar under study, soil application of HA showed positive impacts on yield and physicochemical quality of tomato fruits in both seasons. All three of the tomato cultivars studied responded better to the soil application of HA at a greater dose of 1.5 g/L in terms of their vegetative and reproductive growth, and the physicochemical quality of their fruits was greatly enhanced. The tomato hybrid "Tessera" was determined to be acceptable for growing in a greenhouse, and soil treatment of an aqueous solution of HA at 1.5 g/L significantly increased the yield of high-quality tomato fruits.

Amira and Helaly (2021) conducted an experiment and the findings demonstrated that irrigation with magnetized water had a favorable impact on tomato fruit quality measures, yield and its constituents, and vegetative growth features. As the results showed, the use of the greatest concentration of humic acid (3 g L-1) reflected the highest values for all the tested features, there was also a clear favorable effect of humic acid addition with varying quantities. The results of the interaction between humic acid application and irrigation with magnetized water demonstrated that the best outcomes and highest values for all studied characters were recorded when using magnetic water (MW) combined with 3 g/L of humic acid (HA), without appreciable differences from the interaction treatment MW combined with 2 g/L HA for most traits. For all the examined characters at the two growing seasons, the two treatment combinations- MW with 2 g/L HA and Non-MW with 3 g/L HA did not significantly differ from one another. According to these findings, humic acid could potentially be reduced by one-third when used with magnetic water, which also increases tomato plant quality and crop productivity. In general, we can advise employing humic acid addition with magnetized water irrigation at a concentration of 3.g/L or 2.g/L to improve the yield and quality of the tomato plant.

Kumar *et al.* (2017*)* conducted the study to evaluate how the tomato responded to various concentrations of humic and salicylic acid under salt stress conditions during the kharif season of 2014–15. Results showed that soil pH^2, organic carbon, $CO_3{}^{2-}$ + HCO^{3-} could not significantly affect soil properties while EC^2, Na^+, Ca^{2+} + Mg^{2+}, Cl^- and $SO_4{}^{2-}$ of soil after crop harvest considerably increased with rise in irrigation water salinity. Na^+, Cl^-, and $SO_4{}^{2-}$ dropped greatly and Ca^{2+} +Mg^{2+} of soil after harvest of crop increased significantly with rise in the levels of HA application, however HA could not significantly affect pH^2, EC^2, organic carbon, and $CO_3{}^{2-}$ + $HCO_3{}^-$, SA was unable to affect the soil's pH2, EC^2, organic carbon, $CO_3{}^{2-}$ + $HCO_3{}^-$, Na^+, Ca^{2+} + Mg^{2+}, or $SO_4{}^{2-}$ after a crop was harvested. With 4 and 8 dSm^{-1} levels of salinity in irrigation water, respectively, the number of fruits per plant, average diameter, average weight, and fruit output considerably decreased over control. Application of both HA and SA considerably enhanced fruit yield, average diameter, average weight, and number of fruits per plant. Maximum number of fruits per plant was 54.88, average diameter was 6.15 cm, average weight was 61.47 g, and maximum fruit output was 163.13 q ha^{-1} when saline water of 0.25 dSm^{-1} (control) and 1500 ppm HA level were combined. According to the study's findings, soil applications of HA (1500 ppm) and SA (1.5 mM) were determined to be the most efficient way to increase tomato yield and quality while reducing the harmful effects of salinity stress on the plant

Ymildiri and Dursun (2007) reported that the impact of humic acid (HA) fertilization on the quality, growth, and production of tomatoes grown in greenhouses in 2004 and 2005. At varying concentrations (0 ml/l, 10 ml/l, and 20 ml/l), soil and foliar HA treatments were used to treat tomato plants. HA was sprayed four times at 10-day intervals during the vegetative period three weeks after planting. Additionally, during the vegetative phase at intervals of 10 days, three weeks after planting, 0, 10, and 20 ml/l HA solutions were drenched onto the plant root area four times. The pH and titratable acidity (TA) of tomato were unaffected by HA treatments. Both foliar and soil HA treatments led to an increase in total soluble solids (TSS). The maximum ascorbic acid (AA) content was obtained after foliar 20 ml/l HA treatment. Higher leaf and stem dry matter contents than the control were produced by HA foliar treatments. Fruit attributes like fruit diameter, fruit height, mean fruit weight, and fruit number per plant were positively impacted by both foliar and soil HA treatments. Similar to how HA treatments improved tomato early production in comparison to control. Applications of HA to the soil and tomato leaves had a considerable impact on tomato yield. The foliar 20 ml/l HA treatment produced the best yield. The study demonstrates that HA sprays with a 20 ml/l concentration could be used to improve tomato growth and yield

Kazemi (2013) was conducted an experiment to assess the effects of foliar application of humic acid and calcium chloride on vegetative and reproductive growth, yield, and quality of tomato plants. Calcium chloride (10 and 15 mM) and humic acid (15 and 30 ppm) solutions were used separately or in combination as foliar sprays. Plant height, branches per plant, flowers per cluster, fruits per plant, yield, fruit weight, fruit firmness, and the total amount of soluble solids in the fruiIt. The findings demonstrated a significant impact of humic acid (30 ppm) and calcium chloride (15 mM) sprays on vegetative and reproductive growth as well as chlorophyll content. By increasing humic acid and calcium chloride concentration to 30 ppm and 15 mM, mean comparisons showed that tomato plants' output and quality were increased. Ca (15 mM) + HA (30 ppm) applied via foliar spray produced the highest TSS (5.14 °Brix), vitamin C (25.14), nitrate reductase activity (6.4), yield (25.36 t ha^{-1}), fruit firmness (3.91 kg cm^{-2}), fruit lycopene concentration (2.14), and lowest incidence of blossom end rot (5 percent). Finally, the application of humic acid and calcium chloride can aid to increase yield and prevent yield from declining.

Abdellatif *et al.* (2017) conducted this study, in two tomato hybrids, Nema 1400 and Platinium 5043, were grown in a hot continental climate to determine how humic acid (HA) application rates of 4.8, 9.6, and 14.4 kg/ha-1 affected their development and productivity. In both seasons, HA was administered to the soil twice: the first time, three weeks after transplanting, and the second time, one week after the first treatment. Tomato plant development and productivity were the main goals of HA application over the summer. Tomatoes' vegetative development (plant height and fresh weight), flowering parameters (number of flower clusters and flowers per plant), and yield features (number of fruits per plant and fruit weight), as compared to control, were all improved by HA at 14.4 kg ha^{-1}. Tomatoes' vegetative growth (plant height and fresh weight), flowering parameters (number of flower clusters and flowers per plant), and yield characteristics (number of fruits per plant and fruit weight) all increased with HA at 14.4 $kgha^{-1}$, which resulted in higher early and total yield in both seasons than control RL6. Compared to controls, HA administration had the least effect on total soluble solids (TSS) concentration, vitamin C concentration, and fruit number per plant.

Kumar *et al.* (2017) At the Rajasthan College of Agriculture in Udaipur, to determine how the combination of humic acid and nutrients affected the growth and yield parameters of tomatoes (*Lycopersicon esculentum* Mill). A completely random design was used for the statistical analysis of the data. In order to improve the analysis of leaf nutrients, treatment T7 [RDF + humic acid 10 kg/ha soil application + humic acid 0.1 percent foliar spray + nutrient mixture foliar spray (0.2 percent Ca + 0.5 percent Mg + 0.2 percent B + 0.5 percent Zn)] was found to be excellent. Fruit nutritional analysis includes the following values: total soluble solids (TSS) (6.020 percent), ascorbic acid content (39.85 mg/100g), lycopene content (3.75 mg/100g), magnesium (0.763 percent), zinc (25.07ppm), and boron (61.94ppm). Fruit nutritional analysis also includes the following values: Ca (1.656 percent), Mg (0.763 percent), Zn (25.07ppm).

2.2 Effect of salicylic acid

Abida *et al*. (2020) used Salicylic acid (S_0: 0 mM, S_1: 0.25 mM, S_2: 0.5 mM), micronutrients (M_0: 0, M_1: 20 mg of zinc, M_2: 2 mg of boron, M_3: 10 mg zinc + 1 mg boron, M_4: 20 mg zinc + 2 mg boron), to determine the effects of these treatments on the production of summer tomatoes. for a larger output of tomatoes in the summer, consider the combined effects of salicylic acid and micronutrients season. The highest yield per plant (1260.40 g) was obtained in S2 for salicylic acid, and the S_0 contained the minimal yield (1099.50 g). In terms of micronutrients, M_4 had the largest yield per plant (1691.50 g), whereas M_0 had the lowest yield (793.50 g). All but a few metrics were altered by the interaction between salicylic acid and micronutrients, which produced tomato attributing results characteristics, with S_4M_3 having the highest yield (1872.22 g) and the lowest yield (0.01 g). In S_0M_0, (736.04g) was discovered. These findings imply that vitamins and salicylic acid can reduce summer's negative impact to boost tomato yield.

Chavan and Sakhale (2020) stated an experiment to explore the impact of exogenous salicylic acid application on tomato fruit of Cv. Abhinav during its storage term at 24oC, an investigational research experiment was conducted. The *Lycopersicon esculentum* Mill.) fresh tomato fruits of Cv. Abhinav were picked at the appropriate physiological maturity stage. The fruits were properly cleaned with clean water before receiving a fungicidal treatment with 500 ppm benomyl and salicylic acid. The tomato fruits that had been exposed to the fungicide were then divided into four lots and submerged for 30 minutes in salicylic acid (SA) solutions with concentrations of 50, 100, 150, and 200 ppm, respectively, and kept for storage experiments alongside control fruits. The observations for various physico-chemical parameters were made frequently throughout the storage period, and tomatoes treated with 200 ppm salicylic acid concentration were found to be significant with regard to a lower physiological weight loss (10.3%), a gradual increase in TSS, and color (h), which increased from 1.4 to 3.3o Brix and -3.63 to 2.59, respectively. Additionally, the ascorbic acid (SA) concentration reduced from

73.14 to 22.10 mg/100 g, the titrable acidity decreased from 1.34 to 0.14%, and the texture's stiffness decreased from 354 to 96 gf. Lycopene content increased gradually from 7.01 to 12.31 mg/100 g and the total phenolic content of tomatoes treated with 200 ppm salicylic acid gradually decreased from 3.79 to 3.14 mg GAE/g, which was determined to be significant in comparison to rest of the tratments and control fruits.

Sariñana *et al*. (2020) stated tomato as a specifically designed functional food and a natural source of vitamins, bioactive substances, antioxidants, and nutrients that enhance nutrition and human health. To increase the functionality of this meal in order to promote health, prevent sickness, and promote overall well-being, researchers have focused on tomatoes due to its importance as a vegetable around the world. In this study, an agronomic method was used to assess how the administration of "salicylic acid (SA)" affected the yield and nutraceutical quality of the tomato crop grown hydroponically. Six times were employed in a fully randomized experimental design. On tomato plants grown in a hydroponic system, five dosages of SA (0.025, 0.05, 0.075, 0.1, and 0.125 mM) and one control were applied every 15 days to the nutritive fluid. The yield (the total fruit weight per plant), fruit characteristics (the weight, diameter, firmness, and total soluble solids), percentage of weight loss, and tomato nutraceutical quality were all examined. In comparison to the control without application, the results show that adding salicylic acid to nutritive solution boosted tomato fruit yield and biosynthesis of phytochemical components. In conclusion, it is advised to employ the average concentration (0.125 mM) of SA in order to achieve a greater nutraceutical quality without harming the tomato fruit output.

Kumar *et al.* (2017) stated that the postharvest life of the tomato is quite brief because it is a climacteric fruit. Because there aren't adequate post-harvest storage options, tomato losses range from about 25 to 40 percent annually. Salicylic acid is a natural and secure phenolic molecule that has a significant potential for monitoring post-harvest losses. Consequently, the goal of the current study was to examine the impact of salicylic acid (0.5 mM, 0.75 mM, 1.0 mM, and 1.25

mM).and 1.5 mM) on the biochemical alterations in the Hisar-Arun tomato cultivar throughout the turning stage of storage at ambient temperature a steady rise in lycopene, total soluble solids, and physiological weight loss.There were measurements of content, -carotene content, total sugars, reducing sugars, and non-reducing sugars. According to the findings, salicylic acid at a concentration of 0.75 mM was the most effective at postponing ripening-related physico-biochemical changes. Consequently, exogenous salicylic acid administration is a successful technique to extend the shelf life of tomato fruits by 4 to 6 days.

Mandal *et al.* (2016) stated that tomato, a commonly consumed solanaceous fruit and vegetable, saw a quick decline in fruit edible quality while stored at room temperature, and while refrigeration has shown to improve retention, chilling injury has been the main problem. Under this work, an effort has been made to assess the impact of salicylic acid, a safe phenolic with a known anti-ethylene activity, on the shelf life and quality characteristics of tomato fruit in chilled storage. Four replications of a complete randomized design were used to treat fruits of the tomato variety Samrudhi at the pink to light red stage with varying concentrations of salicylic acid (0.2–1.2 mM) and as a control (water dipping). Results indicated that fruits treated with salicylic acid (SA) maintained their quality better than untreated fruits in concentration dependent manner. Fruits kept in control condition lost 13.69% more weight at 21 days after storage (DAS) than fruits treated with SA at 1.2 mM (5.79%). In comparison to fruits at control, SA at 1-1.2 mM considerably reduced chilling injury (Chilling Injury Index/CII: 1.44–2.88). (CII: 4.98). Fruits in the control group had decreased sugar content, acidity, and ascorbic acid. Furthermore, SA treated fruit at relatively higher concentrations (0.8–1.2 mM) retained fruit quality characteristics with steady intensification of carotenoids and lycopene even at 21 DAS, whereas it took a quick increase in pigment. The greatest shelf life for SA at 1.2 mM was 32.75 days, making it the best treatment with the highest maintenance of fruit edible properties.

Yildirim and Dursan (2009) carried out an experiment to ascertain the impact of foliar salicylic acid (SA) sprays on tomato fruit quality, growth, and yield in greenhouse conditions in 2006 and 2007, this study was carried out. Fruit diameter, length, weight, and quantity of fruits per plant were measured in the study, along with vitamin C levels, pH, total soluble solids (TSS), titratable acidity (TA), stem diameter, leaf dry matter ratio, chlorophyll content, early yield, and total yield. Different concentrations of foliar SA were applied to tomato plants as a treatment (0.00, 0.25, 0.50 and 1.00 mM). Two weeks after planting, SA was sprayed onto the vegetation four times at 10-day intervals. According to the study, foliar sprays of SA had a favorable impact on various fruit attributes, plant growth, leaf chlorophyll content, and other factors. The pH, AA, and TA of tomato were unaffected by SA treatments. With foliar SA treatments, total soluble solids (TSS) rose. The 0.50 mM SA treatment produced the highest stem diameter, leaf dry matter, and chlorophyll content. When compared to the control, SA treatments boosted tomato early output. Applications of foliar SA had a substantial impact on tomato output. The 0.50 mM SA treatment produced the maximum yield. Our findings suggest that 0.50 mM SA applications be suggested in order to increase yield.

Ullah *et al.* (2019) conducted an experiment to test the effects of several plant extracts and salicylic acid as a foliar spray on tomato growth, yield, and fruit quality, the experiment was conducted in 2018 at the University of Agriculture Peshawar, Pakistan (Cv. Rio Grande). Three replicates were employed in the experiment's Randomized Complete Block Design (RCBD) split plot configuration. For foliar application, various salicylic acid concentrations (Control, 2, 4, and 6 mM) and plant extract levels (Moringa 6 percent, Neem 10 percent, and Garlic 4 percent) were used. Foliar treatment of plant extracts (moringa 6%), according to the results, resulted in the highest levels of chlorophyll content (0.0511 mg cm^{-2}), plant height (90.44 cm), single fruit weight (57.79 g), fruit volume (55.68 cm^3), fruit hardness (3.63 kg cm^{-2}), and titratable acidity (0.40). The outcomes showed that foliar administration of plant extracts (moringa 6%) provided Maximum values for the following parameters were observed in the control treatment: maximum chlorophyll content (0.0511 mg cm^{-2}), plant height (90.44 cm), single fruit weight (57.79 g), fruit volume (55.68 cm^3), fruit firmness (3.63 kg cm^{-2}), titratable acidity (0.40 percent), and ascorbic acid (11.76 mg $100gm^{-1}$). In contrast, compared to all treatments, the salicylic acid concentration (6 mM) also had an impact on all the features. Maximum chlorophyll content (0.0522 mg cm^{-2}), plant height (88.38 cm), weight of a single fruit (54.91 g), fruit volume (51.91 cm^3), fruit hardness (3.28 kg cm^{-2}), titratable acidity (0.37 kg percent), ascorbic acid (10.87 mg $100g^{-1}$), and minimum fruit juice pH (4.19) were all observed.

Javanmardi and Akbari (2016) studied the impact of salicylic acid on plant development, secondary metabolites, and fruit quality are scarce. The majority of research on SA has concentrated on postharvest administration or developing stress tolerance. The effects of SA applied topically (0, 150, 300, and 450 mg/L) at various plant growth stages on tomato (*Solanum lycopersicum* L. cv. Kardelen) fruit yield, secondary metabolites, and quality characteristics were assessed. Three weeks after fruit set, 300 mg/L SA produced the maximum fruit yield per plant (approximately 1.3 times more than control). When 450 mg/L was applied, the plants had the maximum fruit firmness, 10 days of prolonged storage ability, total phenolics (22.6 mg of gallic acid equivalent per 100 g fw), and antioxidant activity (65.11), compared to control plants. When 450 mg/L SA was administered at the fruiting stage and three weeks later, the maximum fruit firmness, 10 days of prolonged storability, highest total phenolics (22.6 mg gallic acid equivalent per 100 g fw), and highest antioxidant activity (65.11) were detected when compared to control plants. With rising SA concentration, regardless of application time, an increasing pattern in ascorbic acid content was seen. When plants were treated three weeks after fruiting, the same concentration effect on flavonoid content was seen. Using Pearson correlation, it was determined that flavonoids had the greatest impact on antioxidant activity (r=0.82). All evaluated attributes were significantly negatively impacted by SA concentrations more than 450 mg/L. The developmental stage and SA concentrations measured determine the effect of exogenous SA on tomato plants. A particular concentration range may result in improved fruit quality parameters, however concentrations above that may have a negative or detrimental effect.

Naeem *et al.* (2020) conducted an experiment at the Agriculture Research Institute Tarnab in Peshawar during the summer of 2016, a pot experiment was carried out to examine the impact of salicylic acid on qualitative and quantitative features of tomato plants under salinity stress. The study was carried out in a shadow structure, using a completely randomized design (CRD) consisting of 12 treatments and three replications. The fruit length (5.02 cm), fruit diameter (4.17 cm), number of fruits per plant (18.5), yield per pot (0.86 kg), fruit dry matter (9.04 g), fruit firmness (2.68 kg cm^2), TSS (9.050 Brix), pH (4.33), and vitamin C (17.28 mg per 100 ml) were all significantly improved by the foliar application of salicylic acid at 0.5 mM. Except for fruit hardness, total soluble solids, pH, and vitamin C, all the variables were strongly impacted by the interaction between salinity and salicylic acid. These studies found that, with the exception of pH, salinity boosted the qualitative features while decreasing the quantitative attributes. Salicylic acid may therefore be administered to tomato plants in saline conditions up to 90 mM at a concentration of 0.5 mM to effectively reduce the negative effects of salt stress.

Islam *et al.* (2018) investigated to determine how salicylic acid (SA) affected the fruit quality and shelf life of cherry tomatoes. Different SA concentrations (0.13, 0.25, 0.50, and 1.00 mM) were given to the hydroponic system's nutrient solution at different stages of the plants' fruit growth. Cherry tomato fruits were picked at the light-red maturity stage to gauge the fruit's quality at harvest and stored at 5°C to gauge its quality after harvest and shelf life. The 0.50 mM SA treatment significantly decreased the amount of ethylene produced and the pace at which it was respired out of tomato fruit both during harvest and after storage. In the 0.50 mM SA, increased acetaldehyde (p 0.05) and ethanol (p 0.001) were observed. The 0.50 mM SA treatment had lower final storage day color development and lycopene content than other treatments. At harvest time and following storage, the 0.50 mM SA treatment had the maximum level of firmness. At the time of harvest and following storage, there was evidence of relatively higher vitamin C and fewer soluble solids. Therefore, improving the quality and shelf life of cherry tomato fruit with 0.50 mM SA is successful.

Malik and Lal (2018) conducted an experiment during the rabi season of 2016–17, two sets of experiments (seed treatment and foliar spray) were carried out in Allahabad to investigate the effects of salicylic acid and indole acetic acid on tomato (*Lycopersicon esculentum*) growth, yield, lycopene, and total sugar in a cadmium and salinity stressed environment. In each pot, 20 mg and 100 mM of cadmium and sodium chloride were added to combat salicylic acid (SA) and indole acetic acid, respectively (IAA). Three replications and 16 treatments were used in the factorial randomized design experiment. Results showed that under different treatments, the number of branches and leaf index area of both kinds did not change noticeably. Generally speaking, maximum values of both tomato cultivars were obtained at 2 mM SA + 2 mM IAA. Regarding the total number of fruits and fruit diameter, seed treatment with SA and IAA outperformed foliar spray. All of the parameters' minimal values were noted under supervision. In both tomato types, lycopene levels peaked under 2 mM SA + 2 mM IAA treatments. On the other hand, the tomato plant's soluble sugar level was at its highest under control and its lowest under 2 mM SA + 2 mM IAA.

Qadir *et al.* (2019) done an experiment to ascertain how exogenously administered SA and GB impacted cherry tomato output and quality under various irrigation regimes. Cherry tomato plants were given three irrigation schedules—7, 14 and 21 days—as well as two concentrations of SA and GB—2.5 mM and 5 mM and 25 mM and 50 mM, respectively. The application of GB and SA was not made to the control plants. Levels of irrigation and osmoprotectants had a significant impact on the fresh weight of leaves, saturated weight of leaves, dry weight of leaves, relative water content, leaf chlorophyll content, plant height, stem diameter, fruit diameter, number of fruits, yield total soluble solid (TSS), titratable acidity, ascorbic acid (ASA), and lycopene. A considerable improvement in the parameters of cherry tomato during drought was observed by exogenously applied SA and GB.

Additionally, plants under drought stress showed an increase in yield, which was further increased by various concentrations of exogenous SA and GB. Furthermore, exogenous (GB and SA) application at a 14-day irrigation interval was superior to other treatments in terms of effectiveness. When sprayed to plants that received irrigation at intervals of 21 days rather than 7, SA and GB performed more noticeably.

Mady (2009) conducted two experiments during the 2006 and 2007 growing seasons to examine the effects of foliar applications of salicylic acid (SA) at 50 and 100 ppm and vitamin E (VE) at 100 and 200 ppm and their combination on certain growth aspects, photosynthetic pigments, minerals, endogenous phytohormones, flowering, fruiting, and fruit quality of tomato cv. Super strain B.At 30 and 45 days following transplanting, the plants received two sprayings. Results showed that all growth indices investigated, including the number of branches and leaves per plant, leaf area per plant, and leaf dry weight, were considerably boosted by the various applied treatments. Additionally, the two concentrations of either salicylic acid or applied vitamin E clearly raised the concentrations of photosynthetic pigments, NPK, Fe, Zn, Mn, total carbs, and crude protein concentrations in leaves of treated plants as compared with those of untreated ones. Additionally, all treatments resulted in higher levels of cytokinins and auxins in tomato shoots, while gibberellins and abscisic acid were lower. Salicylic acid 50 ppm + 200 ppm vitamin E produced the highest early and overall yields, followed by SA 100 ppm + 200 ppm vitamin E. Additionally, the same treatments resulted in a rise in the chemical composition of minerals and several bioconstituents like carbohydrates, vitamin C, and total soluble solids in tomato fruits. Since early and total yields are improved as a result of using salicylic acid and vitamin E as foliar applications, the present study substantially supports this claim.

CHAPTER III

MATERIALS AND METHODS

The materials and methods and techniques needed to conduct the experiment are covered in this chapter. The brief explanation contains the experiment's location, soil and climate parameters, land preparation, manuring and fertilizing, transplanting and gap filling, stalking, harvesting, and data gathering.

3.1 Experimental site

From November 2020 to April 2021, the experiment was carried out at the Sher-e-Bangla Agricultural University's Horticulture farm in Dhaka. The site is located at 23°74" N latitude and 90°35" E longitude, and it is 8.2 meters above sea level (Appendix-I).

3.2 Climate

The experimental site is in a subtropical region with a climate that is marked by heavy rain fall from April to September (Kharif season) and little rain fall for the remainder of the month (Rabi season). The Sher-e-Bangla mini weather station provides data on the study period's highest and lowest temperatures, humidity, and rainfall (Appendix-II).

3.3 Soil

Initial soil samples were taken from an experimental field at a depth of 0 to 15 cm. The Soil Resources Development Institute (SRDI), located in Dhaka, Bangladesh, examined the samples that were collected. In Appendix-III, the physio-chemical characteristics of the soil are listed. The soil in the experimental plots belonged to the Madhupur Tract's AEZ-28 (Agro-Ecological Zone), which is depicted in (Appendix-III).

3.4 Plant materials

The tomato variety used in the experiment was BARI Tomato16. This variety is of the determinate type and has a great yield.

3.5 Treatments of the Experiment

The goal of the experiment was to examine how humic and salicylic acids affected the physiological growth, yield, antioxidant content, and quality of tomato. The experiment included the following two components:

Factor A: **Humic Acid**

a. H_0 = 0 ppm

b. H_1 = 30 ppm

c. H_2 = 60 ppm

d. H_3 = 90 ppm

Factor B: **Salicylic Acid**

a. S_0 = 0 ppm

b. S_1 = 40 ppm

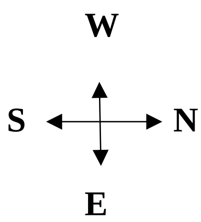
c. S_2 = 80 ppm

d. S_3 = 120 ppm

3.6 Experimental design and layout

A two factorial experiment was used. Three replications of the experiment were set up using a Randomized Complete Block Design (RCBD). Three equal blocks made up the experimental area. Each replication contained sixteen plots with sixteen treatments distributed at random. There were 48 plots in total. Each plot has dimensions of 2 m ×1.8 m. Two blocks and two plots were separated by l.0 meters.

Replication 1	Replication 2	Replication 3
H_0S_O	H_2S_2	H_2S_0
H_1S_O	H_0S_2	H_3S_1
H_0S_1	H_1S_2	H_3S_3
H_1S_0	H_1S_0	H_0S_3
H_2S_O	H_2S_1	H_2S_1
H_3S_0	H_2S_O	H_1S_3
H_1S_1	H_2S_3	H_1S_1
H_3S_2	H_0S_1	H_0S_2
H_2S_O	H_3S_2	H_0S_0
H_0S_2	H_3S_3	H_1S_2
H_3S_3	H_1S_2	H_3S_2
H_2S_2	H_3S_O	H_2S_3
H_3S_1	H_0S_O	H_0S_1
H_0S_3	H_3S_1	H_3S_O
H_2S_1	H_0S_3	H_2S_2
H_1S_2	H_1S_3	H_1S_O



Spacing :60×40

H_0: Control

H_1:30 ppm humic acid

H_2 :60 ppm humic acid

H_3:90 ppm humic acid

S_0: control

S_1:40 ppm salicylic acid

S_2:80 ppm salicylic acid

S_3:120 ppm salicylic acid

Fig. 1. Field layout of the experiment in the Randomized Complete Block Design (RCBD).

3.7 Land preparation

With the use of a power tiller, the experiment's chosen plot of land was prepared on October 13, 2020, and left exposed to the sun for four days before more plowing. At 15 October 2020, cross-plowing and laddering were used to properly prepare the area. Before final land preparation, weeds and stubble were pulled, the basic amount of fertilizer was applied, and the soil was completely mixed with it. The unit plots were set up with l m between each plot and a 50 cm drain dug all around the area. Each block and plot has a drain built into the space between them that is approximately 30 cm deep.

3.8 Seedbed preparation

On a comparatively high piece of ground at the Sher-e-Bangla Agricultural University's Horticulture Farm in Dhaka, tomato seedlings were cultivated there. The seedbed measured 3 m by l m in size. With the aid of a spade, the soil was thoroughly prepared and turned into a loose, friable, and dry mass to produce beautiful beautiful tilth.

Figure 3: seedbed preparation

During seedbed preparation, all weeds and stubble were pulled out, and 5 kg of well-rotten cowdung was spread on the seedbed. On October 20, 2020, the seeds were spread, and after sowing, the seeds were covered with fine soil. As a preventative strategy against ants and worms, heptachlor 40 WP was administered at a rate of 4 kg/ha around each seedbed. Within 5 to 6 days of seeding, the seedlings began to germinate. Banana leaves were used to create the necessary shelter over the seed bed so that the newborn seedlings would be shielded from the hot sun or torrential downpour. No chemical fertilizer was utilized in the seedbed; instead, occasional weeding, mulching, and irrigation were carried out as needed.

3.9 Application of manures and fertilizers

Manure and fertilizer dosages that were recommended for tomato production include the following: fertilizer recommendation guide (2012)

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

During the last stage of land preparation, TSP and half of the cow dung were applied as basal. Before planting the seedlings, the remaining cow manure was poured to the pits. When using the ring method in moist soil conditions, urea and MoP were applied in two equal splits at 15 and 35 days after transplanting. This allowed for better utilization.

3.10 Transplanting of seedlings

On the afternoon of November 26, 2020 healthy and consistent 30 day seedlings were removed separately from the seed bed and replanted into the experimental plots while maintaining a 60 cm x 40 cm distance between the rows and the plants, respectively. Before removing the seedlings from the seedbed, the seedbed was irrigated to reduce root damage. After transplantation, the seedlings received water. From planting till harvest, shading was given using polythene and a bamboo framework to shield the young plants from the summer's harsh weather. For the purpose of filling in any gaps, seedlings were also planted near the experimental plots' borders.

Figure 5: transplanting of tomato seedling

3.11 Application of humic acid and salicylic acid

According to the treatments, humic acid and salicylic acid were synthesized in various doses and sprayed at 30, 70, and 100 days after sowing (DAS).

3.12 Intercultural Operations

The following intercultural procedures were carried out for the plants' better growth and development after the seedlings were transplanted:

3.12.1 Weeding

To keep the crop free of weeds, weeding was done as needed.

3.12.2 Shoot pruning and stalking

The primary stems of the plants were guided upward by hand and with the aid of a bamboo stick for optimal growth and development. Therefore, the rainy and stormy weather was unable to harm the plant stems that were still growing.

3.12.3 Irrigation

The experiment was carried out during rabi. When a result, irrigation was provided as needed. Sometimes rain provides enough water, so irrigation is not necessary.When irrigation was used, it was delivered through the plots' drains.

3.12.4 Plant protection

The tomato plant is extremely susceptible to different insect pest and disease. So, several safety precautions were adopted. Ripcord and Melathion 57 EC were used in a 2-ml application to combat insect pests like beetles, fruit flies, and fruit borer. The pesticide was applied twice a month, beginning 10 days after the seed was sown and ending one week before the first harvest. Spraying was used as a preventative tactic against viral diseases in cloudy and hot weather. As a soil pesticide, furadan 5 G was also treated during pit preparation at a rate of 6 g per pit.

3.13 Harvesting

The green fruits were collected once they were in sellable condition. Fruits were also picked when a reddish hue began to appear where the blossoms had just fallen.

Figure 7: tomato harvesting

3.14 Data collection

Data gathered for the parameters listed below.

3.15 Data collection procedure

3.15.1 Plant height

For each plant in each treatment, the height of the plant was measured three times throughout the course of 30 DAS, 70 DAS, and 100 DAS in centimeters from the ground to the tip of the main stem, and a mean value was derived.

3.15.2 Number of leaves per plant

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 the plants of the treatments and mean value was calculated.

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 Total dry matter

By adding up the dry matter weight of the plant's leaves, stems, roots, and other immature reproductive elements, the total dry matter of the plant at harvest was estimated.

3.15.5 Days to 1st flowering

Days to first flowering were measured by keeping track of how many days each tomato plant in each plot needed after transplanting to begin flowering.

Figure 8: flower initiation

3.15.6 Days to 1st fruit set

The number of days from the date of transplanting until the first tomato plant in each plot began to bear fruit was used to calculate the days to first fruit set.

Figure 9: fruit initiation

3.15.7 Number of flowers per pant

Plant counted the number of flowers on each individual plant. For each treatment, the number of flowers per plant was recorded.

3.15.8 Number of fruits per plant

Fruit was counted from the start to the last stage of harvest. For each treatment, the number of fruits per plant was recorded.

3.15.9 Fruit length and diameter

Vernier scales in centimeters were used to measure the fruit's length and diameter. Each plot's middle region of fruit was measured for diameter, or breath, and the average was calculated. Also measured was the average length of the same fruits.

3.15.10 Weight of individual fruit

The fruits, excluding the first and last harvests, were all counted as part of the total number of fruits harvested over the time from the first to the last harvest (g).

3.15.11 Weight of fruits per plant

The weight of the fruits per plant was measured using a per scale balance. Between the time of fruit set and the last harvest, the total fruit of the plant was measured separately and recorded in kilograms (kg).

3.15.12 Yield of fruits

All 15 plants in each plot and all the fruits from each harvest were taken into account for estimating the yield. The average yield per plot was therefore calculated. The area occupied by the six plants was taken into account while calculating the yield per hectare.

3.15.13 Determination of total ash

The sample was precisely weighed at 10 grams and placed in a crucible. The crucible was set up on a triangle of clay pipe, heated over a low flame until the entire contents were fully burned, and then cooked in a muffle furnace for roughly 5–6 hours at 600°C. It was then weighed after cooling in a desiccator. The crucible was then heated in the muffle furnace for 1 hour, cooled, and weighed to confirm that the ashing process was complete. Until two successive weights were equal and the ash was nearly white or grayish white in hue, this process was repeated.

The following equation was used to determine the total ash:

Ash content (g/l00 g sample) = ash weight × 100 / sample weight (Raghuramulu *et al.,* 2003)

3.15.14 Determination of protein

Digestion: digesting block was activated and heated to the proper temperature. accurately weighted tomato sample of about 0.5 g. kept a weight log. A sample of tomato placed in the digestive tube. repeated two additional samples. Each tube containing the tomato sample received one catalyst tablet and the required amount (for example, 7 ml) of concentrated sulfuric acid. Duplicate blanks were prepared using one catalyst tablet, the amount of sulfuric acid used in the sample, and weigh paper (if weigh paper was added with the tomato sample). On the digestion block, a rack of digestion tubes was placed. digesting block covered and exhaust system activated. Samples should be allowed to digest fully. The samples had no burned debris at all and were clear. samples were removed from the digesting block and let to cool while the exhaust system was still running. Digestion that has been properly diluted with a suitable amount of distilled water. Each tube was twirled.

Distillation: Started the distillation system by following the correct process. A suitable amount of boric acid solution was poured into the receiving flask. Set the receiving flask on the distillation apparatus. Ascertain that the tube from the sample's distillation is immersed in the boric acid solution. Make that the sample tube is securely inserted in its position before starting the distillation. In this distillation procedure, a predetermined amount of NaOH solution is given to the tube, and the sample is then distilled for a predetermined amount of time using a steam generator. After one sample has been thoroughly distilled, start over with a fresh sample tube and receiving flask. Shut off the distillation unit once all samples have been thoroughly distilled.

Titration: Recorded the standardized HCl solution's normalcy once it was verified to be so. The receiver flask should be placed on a stir plate with a magnetic stir bar inside. While titrating, keep the solution churning vigorously, being careful not to let the stir bar touch the electrode. Titrated every sample and blank to a p^H of 4 as the endpoint. utilized HCl titrant volume that was recorded. Put a magnetic stir bar in the receiver flask, set it on a stir plate, and stir the solution vigorously while titrating while using a colorimetric endpoint. With the standardized HCl solution, titrated each sample and blank until the very first faint gray hue appeared. utilized HCl titrant volume that was recorded.

Calculation: In the sample, moles of HCl = moles of NH_3 = moles of N.

To subtract reagent nitrogen from sample nitrogen, a reagent blank was run.

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

In order to convert percent N to percent crude protein, a factor was used. Since 16% of proteins are composed of nitrogen, the conversion factor is 6.25 (100/16).

Protein = % N/0.16

3.15.15 Determination of Sugar Reagents:

(1) Fehling A: Dissolve 69.28 g of copper sulphate in distilled water ($CuSO_4.5H_2O$). 1000 ml of dilution Filter, then put the contents in an amber bottle.

(2) Fehling B: Dissolve 100 g of NaOH and 346 g of Rochelle salt (potassium sodium tartrate) in distilled water. 1000 ml of dilution Filter, then put the contents in an amber bottle.

Standardization of Fehling's solution:

Prepare a 50 ml burette with standard dextrose solution. Find the titre, which is the amount of dextrose solution needed to completely decrease the copper in 10 ml of Fehling solution (Refer table below). Pipette 10 ml of Fehling's solution into a 300 ml conical flask, followed by almost all of the standard dextrose solution needed to reduce all of the copper. This will result in the need for more than one milliliter to finish the titration. Over wire gauze, warm the flask containing the mixture. For 2 minutes, gently boil the flask's contents. One milliliter of the methylene blue indicator solution should be added at the end of the two minutes of boiling without pausing the process. Add standard dextrose solution from the burette (one or two drops at a time) as the flask's contents start to boil until the blue hue of the indicator fades. [To ensure that the contents of the flask boil together for three minutes without interpretation, the titration should be finished in under a minute. Take note of the titrate (which is the total volume in milliliters of standard dextrose solution used to reduce all the copper in 10 milliliters of Fehling's solution). To calculate the dextrose factor, multiply the titre (obtained by direct titration) by the milligrams of anhydrous dextrose present in one milliliter of standard dextrose solution. To determine correction, compare this factor to the dextrose factor.

Place a test sample containing approximately 2-2.5 g of sugar in a 200 ml volumetric flask, dilute to around 100 ml, and then add an excessive amount of saturated neutral lead acetate solution (about 2 ml is usually enough). Filter, after mixing, and discard the first few milliliters of the filtrate. Pour dry pot or soda in.

Mix and filter the oxalate to precipitate any extra lead that was utilized in clarity; discard the first few milliliters of filterate.

Use the Lane and Eynon Volumetric Method to titrate a 25 ml filterate or aliquot containing (if possible) 50–200 mg reducing sugars with a mixed Fehling A–B solution.

Transfer a 50 ml aliquot of the clarified and deleaded solution to a 100 ml volumetric flask, add 10 ml of HCl (1+ 1), and let the mixture at room temperature for 24 hours to allow inversion to occur. (For inversion, the sample containing HCl may be heated for one hour at 700 C. This expedites the procedure and saves time overall. Use phenolphthalein to neutralize precisely with a solution of concentrated NaOH, then dilution to 100 ml. Determine total sugar as invert sugar by titrating against a Fehling A and B solution that has been combined (25 ml of Fehling's Solution can be used for this) (Calculate added sugar by deducting reducing sugars from total sugars).

Figure 10: Determination of nutritional attributes of tomato in BCSIR laboratory

Calculations for reducing and total reducing sugar are as follows:

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

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

Reducing sugar in total (%) =

= (Total reducing sugar – Reducing sugar) x 0.95

Added sugar = Total sugars – Reducing sugars

3.15.16 Vitamin C content

By using a visual titration approach with 2, 6-dichlorophenol indophenols, the

vitamin C content of green and dried fruits was evaluated. The estimation of vitamin C content employed the following reagents.

Reagents

i. **3% Metaphosphoric acid (HPO_3):** 10 % L-ascorbic acid solvent was made by combining 30 g of HPO_3 and 80 ml of glacial acetic acid in distilled water to get a liter-sized solution.

ii. **Standard ascorbic acid solution**: Ascorbic acid was dissolved in a solution of 3 metaphosphoric acid to create 10% of L-ascorbic acid solvent.

iii. **Dry solution**: To make the dry solution, 260 mg of sodium salt of 2, 6-dichlorophenol indophenols were dissolved in one liter of distilled water.

Procedure

Dilute 5 ml of a standard ascorbic acid solution with 5 ml of meta phosphoric acid to standardize the dye solution. Using phenolphthalein as an indicator, a microburette was loaded with dye solution, and the combined solution was titrated with dye solution until the pink end point persisted for at least 15 seconds.

The following formula was used to determine the dye factor:

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

Titration

With the help of phenolphthalein as an indicator, 5 ml of the aliquot was placed in a conical flask and titrated with 2, 6-dichlorophenol indophenols dye. The end point had a ping-colored appearance and persisted for at least 15 seconds. The following formula was used to determine the sample's ascorbic acid (Vitamin C) content:

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

Where,

T = The title value (ml) dye factor

D = Dye factor

V_1 = the amount to be made (ml)

V_2 =the amount of extract used in the titration (ml) W stands for the sample weight used for estimate (g)

W = Weight of sample taken for estimation (g)

3.15.17 Lycopene content

Procedure

I. Started with 100 L of well-homogenized tomato juice that was processed under vacuum to prevent the entrance of air bubbles. Using a micropipettor to collect the sample poured the sample into a tube with a screw cover. Additionally, several control samples were prepared using 100 L of water instead of tomato pulp.

II. Using a repipetter, 8.0 ml of hexane, ethanol, and acetone (2:1:1) was added. quickly cap and vortex the tube, then incubate away from direct sunlight.

III. Added 1.0 ml of water to each sample and vortexed it once more after waiting for at least 10 minutes or up to several hours.

IV.Samples are allowed to stand for 10 minutes to allow for phase separation and the elimination of all air bubbles.

V. Rinsed the cuvette using one of the blank samples' top layer. After discarding, zero the spectrophotometer at 503 nm using a new blank. figured out the A503 of the samples' upper layers of lycopene.

Calculation of lycopene levels

The following formula was used to determine the amount of lycopene in the hexane extracts: Lycopene (mg/kg fresh wt.) = $(A_{503} \times 537 \times 8 \times 0.55) / (0.10 \times 172)$ (1)

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

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

3.16 Statistical analysis

To evaluate tomato growth, antioxidant content, and nutritional quality in response to humic acid and salicylic acid, analysis of variance was carried out. The variations between each treatment were compared using LSD tests, where $P < 0.05$ was deemed significant. Statistic 10 was used for the statistical analysis.

CHAPTER IV

RESULT AND DISCUSSION

The presentation and discussion of the experiment's findings are included in this chapter. The goal of the experiment was to ascertain how humic and salicylic acids affected tomato growth and nutritional value. For convenience of discussion, comparison, and understanding, some of the data have been given and described in table(s) and some in figures. The following headings provide a summary of all the parameters with possible interpretations where applicable.

4.1 Plant height

Plant height was significantly affected by humic acid at 30, 70, and 100 days after sowing (DAS) (Appendix iv). The H_3 (80 ppm humic acid) treatment generated the tallest plant (14.84, 41.88 and 94.37 cm at 30, 70, and 100 DAS, respectively), while the H_0 (control) treatment produced the shortest plant (13.57, 40.15 and 82.72 cm at 30, 70, and 100 DAS, respectively) (Figure 1). Humic acid was dramatically raised up to a specific level, which resulted in an increase in plant height. At 30, 70, and 100 DAS, plant height was noted.

There was a substantial difference in plant height at 30, 70, and 100 DAS as a result of the varied salicylic acid fertilizer levels (Appendix iv). The S_2 (110 ppm salicylic acid) treatment led to the highest plant height (14.66, 41.76, and 94.95 cm at 30, 70, and 100 DAS, respectively). However, the S_0 (control) treatment produced the smallest plant height (13.26, 39.62, and 83.43 cm at 30, 70, and 100 DAS, respectively) (Figure 2). It was discovered that plants grow taller when salicylic acid levels rise. These results support the claims made by (Kazemi, 2013) that SA independently improved tomato plant height.

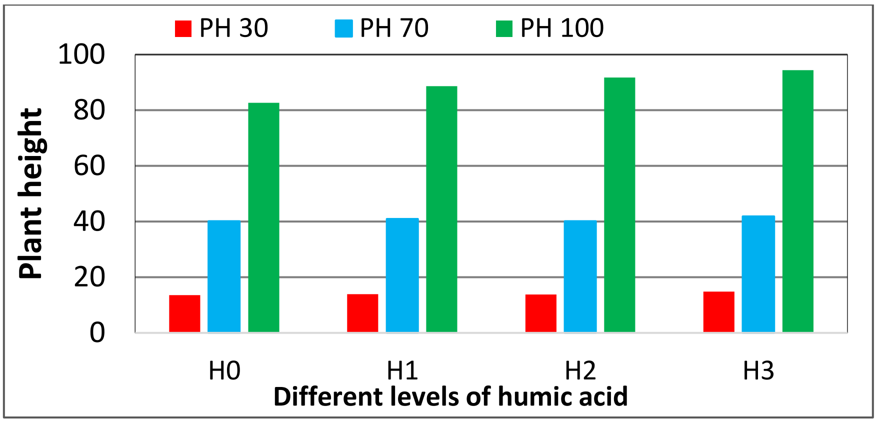


Figure 1: Effect of humic acid on the plant height of tomato at different days after sowing (DAS)

Note : H_0: Control

H_1: 30 ppm humic acid

H_2: 60 ppm humic acid

H_3: 90 ppm humic acid

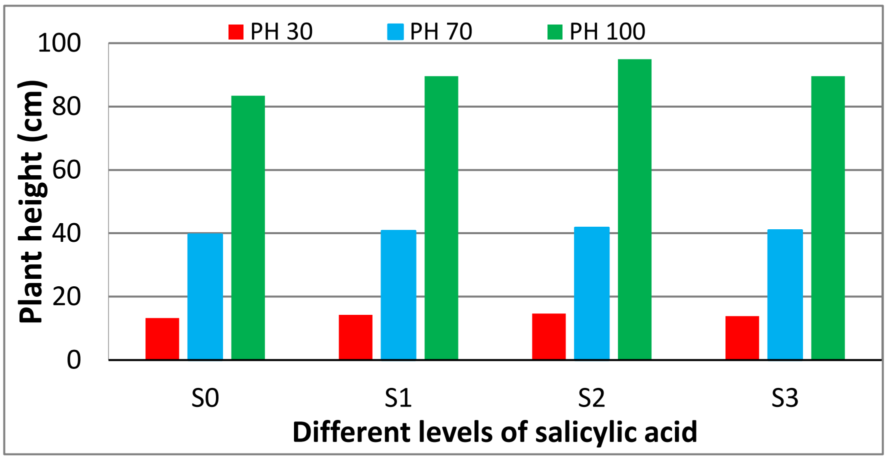


Figure 2. Effect of salicylic acid on the plant height of tomato at different days after sowing (DAS)

Note : S_0 : Control

S_1: 40 ppm salicylic acid

S_2: 80 ppm salicylic acid

S_3 : 120 ppm salicylic acid

Table 1: 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	11.63^{e}	37.80^{d}	74.67^{d}
H_0S_1	14.84^{b}	40.27^{c}	8.63^{cd}
H_0S_2	14.71^{bc}	40.90^{bc}	87.82^{bc}
H_0S_3	13.10^{de}	41.63^{bc}	84.78^{bc}
H_1S_0	13.84^{bcd}	40.48^{bc}	86.70^{bc}
H_1S_1	14.64^{bcd}	40.71^{bc}	90.11^{bc}
H_1S_2	13.51^{bcd}	41.26^{bc}	92.00^{bc}
H_1S_3	13.70^{bcd}	41.08^{bc}	85.87^{bc}
H_2S_0	13.40^{bcd}	38.74^{d}	88.48^{bc}
H_2S_1	13.19^{cd}	40.44^{bc}	91.37^{bc}
H_2S_2	13.51^{bcd}	41.26^{bc}	93.89^{b}
H_2S_3	14.80^{b}	40.30^{bc}	93.39^{b}
H_3S_0	14.18^{bcd}	41.45^{bc}	83.89^{cd}
H_3S_1	14.49^{bcd}	41.66^{b}	93.37^{b}
H_3S_2	16.99^{a}	43.62^{a}	106.11^{a}
H_3S_3	13.77^{bcd}	40.78^{bc}	94.11^{b}
LSD $_{(0.05)}$	1.54	1.36	9.38
P-value	0.00	0.00	0.28
CV (%)	6.59	2.01	6.30

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 = 30 ppm, H_2 = 60 ppm, H_3 = 90 ppm of humic acid and S_0 = 0, S_1 = 40 ppm, S_2 = 80 ppm, S_3 = 120 ppm of salicylic acid. DAS = days after sowing.

There was a substantial difference in plant height at the sites where humic and salicylic acid had an impact and (Appendix iv). The H_3S_2 treatment (80 ppm humic acid with 70 ppm salicylic acid) produced the tallest plants (16.99, 43.62, and 106.11 cm at 30, 70, and 100 DAS, respectively), while the H_0S_0 (control) treatment produced the shortest plants (11.63, 37.80, and 74.67 cm at 30, 70, and 100 DAS, respectively) (Table 1).

4.2 Number of leaves per plant

A healthy leaf count indicated improved crop growth and development. It might also have something to do with tomato yield. The photosynthetic area increases with leaf count, potentially increasing fruit yield. At 30, 70, and 100 DAS, there was a discernible change in the humic acid in terms of the number of leaves per plant. H_3 treatment produced the most leaves per plant, which was statistically identical to other treatments (8.04, 20.25, and 34.83 at 30, 70, and 100 DAS, respectively), whereas H_0 treatment produced the fewest leaves per plant (6.20, 15.75, and 31.35 at 30, 70, and 100 DAS, respectively) (Figure 3 and Appendix v). As humic acid levels rise, so did the number of leaves per plant increased.

At 30, 70, and 100 DAS, the number of leaves per plant as a result of salicylic acid's impact was not statistically significant (Appendix v). The most leaves per plant were found in the S_2 treatment (7.59, 17.87, 21.82 and 35.35 at 30, 70 and 100 DAS, respectively). However, the S_0 treatment produced the fewest leaves per plant (6.72, 16.40, and 31.40 at 30, 70, and 100 DAS, respectively) (Figure 4). These findings imply that SA was applied simultaneously, which led to a greater production of tomato leaves. Numerous authors, including (Kazemi, 2013); (Zamaninejad *et al.,* 2013) endorsed this fact.

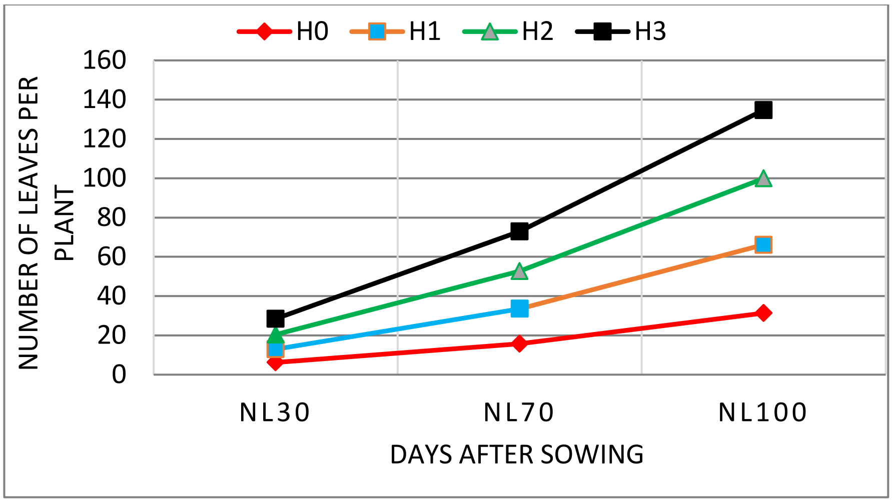


Figure 3: Effect of humic acid on the number of leaves per plant at different days after days (DAS)

Note : H_0 : Control

H_1 : 30 ppm humic acid

H_2 : 60 ppm humic acid

H_3 :90 ppm humic acid

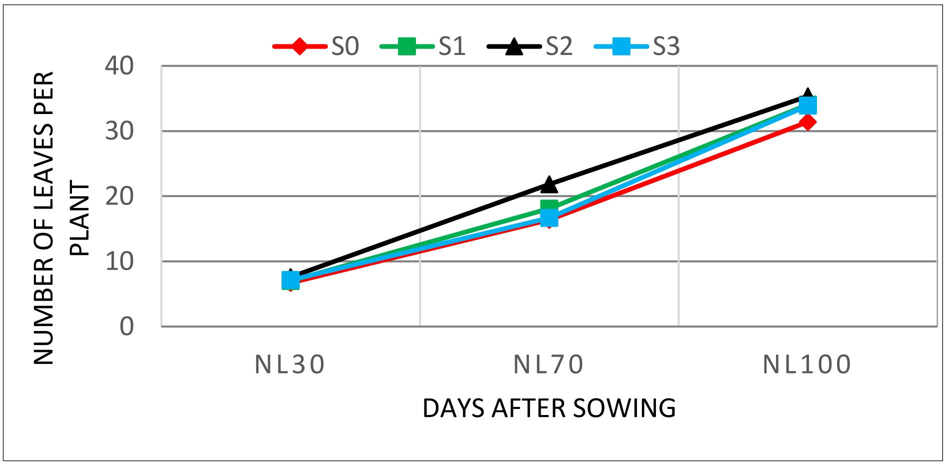


Figure 4. Effect of salicylic acid on the number of leaves per plant at different days after sowing (DAS)

Note: S_0: Control

S_1: 40 ppm salicylic acid

S_2: 80 ppm salicylic acid

S_3: 120 ppm salicylic acid

Table 2. 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	5.60^{g}	12.00^{g}	29.16^{g}
H_0S_1	6.53^{defg}	19.46^{cde}	29.86^{fg}
H_0S_2	6.43^{defg}	16.46^{def}	32.86^{bcdef}
H_0S_3	6.25^{efg}	15.06^{fg}	33.53^{bcde}
H_1S_0	6.43^{defg}	13.20^{fg}	32.64^{cdef}
H_1S_1	6.16^{fg}	20.29^{bcd}	35.43^{bc}
H_1S_2	7.22^{cdef}	22.00^{bc}	35.30^{bc}
H_1S_3	7.20^{cdef}	15.48^{fg}	35.83^{b}
H_2S_0	7.53^{bcd}	23.53^{ab}	33.29^{bcde}
H_2S_1	6.96^{cdef}	15.75^{efg}	35.85^{b}
H_2S_2	8.00^{abc}	22.86^{abc}	32.10^{defg}
H_2S_3	7.33^{bcde}	14.86^{fg}	33.76^{bcd}
H_3S_0	7.33^{bcde}	16.86^{def}	30.51^{efg}
H_3S_1	8.33^{ab}	16.86^{def}	35.13^{bcd}
H_3S_2	8.73^{a}	25.97^{a}	41.15^{a}
H_3S_3	7.76^{abc}	21.33^{bc}	$32.53cd^{cdef}$
LSD $_{(0.05)}$	1.10	3.95	3.17
P-value	0.36	0.00	0.00
CV (%)	9.29	12.98	5.65

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 = 30 ppm, H_2 = 60 ppm, H_3 = 90 ppm of humic acid and S_0 = 0, S_1 = 40 ppm, S_2 = 80 ppm, S_3 = 120 ppm of salicylic acid. DAS = days after sowing.

Humic acid and salicylic acid showed a significant difference in the number of leaves per plant (Appendix v). The most leaves per plant there can be (8.73, 25.97 and 41.15 at 30, 70 and 100 DAS, respectively) was discovered in the H_3S_2 treatment, however the fewest leaves per plant (5.60, 12.00 and 29.16) contained H_0S_0 treatment at 30, 40, and 100 DAS, respectively (Table 2).

4.3 Number of branches per plant

At 70 and 100 DAS, the humic acid revealed a significant change in the number of branches per plant (Appendix vi). H_3 treatment resulted in the highest number of branches per plant (3.82 and 6.92 at 70 and 100 DAS). The least amount of branches per plant (2.92 and 5.69) were produced by the H_0 treatment (Table 3). These findings show that humic acid promotes tomato plant growth, resulting in more branches than the control plant.

The number of branches per plant was not considerably impacted by salicylic acid and (Appendix vi). The S_0 treatment resulted in the lowest number of branches per plant (3.15, 6.13 at 70 and 100 DAS, respectively), whereas the S_2 had the highest number of branches per plant (3.70 and 6.64 at 70 and 100 DAS, respectively) (Table 4). In contrast, SA was found to significantly increase the number of branches in plants by Kazemi (2013) and Yildirim *et al.* (2009). Therefore, the generation of significant branches may be affected in some way by variety and environmental conditions.

The number of branches per plant significantly increased when different dosages of humic acid and salicylic acid were combined (Appendix vi). The H_3S_2 treatment had the most branches per plant (3.92 and 7.28 at 70 and 100 DAS, respectively), whereas the H_0S_0 (control) treatment had the fewest (2.00 and 4.47 at 70, and 100 DAS, respectively (Table 5).

Table 3. Effect of humic acid on the number of branches per plant and total dry weight of plant

Treatments	Number of branches per plant		Total dry weight of plant
	70 DAS	100 DAS	(g)
H_0	2.92[c]	5.69[c]	41.56[a]
H_1	3.39[b]	6.66[b]	41.72[a]
H_2	3.59[ab]	6.61[b]	38.94[b]
H_3	3.82[a]	6.92[a]	38.84[b]
LSD (0.05)	0.25	0.21	2.05
P-value	0.00	0.00	0.00
CV (%)	6.70	2.93	3.17

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 = 30 ppm, H_2 = 60 ppm, H_3 = 90 ppm of humic acid.

Table 4. Effect of salicylic acid on the number of branches per plant and total dry weight of plant

Treatments	Number of branches per plant		Total dry weight of plant
	70 DAS	100 DAS	(g)
S_0	3.15[b]	6.13[b]	41.39[a]
S_1	3.27[b]	6.52[a]	41.36[a]
S_2	3.70[a]	6.64[a]	39.54[ab]
S_3	3.60[a]	6.60[a]	38.76[b]
LSD (0.05)	0.25	0.21	2.05
P-value	0.00	0.00	0.00
CV (%)	6.70	2.93	3.17

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 = 40 ppm, S_2 = 80 ppm, S_3 = 120 ppm of humic acid. DAS = days after sowing.

Table 5. Combined effect of humic acid and salicylic acid on the number of branches per plant and total dry weight of plant

Treatments	Number of branches per plant		Total dry weight of plant
	70 DAS	100 DAS	(gm)
H_0S_0	2.00^{d}	4.47^{f}	41.22^{a}
H_0S_1	3.14^{bc}	5.86^{e}	41.76^{a}
H_0S_2	3.32^{abc}	6.16^{de}	41.54^{a}
H_0S_3	3.24^{abc}	6.26^{cde}	41.71^{a}
H_1S_0	3.07^{c}	6.65^{bcd}	41.97^{a}
H_1S_1	3.16^{bc}	6.66^{bcd}	41.32^{a}
H_1S_2	3.75^{abc}	6.49^{bcd}	41.51^{a}
H_1S_3	3.58^{abc}	6.83^{abc}	41.51^{a}
H_2S_0	3.66^{abc}	6.33^{cde}	41.50^{a}
H_2S_1	3.12^{bc}	6.95^{ab}	41.33^{a}
H_2S_2	3.82^{ab}	6.62^{bcd}	34.26^{b}
H_2S_3	3.78^{ab}	6.54^{bcd}	38.68^{a}
H_3S_0	3.88^{a}	7.06^{ab}	40.89^{a}
H_3S_1	3.67^{abc}	6.59^{bcd}	41.04^{a}
H_3S_2	3.92^{a}	7.28^{a}	40.85^{a}
H_3S_3	3.80^{ab}	6.76^{abc}	32.59^{b}
$LSD_{(0.05)}$	0.70	0.57	4.11
P-value	0.00	0.00	0.00
CV(%)	6.70	2.93	3.17

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 = 30 ppm, H_2 = 60 ppm, H_3 = 90 ppm of humic acid and S_0 = 0, S_1 = 40 ppm, S_2 = 80 ppm, S_3 = 120 ppm of salicylic acid. DAS = days after sowing.

4.4 Total dry weight of plant

A considerable impact of humic acid was seen on the plant's overall dry weight. H_1 had the highest total dry weight per plant (41.72 g), (Table 6 and Appendix vi). H_3 had the lowest average dry weight per plant (38.84 g). Variations in morpho-physiological traits may have an impact on the photosynthetic traits, which in turn may have an impact on the overall production of dry matter.

The total dry weight per plant was significantly impacted by the interaction between humic acid and SA (Appendix vi). Due to SA, there was a significant difference in the overall dry weight per plant. S_0 yielded the highest total dry weight per plant (41.39 g), while S_3 yielded the lowest total dry weight per plant (40.44 g) (Table 7).

Humic acid and salicylic acid were discovered to have a significant combined effect on plant dry weight (Appendix vi). The H_1S_0 plant produced the highest total dry weight per plant (41.97 g), and the lowest (32.59 g) to the H_3S_3 plant (Table 8).

4.5 Days to first flowering

Days to initial flowering showed a significant variance because of humic acid (Appendix vii). The necessary number of days required for the first blossoming was found in the H_3 treatment (45.83 days). The H_0 treatment had the longest first flowering period (49.69 days) (Table 6).

In the days leading up to first flowering, a significant variation in salicylic acid concentration was seen (Appendix vii). First flowering began later (49.60 days) in the S_0 treatment than it did earlier (46.32 days) in the S_2 treatment (Table 7).

Humic acid and salicylic acid were discovered to have a significant combined influence on days of first flowering (appendix vii). The days of initial flowering were minimum in H_3S_2 treatment (41.47 days) and maximum in H_0S_1 treatment (51.11 days), as shown in (table 8).

4.6 Days to first fruit set

Days to initial fruit set vary significantly among the various humic acids (Appendix vii). When they received a foliar salicylic acid spray, the flowers appeared substantially sooner than under the control condition (Larque-Saavedra and Martin-Mex, 2007) The H_0 treatment demanded the longest number of days before the first fruit set (70.58 days). The earliest number of days (67.09 days) was found during the first set in H_3 treatment (Table 10).

In the days leading up to the first fruit set, there was a noticeable variation in the salicylic acid (Appendix vii). First fruit set was found to be delayed in the S_0 treatment (70.54 days), and first fruit set was found to be earliest in the S_3 treatment (68.71 days) (Table 11).

Different combinations of humic acid and salicylic acid were found to have a significant impact on days to first fruit set (Appendix vii). There were discovered to be 62.71 days as the earliest possible fruit set. in H_3S_2 treatment. The maximum days to first fruit set (72.01 days) was found in H_0S_1 treatment (Table 12).

Table 6. Effect of humic acid on days to first flowering and first fruit set, of tomato plant

Treatments	Days to first flowering	Days to first fruit set
H_0	49.69[a]	70.58[a]
H_1	48.76[ab]	69.64[a]
H_2	48.76[ab]	69.55[a]
H_3	45.83[c]	67.09[b]
LSD (0.05)	0.98	1.09
P-value	0.00	0.00
CV (%)	2.46	1.89

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 = 30 ppm, H_2 = 60 ppm, H_3 = 90 ppm of humic acid

Table 7. Effect of salicylic acid on days to first flowering and first fruit set, of tomato plant

Treatments	Days to first flowering	Days to first fruit set
S_0	49.60[a]	70.54[a]
S_1	49.27[a]	70.20[a]
S_2	46.32[c]	67.41[c]
S_3	47.71[b]	68.71[b]
LSD (0.05)	0.98	1.09
P-value	0.00	0.00
CV (%)	2.46	1.89

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 = 40 ppm, S_2 = 80 ppm, S_3 = 120 ppm of salicylic acid.

Table 8. Combined effect of humic acid and salicylic acid on days to first flowering and first fruit set of tomato plant

Treatments	Days to first flowering	Days to first fruit set
H_0S_0	50.03^{abc}	70.93^{abc}
H_0S_1	51.11^{a}	72.01^{a}
H_0S_2	49.44^{abcd}	70.34^{abc}
H_0S_3	48.18^{cde}	69.04^{cde}
H_1S_0	48.77^{bcd}	69.67^{bcd}
H_1S_1	50.62^{ab}	71.56^{ab}
H_1S_2	46.66^{ef}	67.66^{de}
H_1S_3	49.00^{bcd}	69.66^{bcd}
H_2S_0	50.29^{ab}	70.89^{abc}
H_2S_1	48.92^{bcd}	69.55^{bcd}
H_2S_2	47.69^{def}	68.93^{cde}
H_2S_3	47.58^{def}	68.82^{cde}
H_3S_0	49.33^{abcd}	70.66^{abc}
H_3S_1	46.44^{ef}	67.67^{de}
H_3S_2	41.47^{g}	62.71^{f}
H_3S_3	46.10^{f}	67.33^{e}
$LSD_{(0.05)}$	1.97	2.18
P-value	0.00	0.00
CV (%)	2.46	1.89

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 = 30 ppm, H_2 = 60 ppm, H_3 = 90 ppm of humic acid and S_0 = 0, S_1 = 40 ppm, S_2 = 80 ppm, S_3 = 120 ppm of salicylic acid. DAS = days after sowing.

4.7 Number of flowers per plant

The amount of flowers per plant varied significantly depending on the humic acid (Appendix vii). H_3 treatment produced the most flowers per plant (53.67), whereas H_0 treatment produced the fewest flowers per plant (42.82), which was statistically comparable with H_1 and H_2 treatment (Figure 5).

The quantity of flowers per plant varied significantly depending on the salicylic acid fertilizer (Appendix vii). The S_2 treatment generated the most blooms per plant (54.43). S_0 treatment resulted in the fewest flowers per cluster (42.20) (Figure 6).

The results of the analysis of variance (Appendix vii) showed that the quantity of blooms produced by each plant varied significantly depending on whether humic acid and salicylic acid were used as treatments. The H_3S_2 treatment had the most flowers per plant (59.26), while the H_0S_0 treatment had the fewest flowers per plant (37.08) (Table 9).

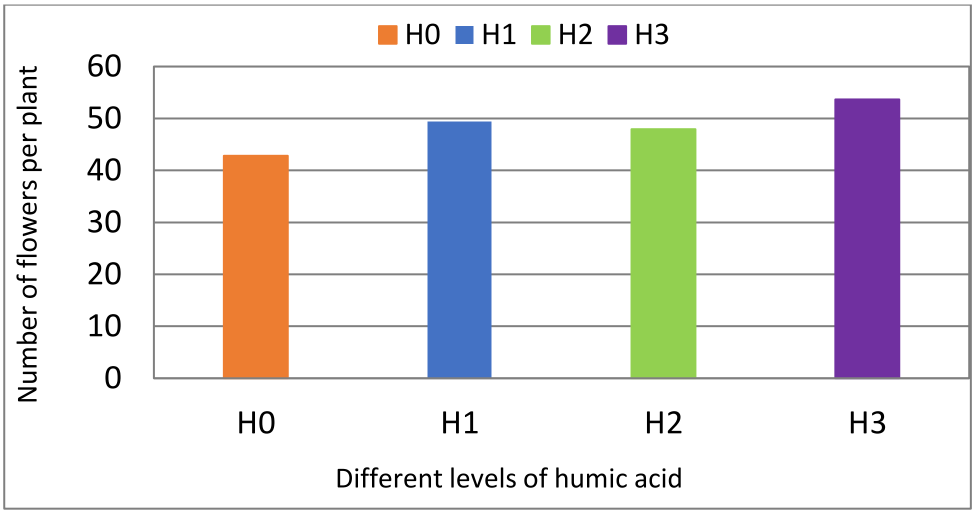


Figure 5: Effect of humic acid on number of flowers per plant of tomato

Note: H_0: Control

H_1: 30 ppm humic acid

H_2: 50 ppm humic acid

H_3: 90 ppm humic acid

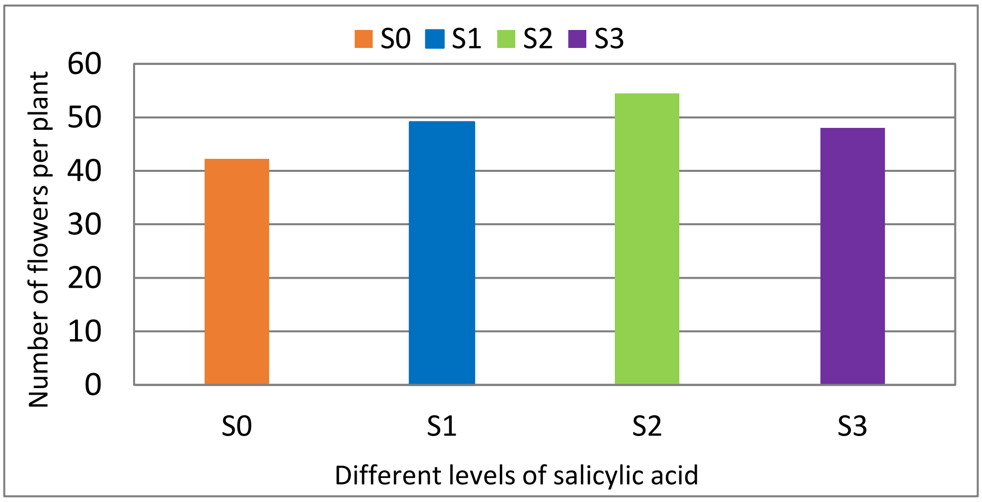


Figure 6: Effect of salicylic acid on number of flowers per plant of tomato

Note: S_0: Control

S_1: 40 ppm salicylic acid

S_2: 80 ppm salicylic acid

S_3: 120 ppm salicylic acid

Table 9. Combined effect of humic acid and salicylic acid on number of flowers per plant of tomato

Treatments	**Number of flowers per plant**
H_0S_0	37.08^{j}
H_0S_1	41.15^{hij}
H_0S_2	50.11^{de}
H_0S_3	42.96^{ghi}
H_1S_0	47.67^{efg}
H_1S_1	49.11^{def}
H_1S_2	58.15^{ab}
H_1S_3	42.56^{hi}
H_2S_0	39.19^{ij}
H_2S_1	49.26^{def}
H_2S_2	50.22^{de}
H_2S_3	53.11^{cd}
H_3S_0	44.85^{fgh}
H_3S_1	56.93^{abc}
H_3S_2	59.26^{ab}
H_3S_3	53.63^{bcd}
LSD $_{(0.05)}$	5.03
P-value	0.00
CV (%)	6.24

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 = 30 ppm, H_2 = 60 ppm, H_3 = 90 ppm of humic acid and S_0 = 0, S_1 = 40 ppm, S_2 = 80 ppm, S_3 = 120 ppm of salicylic acid. DAS = days after sowing.

4.8 Numer of fruits per plant

The amount of fruit produced by each plant varied significant in response to humic acid (Appendix vii). H_3 treatment generated the most fruit per plant (34.58), whereas H_0 produced the least amount of fruit per plant (30.32) (Figure 7).

There are significant effect on fruits per plant as a result of salicylic acid's action (Appendix vii). The S_2 treatment produced the most fruit per plant (34.20), while the S_0 treatments produced the least fruit per plant (31.95) (Figure 8). Fruits with vascular cambium capable of meristematic activity are affected by salicylic acid. According to Muhal and Solanki (2014), foliar spray with 100 ppm SA greatly increased the quantity of siliqua per plant compared to watter spray. The spraying of concentrations of SA had a growth regulatory effect on the number of fruist per plant and increased the fruit yield as suggested by (Javaheri *et al.*, 2012).

Humic acid and salicylic acid interaction was discovered to have a considerable significant impact on the number of fruits produced per plant (Appendix vii). H_3S_2 had the highest average number of fruits per plant (36.67), whereas H_0S_0 had the lowest average number of fruits per plant (26.11) (Table 10).

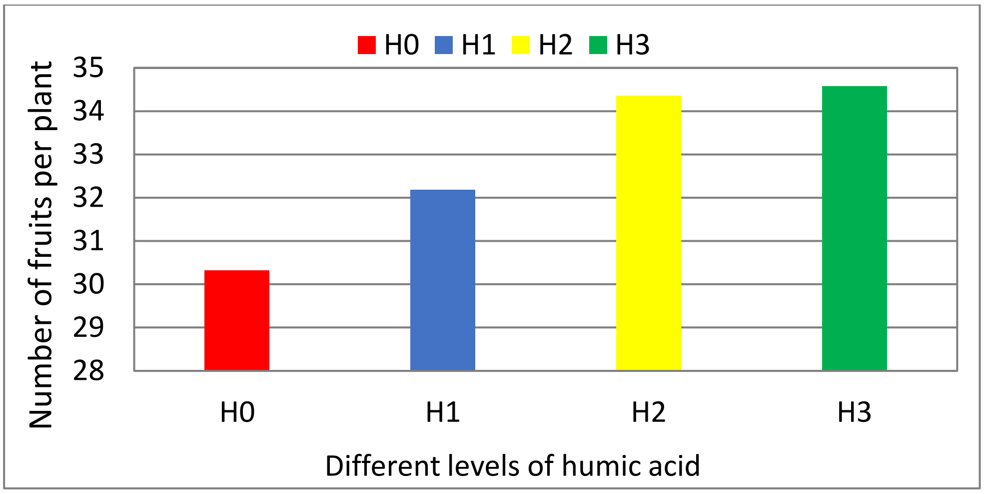


Figure 7: Effect of humic acid on number of fruits per plant of tomato

Note: H_0: Control

H_1: 30 ppm humic acid

H_2: 60 ppm humic acid

H_3: 90 ppm humic acid

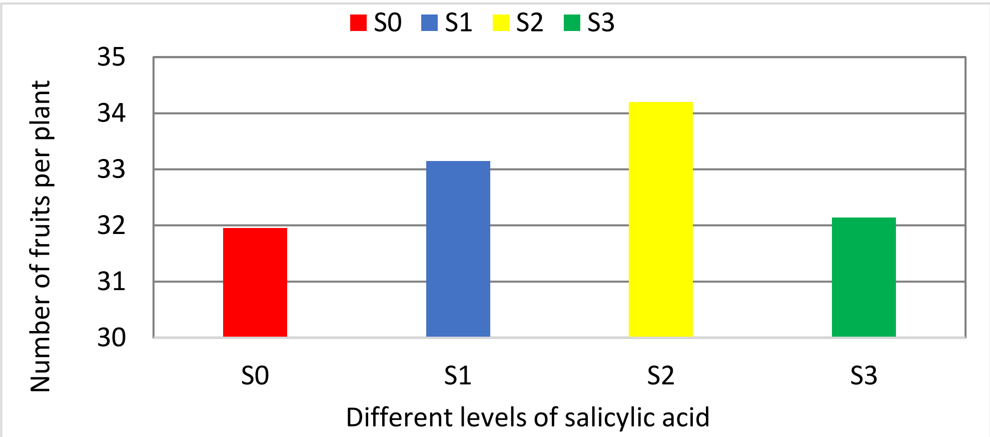


Figure 8: Effect of salicylic acid on number of fruits per plant of tomato

Note : S_0: Control

S_1: 40 ppm salicylic acid

S_2: 80 ppm salicylic acid

S_3: 120 ppm salicylic acid

Table 10. Combined effect of humic acid and salicylic acid on number of flowers per plant of tomato

Treatments	Number of fruits per plant
H_0S_0	26.11[h]
H_0S_1	32.33[defg]
H_0S_2	32.56[cdefg]
H_0S_3	30.30[g]
H_1S_0	31.81[efg]
H_1S_1	33.04[cdefg]
H_1S_2	32.37[defg]
H_1S_3	31.52[fg]
H_2S_0	36[ab]
H_2S_1	34.34[abcde]
H_2S_2	35.22[abc]
H_2S_3	31.85[efg]
H_3S_0	33.89[bcdef]
H_3S_1	32.89[cdefg]
H_3S_2	36.67[a]
H_3S_3	34.89[abcd]
$LSD_{(0.05)}$	2.74
P-value	0.00
CV(%)	6.24

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 = 30 ppm, H_2 = 60 ppm, H_3 = 90 ppm of humic acid and S_0 = 0, S_1 = 40 ppm, S_2 = 80 ppm, S_3 = 120 ppm of salicylic acid. DAS = days after sowing

4.9 Length of fruit

The length of the fruit significantly varied according to the presence of humic acid (Appendix viii). However, H_1 produced the fruit with the longest length (6.31 cm), while H_0 and H_2 treatment produced the fruit with the smallest length (5.70 cm) (Table 11). It was discovered that raising humic acid up to a certain point causes fruits to grow longer. (Gelmesa *et al.*,2010) also reported similar results.

There was very little difference in fruit length among the salicylic acid species (Appendix viii). S_0 produced the fruit with the largest length (5.96 cm), while S_1 produced the fruit with the smallest length (5.85 cm) (Table 12).

The variation in fruit length due to combined effect of humic acid and salicylic acid was found statistically significant (Appendix viii). The longest fruit length (6.86 cm) was found in H_1S_0, whereas the shortest fruit length (5.18 cm) was found from H_0S_0 (Table 13).

4.10 Diameter of fruit

Fruit humic acid diameter showed a large amount of variance (Appendix viii). H_1 generated the fruit with the biggest diameter (6.89 cm), and H_0 produced the fruit with the shortest fruit breath (5.69 cm). Gelmesa *et al.,* (2010) also reported similar results (Table 11).

The diameter of the fruit varied significantly among the salicylic acid (Appendix viii). S_3 yielded the fruit with the largest diameter (6.68 cm), whereas S_0 yielded the fruit with the smallest diameter (6.28 cm) (Table 12). All things considered, many researchers have recently made the case that SA has beneficial effects on tomato fruit output and fruit yield as indicated by (Javaheri *et al*. 2012).

It was determined that the variance in fruit diameter caused by the combined effects of humic and salicylic acids was statistically significant (Appendix viii). H_1S_0 contained the fruit with the biggest diameter (7.26 cm). The H_0S_0 treatment produced the fruits with the smallest diameter (4.47 cm) (Table 13).

Table 11. Effect of humic acid on yield and yield contributing characters of tomato

Treatments	Fruit length (cm)	Fruit diameter (cm)
H_0	5.70^c	5.69^d
H_1	5.96^b	6.74^b
H_2	5.70^c	6.55^c
H_3	6.25^a	6.90^a
LSD (0.05 %)	0.23	1.53
P- value	0.00	0.00
CV (%)	4.71	2.84

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 = 30 ppm, H_2 = 60 ppm, H_3 = 90 ppm of humic acid.

Table 12. Effect of salicylic acid acid on yield and yield contributing characters of tomato

Treatments	Fruit length (cm)	Fruit diameter (cm)
S_0	5.70^c	6.13^c
S_1	5.76^{bc}	6.46^b
S_2	6.21^a	6.62^a
S_3	5.94^b	6.68^a
LSD (0.05 %)	0.23	0.15
P-value	0.00	0.00
CV (%)	4.71	2.84

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 = 40 ppm, S_2 = 80 ppm, S_3 = 120 ppm of humic acid

Table 13. Combined effect of humic acid and salicylic acid on yield and yield contributing characters of tomato

Treatments	Fruit length	Fruit diameter
H_0S_0	5.18^{h}	4.47^{h}
H_0S_1	5.48^{gh}	5.86^{g}
H_0S_2	5.83^{cdefg}	6.16^{fg}
H_0S_3	6.30^{b}	6.26^{ef}
H_1S_0	5.82^{cdefg}	6.65^{c}
H_1S_1	6.00^{bcdef}	6.66^{c}
H_1S_2	6.18^{bcd}	6.49^{cde}
H_1S_3	5.84^{bcdefg}	7.14^{a}
H_2S_0	5.50^{gh}	6.33^{def}
H_2S_1	5.54^{fgh}	6.73^{c}
H_2S_2	5.73^{defg}	6.62^{cd}
H_2S_3	6.02^{bcde}	6.54^{cde}
H_3S_0	6.28^{bc}	7.06^{ab}
H_3S_1	6.03^{bcde}	6.59^{cd}
H_3S_2	7.10^{a}	7.20^{a}
H_3S_3	5.60^{efgh}	6.76^{bc}
LSD $_{(0.05)}$	0.46	0.30
P-value	0.00	0.00
CV(%)	4.71	2.84

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 = 30 ppm, H_2 = 50 ppm, H_3 = 90 ppm of humic acid and S_0 = 0, S_1 = 20 ppm, S_2 = 80 ppm, S_3 = 120 ppm of salicylic acid.

4.11 Individual fruit weight

Humic acid had a considerable impact on the weight of each fruit, on average (Appendix viii). H_3 treatment produced the biggest individual fruit weight (86.02 g), whereas H_0 produced the smallest individual fruit weight (72.38 g) (Figure 9).

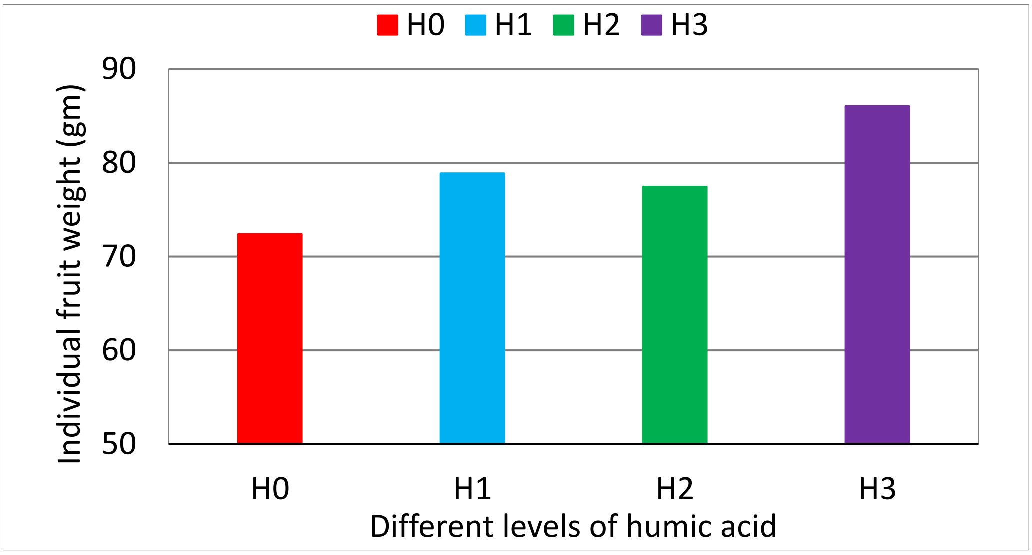


Figure 9. Effect of humic acid on Individual fruit weight of tomato

Note:

H_0: Control

H_1: 30 ppm humic acid

H_2: 60 ppm humic acid

H_3: 90 ppm humic acid

Salicylic acid has a considerable impact on how much each fruit weighed (Appendix viii). The biggest fruit (weighing 84.83 g) came from the S_2 treatment. S_0 produced the fruit with the lightest weight (72.35 g). These findings show that salicylic acid promotes tomato development, resulting in greater fruit/plant weight than control (Figure 10).

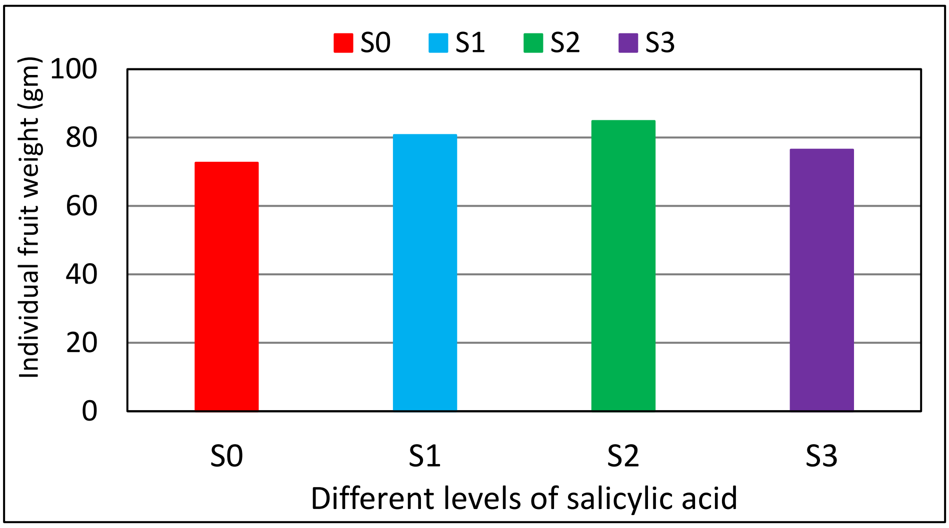


Figure 10. Effect of salicylic acid on Individual fruit weight of tomato

Note:

S_0: Control

S_1: 40 ppm salisylic acid

S_2: 80 ppm salisylic acid

S_3: 120 ppm salisylic acid

Table 14. Combined effect of humic acid and salicylic acid on individual fruit weight of tomato

Treatments	Individual fruit weight (gm)
H_0S_0	67.41^{j}
H_0S_1	72.96^{gh}
H_0S_2	78.00^{ef}
H_0S_3	71.15^{hi}
H_1S_0	72.78^{gh}
H_1S_1	80.89^{de}
H_1S_2	86.93^{ab}
H_1S_3	74.85^{fg}
H_2S_0	68.96^{ij}
H_2S_1	80.89^{de}
H_2S_2	84.59^{bc}
H_2S_3	75.22^{fg}
H_3S_0	81.44^{cd}
H_3S_1	88.21^{a}
H_3S_2	89.82^{a}
H_3S_3	84.63^{bc}
LSD (0.05	3.23
P-value	0.02
CV (%)	2.47

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 = 30 ppm, H_2 = 60 ppm, H_3 = 90 ppm of humic acid and S_0 = 0, S_1 = 40 ppm, S_2 = 80 ppm, S_3 = 120 ppm of salicylic acid.

Humic acid and salicylic acid have a considerable impact on fruit's weight (Table 14 and Appendix viii). H_3S_2 had the largest individual fruit weight (89.82 g). While H_0S_0 treatment had the lightest weight of any individual fruit (67.41 g).

4.12 Yield of fruits per plant

Humic acid significantly affected the amount of fruits produced by each plant (Figure 11 and Appendix viii). The H_3 treatment, which was statistically comparable to H_1 and H_2, generated the highest production of fruits per plant (2.97 kg), whereas the H_0 treatment produced the lowest yield of fruits per plant (2.19 kg).

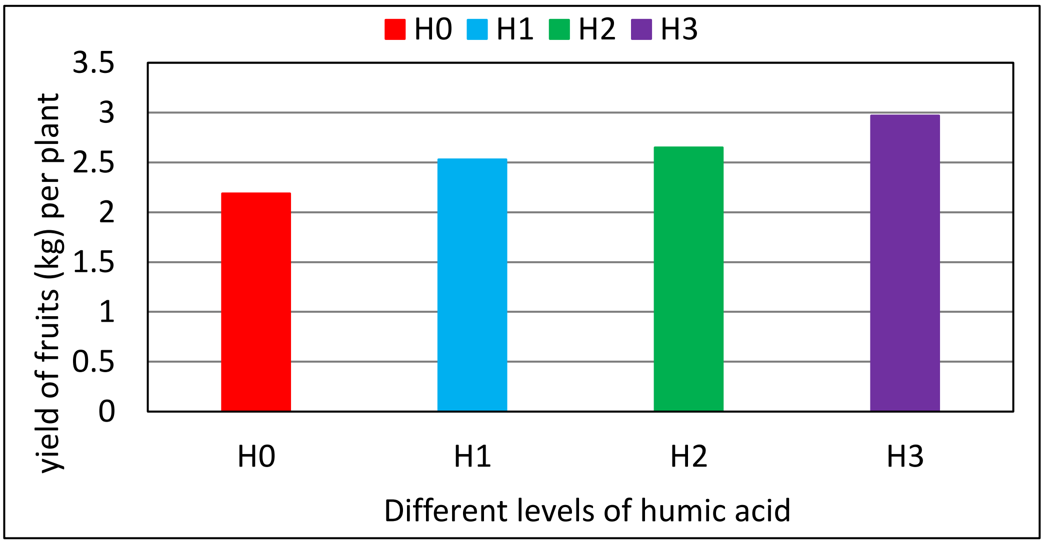


Figure 11. Effect of humic acid on yield of tomato fruits per plant

Note:

H_0: Control

H_1: 30 ppm humic acid

H_2: 60 ppm humic acid

H_3: 90 ppm humic acid

Similar findings were made by Anuja and Shakila (2006), who discovered that salicylic acid had a significant impact on the plants' fruit yield (Figure 12 and Appendix viii). S_2 treatment produced the highest fruit production per plant (2.90 kg), whereas the S_0 treatment produced the lowest fruit output per plant (2.32 kg), which was statistically comparable to the S_1 and S_3 treatments. Meena (2010) also reported similar.

Humic acid and salicylic acid together have a considerable impact on the amount of fruit produced per plant (Table 15 and Appendix viii). The H_3S_2 plant produced the most fruits per plant (3.29 kg). The plant H_0S_0 produced the fewest fruits per plant (1.75 kg).

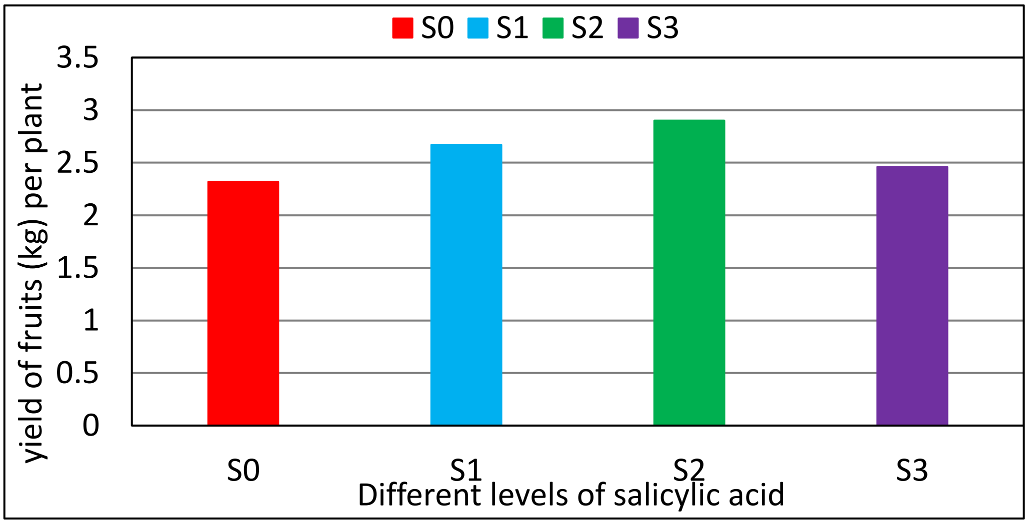


Figure 12. Effect of salisylic acid on yield of tomato fruits (kg) per plant

Note:

S_0: Control

S_1: 40 ppm salisylic acid

S_2: 80 ppm salisylic acid

S_3: 120 ppm salisylic acid

Table 15. Combined effect of humic acid and salicylic acid on yield of fruits per tomato plants

Treatments	**Yield of fruits per plant (kg)**
H_0S_0	1.75^{i}
H_0S_1	2.35^{fgh}
H_0S_2	2.53^{ef}
H_0S_3	2.15^{h}
H_1S_0	2.31^{gh}
H_1S_1	2.66^{de}
H_1S_2	2.80^{bcd}
H_1S_3	2.35^{fgh}
H_2S_0	2.47^{efg}
H_2S_1	2.77^{bcd}
H_2S_2	2.97^{b}
H_2S_3	2.39^{fg}
H_3S_0	2.75^{cd}
H_3S_1	2.89^{bc}
H_3S_2	3.29^{a}
H_3S_3	2.95^{bc}
$LSD_{(0.05)}$	0.20
P-value	0.02
CV (%)	4.79

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 = 30 ppm, H_2 = 60 ppm, H_3 = 90 ppm of humic acid and S_0 = 0, S_1 = 40 ppm, S_2 = 80 ppm, S_3 = 120 ppm of salicylic acid.

4.13 Yield per hectare

The fruit productivity per hectare was significantly influenced by the various humic acids (Table 13 and Appendix viii). The H_3 (90 ppm) treatment, produced the highest yield of fruits per hectare (123.38 tons), whereas the H_0 treatment generated the lowest yield (91.48 tons). Due to a combination of the number of fruits generated per plant, the weight of each fruit, and the low flower dropping, the fruit yield was at its highest level at 90 ppm humic acid.

Due to the use of various salicylic acid concentrations, the tomato crop's overall production fluctuated dramatically (Table 14 and Appendix viii). S_2 produced the most fruit (120.84 t/ha), whereas S_0 produced the least (96.75 t/ha), which was statistically comparable to S_1 and S_3. This outcome demonstrated that tomato yield steadily rose with higher salicylic acid doses. This outcome demonstrated that tomato yield steadily rose with higher salicylic acid concentration. The present morpho-physiological and yield-contributing features, such as plant height, leaf number per plant, branch number per plant, number of flowers per plant, fruit number, and fruit length, are compatible with these results. According to (Kazemi, 2013), SA boosts tomato yield. Many authors, like Salem *et al*. have reported on the tremendous effect that salicylic acid levels have on increasing tomato output, which is consistent with the findings of the current study.

Humic acid and salicylic acid had a significant impact on the amount of fruit produced per hectare (Table 16 and Appendix viii). The H_3S_2 treatment produced the maximum fruit output per hectare (137.06 tons). The H_0S_0 treatment produced the lowest fruit output per acre (72.92 tons).

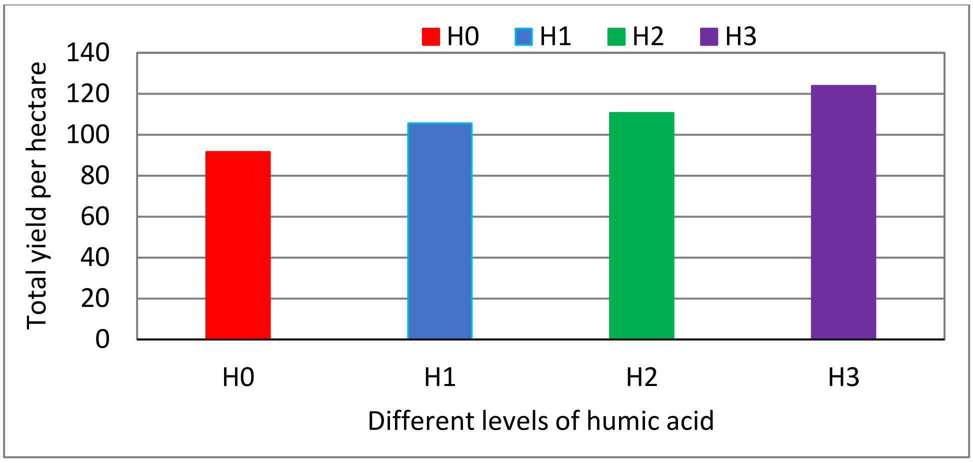


Figure 13. Effect of humic acid on total yield of tomato fruits (ton) per hectare

Note:

H_0: Control

H_1: 30 ppm humic acid

H_2: 60 ppm humic acid

H_3: 90 ppm humic acid

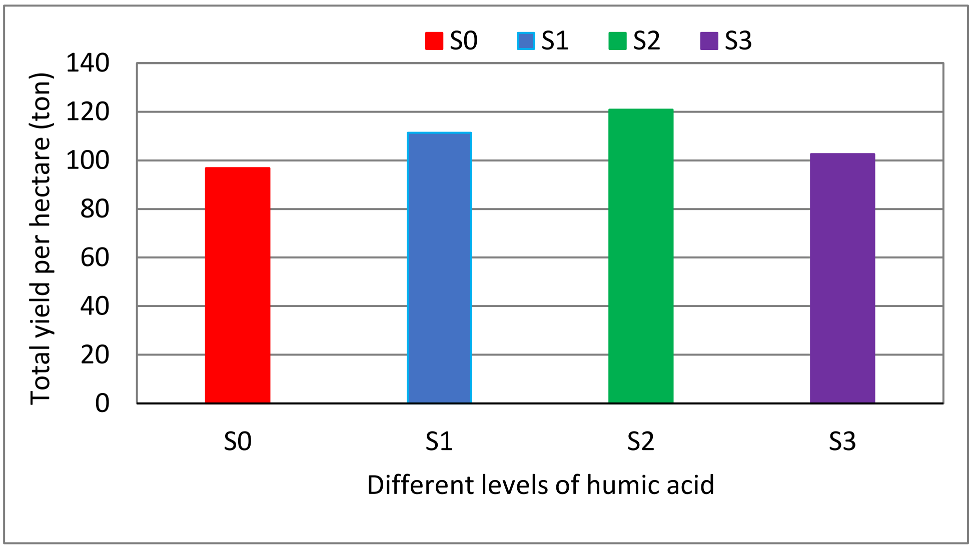


Figure 14. Effect of salicylic acid on total yield of tomato fruits per hectar

Note :

S_0: Control

S_1: 40 ppm salicylic acid

S_2: 80 ppm salicylic acid

S_3: 120 ppm salicylic acid

Table 16. Combined effect of humic acid and salicylic acid on total yield of tomato (ton) per hectare

Treatments	Total yield per hectare (ton)
H_0S_0	72.92^{h}
H_0S_1	98.04^{fgh}
H_0S_2	105.40^{ef}
H_0S_3	89.56^{h}
H_1S_0	96.23^{gh}
H_1S_1	11.09^{de}
H_1S_2	116.92^{bcd}
H_1S_3	98.03^{fgh}
H_2S_0	103.17^{efg}
H_2S_1	115.53^{bcd}
H_2S_2	124.00^{b}
H_2S_3	99.70^{fg}
H_3S_0	114.70^{cd}
H_3S_1	120.67^{bc}
H_3S_2	137.06^{a}
H_3S_3	122.89^{bc}
LSD $_{(0.05)}$	8.61
P-value	0.02
CV (%)	4.79

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 = 30 ppm, H_2 = 60 ppm, H_3 = 90 ppm of humic acid and S_0 = 0, S_1 = 40 ppm, S_2 = 80 ppm, S_3 = 120 ppm of salicylic acid.

4.14 Total sugar percentage on fruit

Humic acid affected the amount of total sugar on fruit. The H_3 treatment, which was statistically identical to the other treatments, produced the greatest total sugar percentage on fruit (5.62), whereas the H_0 treatment produced the lowest (4.28). (Appendix x and Table 15)

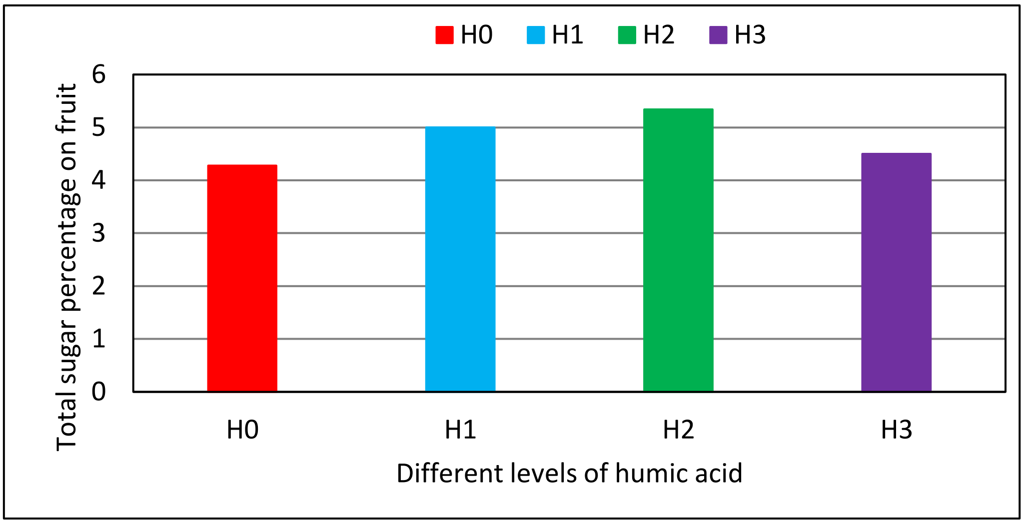


Figure 15: Effect of humic acid on sugar percentage of tomato

Note:

H_0: Control

H_1: 30 ppm humic acid

H_2: 60 ppm humic acid

H_3: 90 ppm humic acid

The overall sugar percentage of the fruit was dramatically altered by various SA dosages. The S_3 treatment produced the fruit with the highest total sugar percentage (5.46), whereas the S_0 treatment produced the fruit with the lowest total sugar percentage (4.73), which was statistically comparable to the S_1 and S_2 treatments (Table 16 and Appendix x).

Humic acid and SA together had a statistically significant impact on the amount of total sugar in the fruit. H_3S_0 had the highest total sugar content on fruit (5.83), whereas H_0S_0 had the lowest total sugar content on fruit (3.14). (Table 17 and Appendix x).

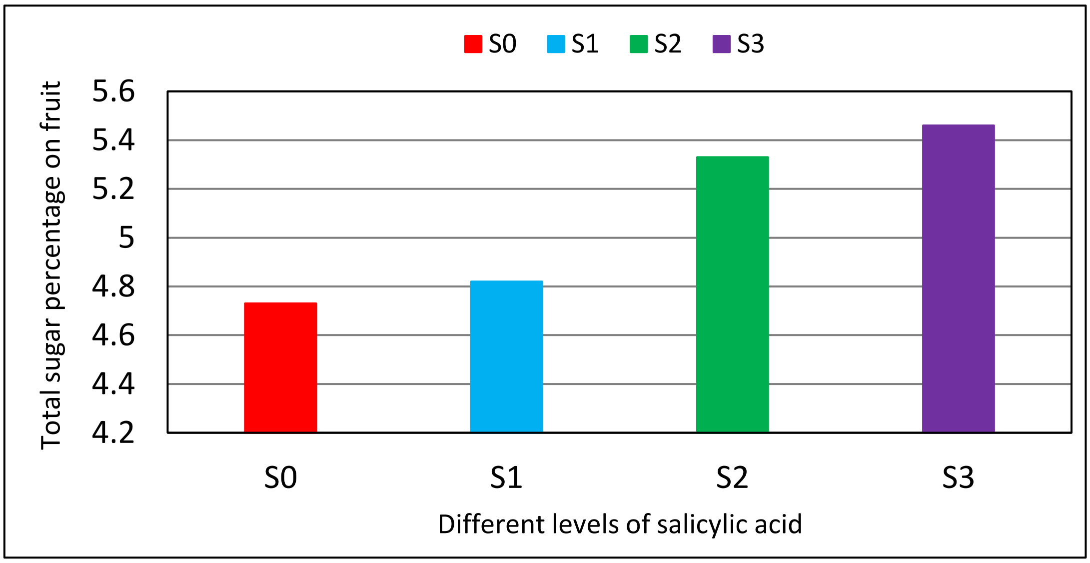


Table 16. Effect of salicylic acid on sugar percentage of tomato

Note:

S_0: Control

S_1: 40 ppm salicylic acid

S_2: 80 ppm salicylic acid

S_3: 120 ppm salicylic acid

Table 17. Combined effect of humic acid and salicylic acid on sugar percentage of tomato

Treatments	Total sugar percentage on fruit
H_0S_0	3.14^{f}
H_0S_1	4.30^{e}
H_0S_2	4.69^{de}
H_0S_3	5.00^{cd}
H_1S_0	4.44^{e}
H_1S_1	4.98^{cd}
H_1S_2	5.30^{bc}
H_1S_3	5.65^{ab}
H_2S_0	5.51^{ab}
H_2S_1	4.65^{de}
H_2S_2	5.64^{ab}
H_2S_3	5.57^{ab}
H_3S_0	5.83^{a}
H_3S_1	5.34^{bc}
H_3S_2	5.68^{ab}
H_3S_3	5.63^{ab}
$LSD_{(0.05)}$	0.45
P-value	0.00
CV (%)	5.38

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 = 30 ppm, H_2 = 60 ppm, H_3 = 90 ppm of humic acid and S_0 = 0 ppm, S_1 = 40 ppm, S_2 = 80 ppm, S_3 = 120 ppm of salicylic acid.

4.15 Reducing sugar percentage on fruit

Humic acid affected fruit reducing sugar content. The H_3 treatment had the highest decreasing sugar percentage on fruit (3.82), which was statistically comperable to that of the H_1 and H_2 treatments, whereas the H_0 treatment had the lowest (2.90) (Appendix x and Table 17).

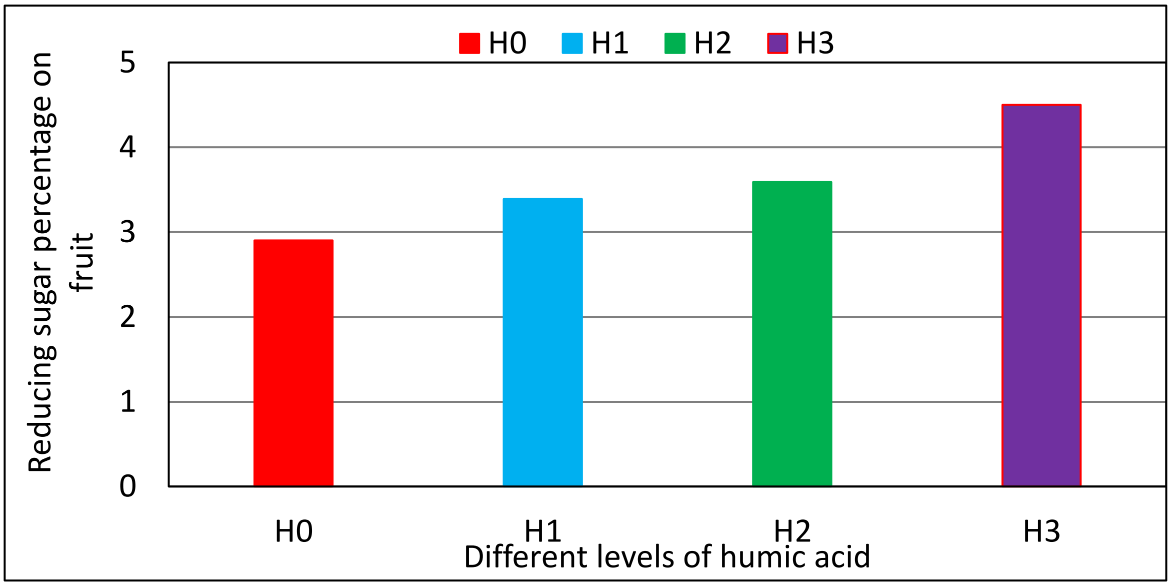


Figure 17: Effect of humic acid on reducing sugar percentage of tomato

Note:

H_0: Control

H_1: 30 ppm humic acid

H_2: 60 ppm humic acid

H_3: 90 ppm humic acid

Different SA dosages had a noticeable impact on lowering the fruit's sugar content. Fruit with the highest reducing sugar percentage (3.15) was produced by S_0, while fruit with the lowest reducing sugar percentage (3.66) was produced by S_3 treatment (Figure 18 and Appendix x).

Humic acid and SA together had a statistically significant impact on the fruit's decreasing sugar percentage. The lowest reducing sugar content on fruit (2.00) was identified in H_0S_0, while the highest reducing sugar content on fruit (3.92) was discovered in H_3S_2 (Table 18 and Appendix x).

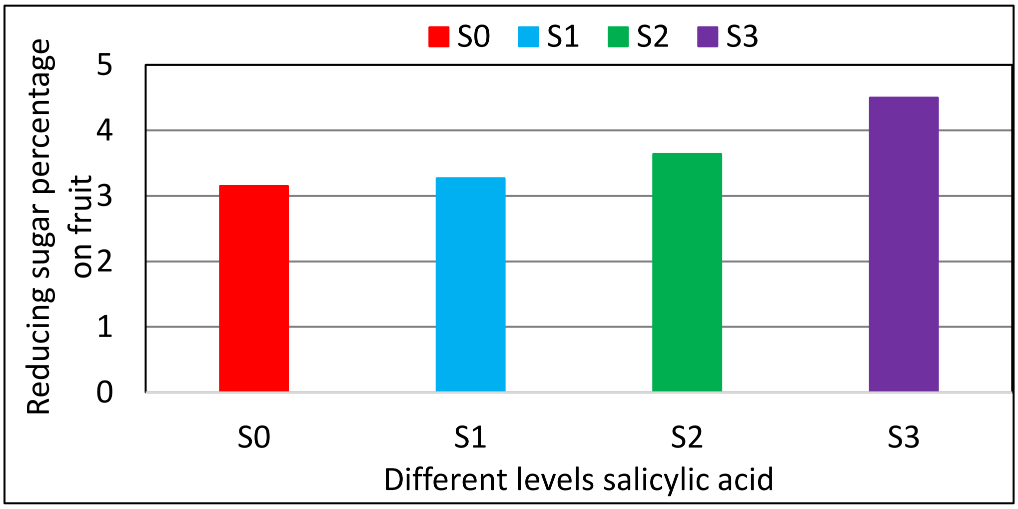


Table 18. Effect of salicylic acid on reducing sugar percentage of tomato

Note:

S_0: Control

S_1: 40 ppm salicylic acid

S_2: 80 ppm salicylic acid

S_3: 120 ppm salicylic acid

Table 18. Combined effect of humic acid and salicylic acid on sugar percentage of tomato

Treatments	Reducing sugar percentage on fruit
H_0S_0	2.00[e]
H_0S_1	3.14[d]
H_0S_2	3.25[cd]
H_0S_3	3.31[bcd]
H_1S_0	3.07[d]
H_1S_1	3.16[d]
H_1S_2	3.58[abc]
H_1S_3	3.75[a]
H_2S_0	3.66[ab]
H_2S_1	3.12[d]
H_2S_2	3.82[a]
H_2S_3	3.78[a]
H_3S_0	3.88[a]
H_3S_1	3.67[ab]
H_3S_2	3.92[a]
H_3S_3	3.80[a]
$LSD_{(0.05)}$	0.38
P-value	0.00
CV (%)	6.71

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 = 30 ppm, H_2 = 60 ppm, H_3 = 90 ppm of humic acid and S_0 = 0, S_1 = 40 ppm, S_2 = 80 ppm, S_3 = 120 ppm of salicylic acid.

4.16 Non-reducing sugar percentage on fruit

Humic acid had an significant impact on fruit's non-reducing sugar content. The H_3 treatment, which were statistically comparable with the H_1 and H_2 treatment, produced the highest non-reducing sugar percentage on fruit (1.80), whereas the H_0 treatment produced the lowest (1.10). (Appendix x and Figure 19).

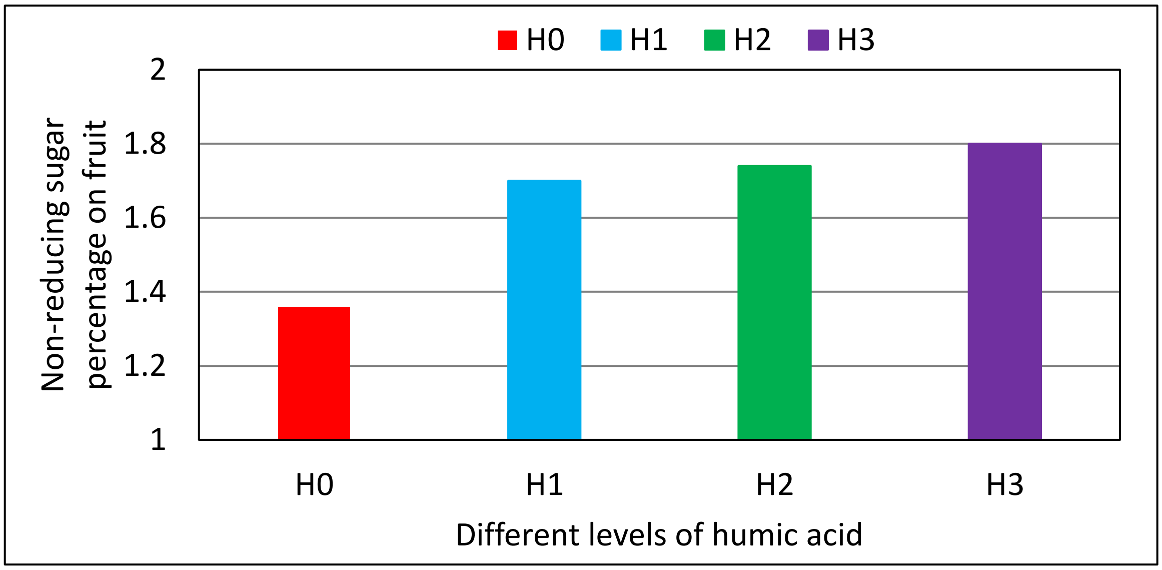


Figure 19: Effect of humic acid on non-reducing sugar percentage of tomato

Note:

H_0: Control

H_1: 30 ppm humic acid

H_2: 60 ppm humic acid

H_3: 90 ppm humic acid

The amount of non-reducing sugar in fruit was dramatically altered by various SA dosages. S_3 produced the fruit with the highest non-reducing sugar percentage (1.80), whereas S_0 produced the fruit with the lowest non-reducing sugar percentage (1.57). (Figure 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 (1.94) was found from H_1S_0, while the lowest non reducing sugar percentage on fruit (1.14) was recorded from H_0S_0 (Figure 19 and Appendix x).

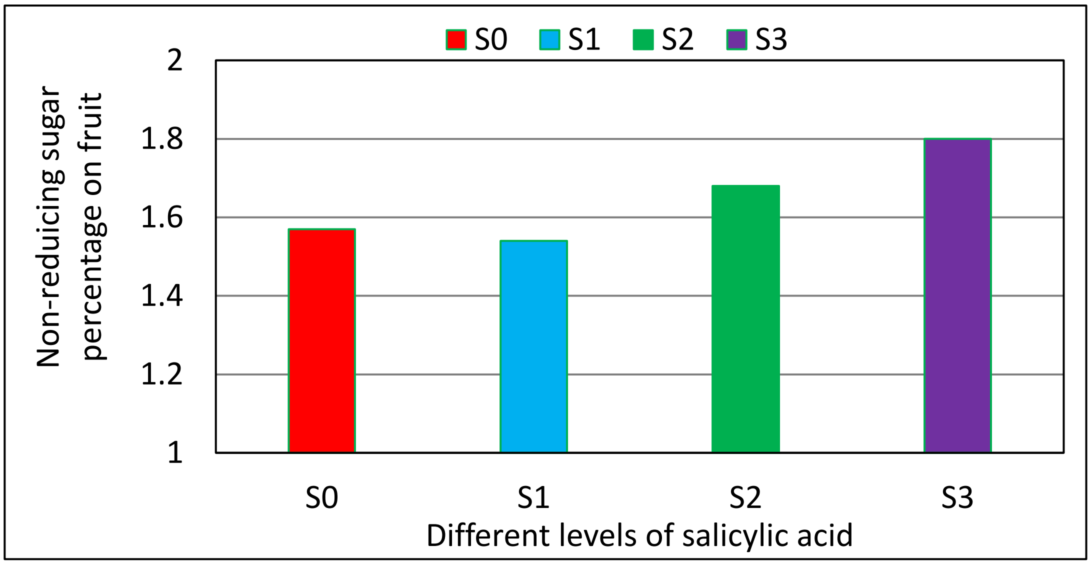


Table 20. Effect of salicylic acid on non-reducing sugar percentage of tomato

Note:

S_0: Control

S_1: 40 ppm salicylic acid

S_2: 80 ppm salicylic acid

S_3: 120 ppm salicylic acid

Table 19. Combined effect of humic acid and salicylic acid on sugar percentage of tomato

Treatments	Non-reducing sugar percentage on fruit
H_0S_0	1.14^{f}
H_0S_1	1.16^{f}
H_0S_2	1.44^{de}
H_0S_3	1.69^{bc}
H_1S_0	1.36^{ef}
H_1S_1	1.82^{ab}
H_1S_2	1.72^{abc}
H_1S_3	1.90^{ab}
H_2S_0	1.85^{ab}
H_2S_1	1.53^{cde}
H_2S_2	1.82^{ab}
H_2S_3	1.78^{ab}
H_3S_0	1.94^{a}
H_3S_1	1.67^{bcd}
H_3S_2	1.76^{abc}
H_3S_3	1.83^{ab}
$LSD_{(0.05)}$	0.24
P-value	0.00
CV (%)	9.05

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 = 30 ppm, H_2 = 60 ppm, H_3 = 90 ppm of humic acid and S_0 = 0, S_1 = 40 ppm, S_2 = 80 ppm, S_3 = 120 ppm of salicylic acid.

4.17 Vitamin C content

When tomato fruit is properly sampled and its vitamin C content is measured, the humic acid shows a large fluctuation. Vit-C levels were greater in the H_3 treatment (14.85 mg/100 g) and lower in the H_0 treatment (13.32 mg/100 g), which was statistically different to the H_1 and H_2 treatment (Figure 21 and Appendix x).

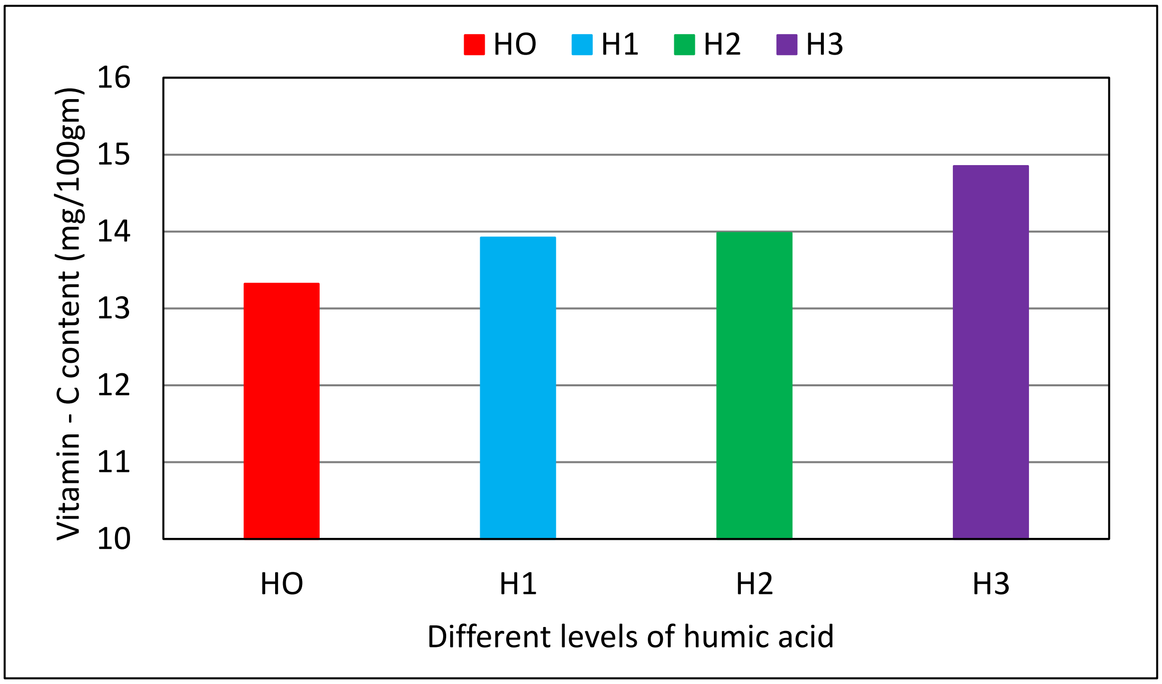


Figure 21. Effect of humic acid on vit-C content in tomato

Note:

H_0: Control

H_1: 30 ppm humic acid

H_2: 60 ppm humic acid

H_3: 90 ppm humic acid

SA dosages affect significantly the vitamin C content of tomato fruit. The S_2 treatment had a greater concentration of vitamin C (15.24 mg/100 g), which was statistically comparable to S_2 and S_3 treatments. The S_0 therapy has less vitamin C (13.22 mg/100 g). (Appendix x and Figure 22)

Humic acid and various SA dosages worked together to have a noticeable impact on the vitamin C level. The H_3S_2 treatment combination had the highest vit-C content (16.93 mg/100 g), whereas the H_0S_0 treatment combination had the lowest vit-C content (11.45mg/100 g) (Table 20 and Appendix x).

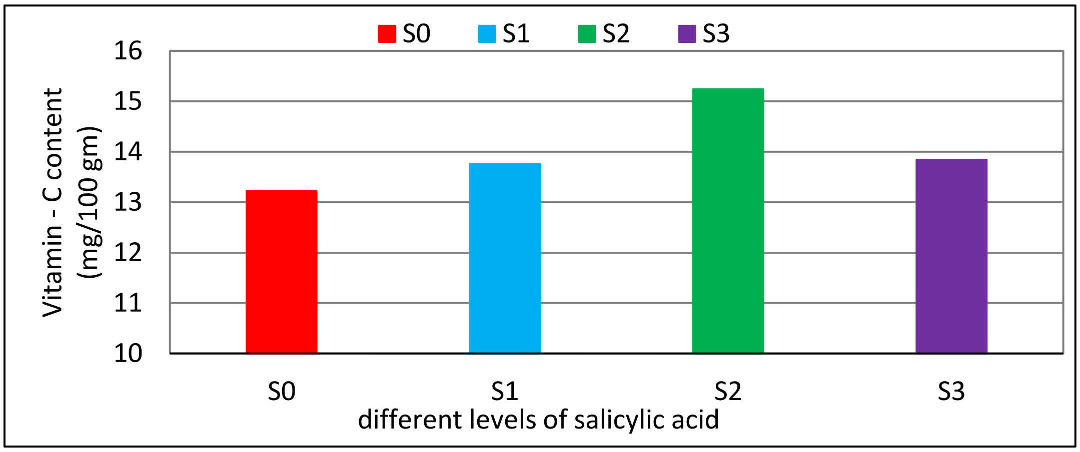


Figure 22. Effect of salicylic acid on vit-C content in tomato

Note:

S_0: Control

S_1: 20 ppm salicylic acid

S_2: 80 ppm salicylic acid

S_3: 120 ppm salicylic acid

Table 20. Combined effect of humic acid and salicylic acid on vit-C content in tomato

Treatments	Vitamin-C content on fruit mg/100gm
H_0S_0	11.45[e]
H_0S_1	13.77[bcd]
H_0S_2	15.00[b]
H_0S_3	13.06[d]
H_1S_0	13.84[bcd]
H_1S_1	13.28[d]
H_1S_2	14.86[bc]
H_1S_3	13.70[bcd]
H_2S_0	13.40[cd]
H_2S_1	13.49[cd]
H_2S_2	14.18[bcd]
H_2S_3	14.85[bc]
H_3S_0	14.22[bcd]
H_3S_1	14.49[bcd]
H_3S_2	16.93[a]
H_3S_3	13.77[bcd]
$LSD_{(0.05)}$	1.48
P-value	0.01
CV (%)	6.36

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 = 30 ppm, H_2 = 60 ppm, H_3 = 90 ppm of humic acid and S_0 = 0, S_1 = 40 ppm, S_2 = 80 ppm, S_3 = 120 ppm of salicylic acid.

4.18 Lycopene content on fruit

Humic acid exhibits significant change when the lycopene concentration of tomato fruit is properly sampled and analyzed (Figure 23 and Appendix x). Fruit with a higher lycopene content (4.57 mg/100 g) was found in the H_3 treatments, while fruit with a lower lycopene content (4.43 mg/100 g), was found in H_0 treatment that was statistically comparable to the H_1 and H_2 treatment.

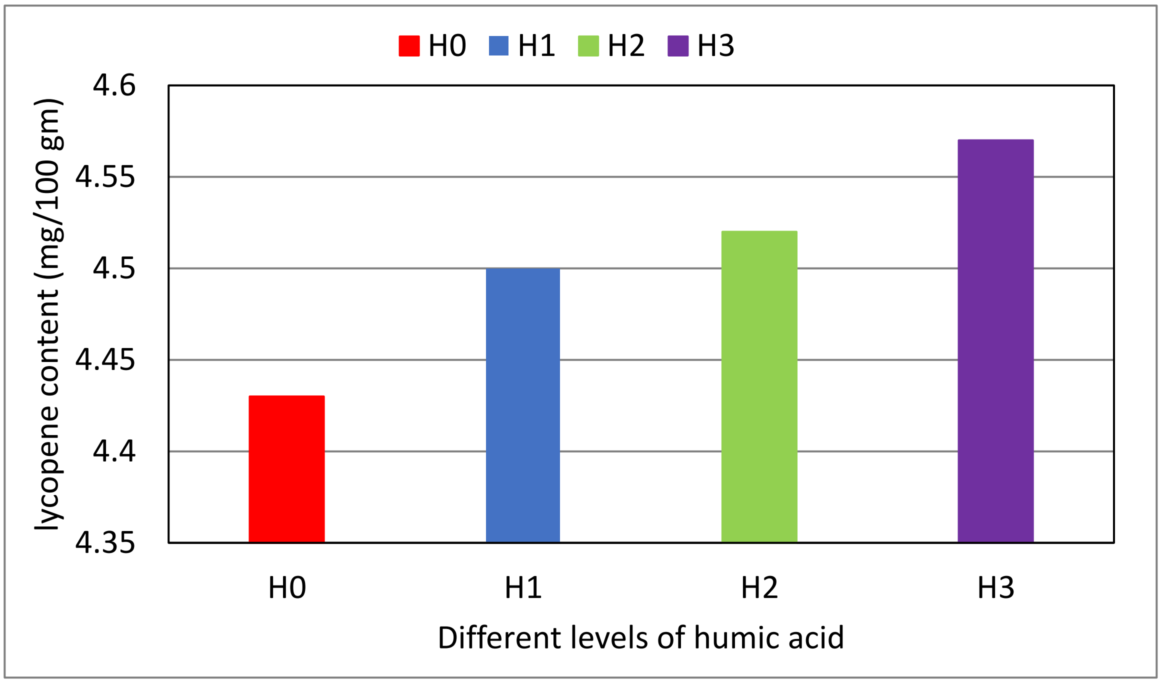


Figure 23. Effect of humic acid on lycopene content in tomato

Note:

H_0: Control

H_1: 30 ppm humic acid

H_2: 60 ppm humic acid

H_3: 90 ppm humic acid

Due to various SA dosages, there is a significant difference in the amount of lycopene in fruit. Fruit with a lower lycopene content (4.44 mg/100 g), which is statistically comparable to S_1 and S_3 treatment, was detected in the S_0 treatment. Fruit with a increased lycopene content (4.55 mg/100 g) was detected in the S_2 treatment. (Appendix x and Figure 24).

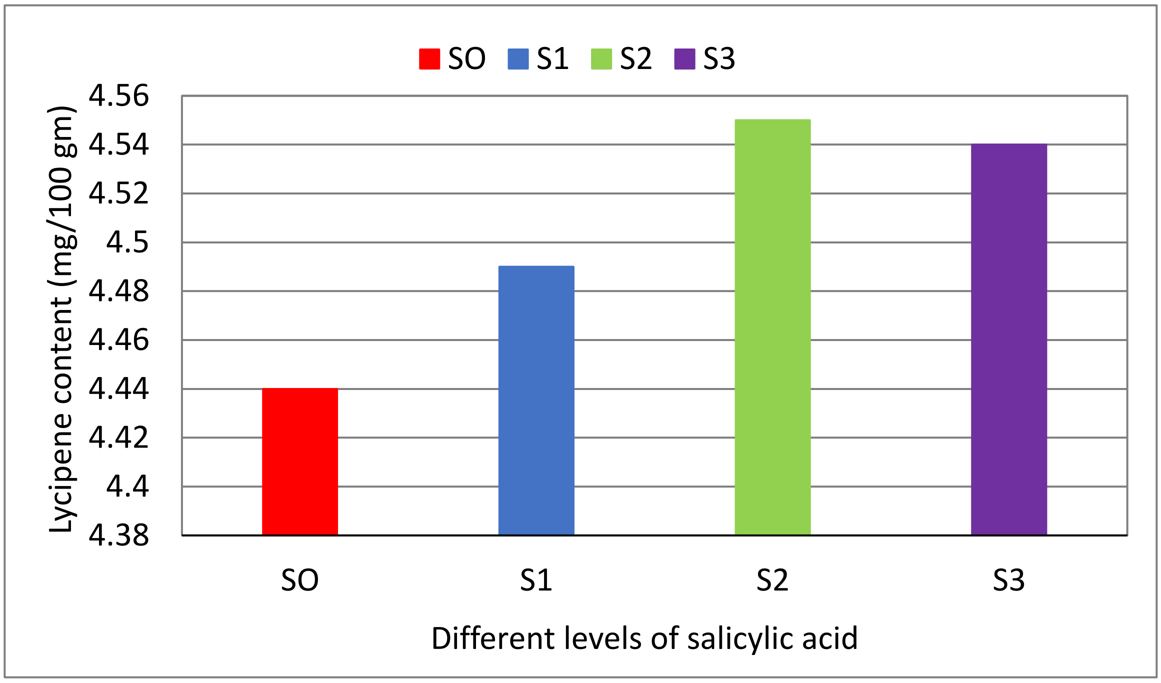


Figure 24. Effect of salicylic acid on lycopene content in tomato

Note:

S_0: Control

S_1: 40 ppm salicylic acid

S_2: 80 ppm salicylic acid

S_3: 120 ppm salicylic acid

Table 21. Combined effect of humic acid and salicylic acid on lycopene content in tomato

Treatments	Lycopene content in fruit mg/100gm
H_0S_0	4.33[g]
H_0S_1	4.45[ef]
H_0S_2	4.42[f]
H_0S_3	4.52[cde]
H_1S_0	4.49[def]
H_1S_1	4.42[f]
H_1S_2	4.52[cde]
H_1S_3	4.59[bc]
H_2S_0	4.52[cde]
H_2S_1	4.59[bc]
H_2S_2	4.55[bcd]
H_2S_3	4.42[f]
H_3S_0	4.42[f]
H_3S_1	4.52[cde]
H_3S_2	4.72[a]
H_3S_3	4.62[b]
LSD $_{(0.05)}$	0.06
P-value	0.00
CV (%)	0.92

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 = 30 ppm, H_2 = 60 ppm, H_3 = 90 ppm of humic acid and S_0 = 0, S_1 = 40 ppm, S_2 = 80 ppm, S_3 = 120 ppm of salicylic acid significant difference exists between the treatments in terms of the amount of lycopene in tomatoes when humic and salicylic acids are combined (Table 21 and Appendix x). The H_3S_2 treatment combination produced fruit with the highest lycopene content (4.72 mg/100 g) and the fruit with the lowest amount of lycopene (4.33 mg/100 g) was discovered after H_2S_0 treatment.

4.19 °Brix on fruit

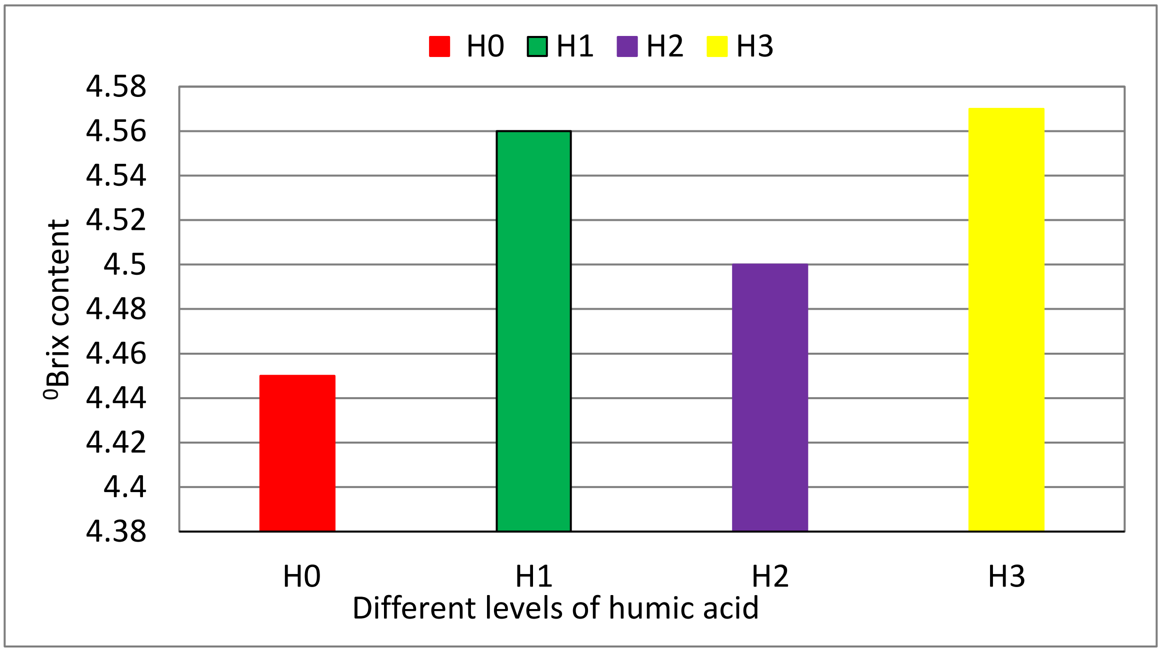


Figure 25. Effect of humic acid on ^{0}brix content in tomato

Note:

H_0: Control

H_1: 30 ppm humic acid

H_2: 60 ppm humic acid

H_3: 90 ppm humic acid

Humic acid influenced the °Brix on fruit. The H_3 treatment produced the highest °Brix on fruit (4.59) whereas the H_0 treatment produced the lowest (4.45). (Appendix ix and Figure 25)

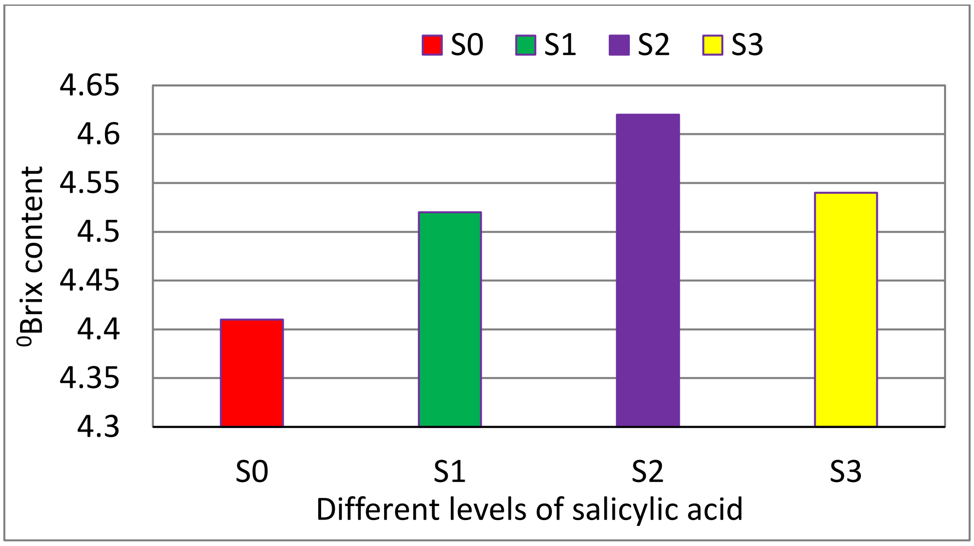


Figure 26. Effect of salicylic acid on ^{0}brix content in tomato

Note:

S_0: Control

S_1: 40 ppm salicylic acid

S_2: 80 ppm salicylic acid

S_3: 120 ppm salicylic acid

^{o}Brix on fruit was significantly impacted by various SA dosages (Appendix ix). The S_2 treatment produced the highest ^{o}Brix on fruit (4.62), which was statistically identical to other results, whereas the S_0 treatment produced the lowest ^{o}Brix on fruit (4.41) (Figure 26)

Table 22. Combined effect of humic acid and salicylic acid on ^{0}brix content in tomato

Treatments	^{0}Brix content in fruit mg/100gm
H_0S_0	4.33^{i}
H_0S_1	4.50^{ef}
H_0S_2	4.55^{de}
H_0S_3	4.43^{gh}
H_1S_0	4.47^{fg}
H_1S_1	4.53^{de}
H_1S_2	4.61^{bc}
H_1S_3	4.63^{bc}
H_2S_0	4.43^{gh}
H_2S_1	4.53^{de}
H_2S_2	4.57^{cd}
H_2S_3	4.50^{ef}
H_3S_0	4.41^{h}
H_3S_1	4.52^{def}
H_3S_2	4.75^{a}
H_3S_3	4.60^{bc}
$LSD_{(0.05)}$	0.05
P-value	0.00
CV (%)	0.70

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 = 30 ppm, H_2 = 60 ppm, H_3 = 90 ppm of humic acid and S_0 = 0, S_1 = 40 ppm, S_2 = 80 ppm, S_3 = 120 ppm of salicylic acid

Humic acid and SA together had a statistically significant effect on how fruit's °Brix changed. The fruit samples from H_3S_2 had the greatest °Brix (5.75) while H_0S_0 had the lowest °Brix (4.33) (Table 22 and Appendix ix).

4.20 Shelf-life of tomato fruit

Fruit shelf-life showed a substantial fluctuation because of humic acid (Figure 27 and Appendix ix). Fruit has to undergo the H_3 treatment to extend its shelf life (25.83 days). The fruit's minimal shelf life was H_0 treatment (24.79 days).

The shelf-life of fruits varied significantly depending on the salicylic acid (Figure 28 and Appendix ix). The S_1 treatment had the longest fruit shelf life (25.85 days), and the S_0 treatment had the earliest first flowering (25.25 days), which was statistically comparable to the S_2 and S_3 treatments.

The combined effect of humic acid and salicylic acid on days of fruit shelf-life was found to be significant (Table 23 and Appendix ix). The days of fruit shelf-life was maximum (26.23 days) in H_3S_0, while it was minimum (23.65 days) in H_0S_0 treatment.

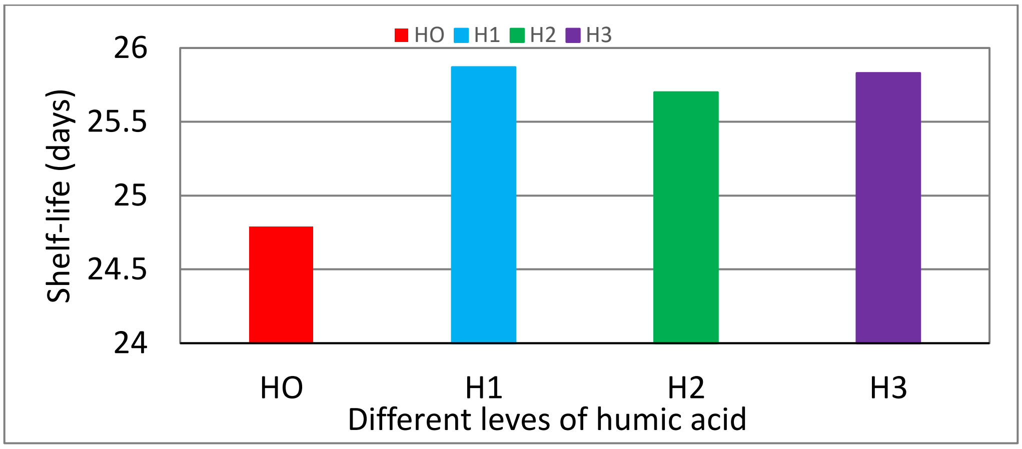


Figure 27. Effect of humic acid on shelf-life(days) of tomato.

Note:

H_0: Control

H_1: 30 ppm humic acid

H_2: 60 ppm humic acid

H_3: 90 ppm humic acid

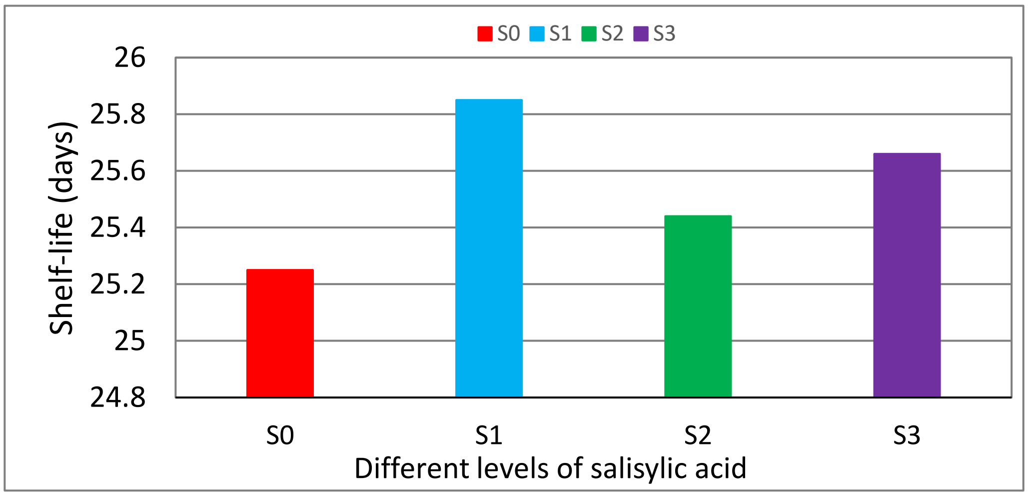


Figure 28. Effect of salicylic acid on shelf-life of tomato

Note: S_0: Control

S_1: 20 ppm salisylic acid

S_2: 80 ppm salisylic acid

S_3: 120 ppm salisylic acid

Table 23: Combined effect of humic acid and salicylic acid on shelf-life of tomato fruit

Treatments	Shelf-life (days)
H_0S_0	23.65^{g}
H_0S_1	25.73^{abcd}
H_0S_2	25.00^{ef}
H_0S_3	24.80^{f}
H_1S_0	25.80^{abcd}
H_1S_1	25.86^{abcd}
H_1S_2	25.61^{bcd}
H_1S_3	26.22^{ab}
H_2S_0	25.33^{def}
H_2S_1	26.09^{ab}
H_2S_2	25.74^{abcd}
H_2S_3	25.66^{abcd}
H_3S_0	26.23^{a}
H_3S_1	25.71^{abcd}
H_3S_2	25.42^{cde}
H_3S_3	25.96^{abc}
LSD $_{(0.05)}$	0.60
P-value	0.00
CV (%)	1.42

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 = 30 ppm, H_2 = 60 ppm, H_3 = 90 ppm of humic acid and S_0 = 0, S_1 = 40 ppm, S_2 = 80 ppm, S_3 = 120 ppm of salicylic acid.

4.21 Ash percentage on fruit

Humic acid significantly affected the amount of ash on fruit. The H_3 treatment had the greatest fruit ash percentage (0.61), whereas the H_0 (control) treatment had the lowest (0.45). (Appendix ix and Figure 29).

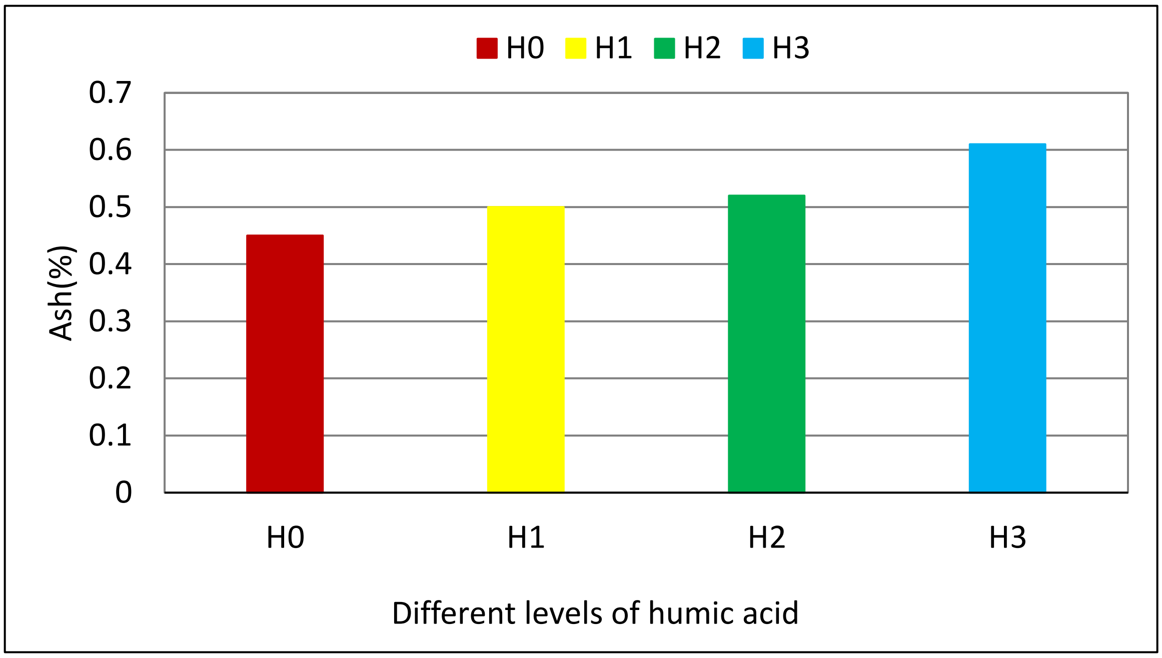


Figure 29. Effect of humic acid on Ash (%) of tomato.

Note:

H_0: Control

H_1: 30 ppm humic acid

H_2: 60 ppm humic acid

H_3: 90 ppm humic acid

The amount of ash in the fruit was not significantly impacted by different SA dosages. It was clear from the data that the S_2 treatment had the greatest recorded ash percentage on fruit (0.59) and the S_0 treatment had the lowest recorded ash percentage on fruit (0.44). (Figure 30 and Appendix ix).

Humic acid and SA together had a statistically significant impact on the fruit's ash content. The fruit samples from H_3S_2 had the highest ash content (0.75) whereas H_0S_1 had the lowest ash content (0.33) (Table 24 and Appendix ix).

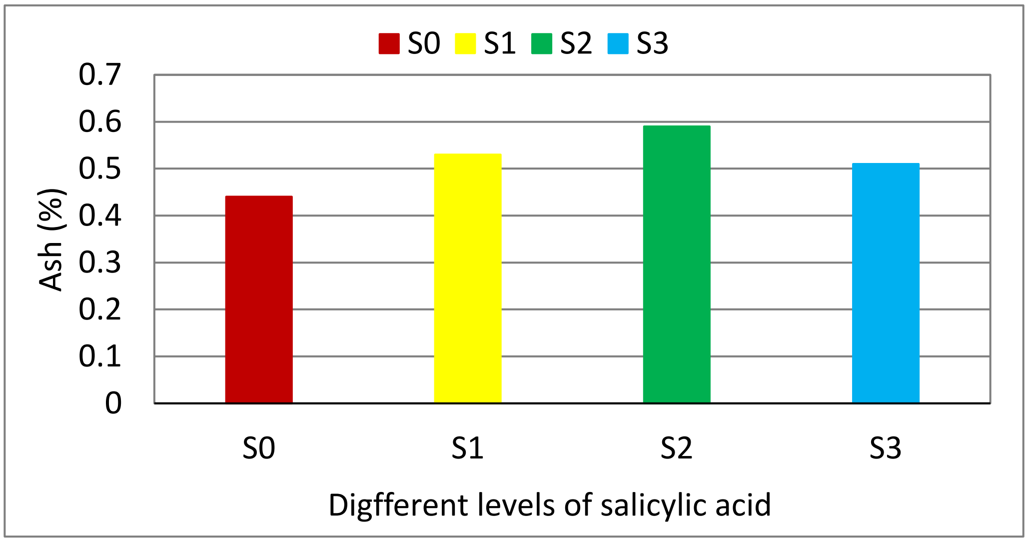


Figure 30. Effect of salicylic acid on Ash (%) of tomato fruit

Note:

S_0: Control

S_1: 40 ppm salicylic acid

S_2: 80 ppm salicylic acid

S_3: 120 ppm salicylic acid

Table 24: Combined effect of humic acid and salicylic acid on Ash (%) of tomato

Treatments	Ash (%)
H_0S_0	0.33^{g}
H_0S_1	0.49^{derf}
H_0S_2	0.49^{def}
H_0S_3	0.48^{def}
H_1S_0	0.41^{fg}
H_1S_1	0.49^{def}
H_1S_2	0.59^{bc}
H_1S_3	0.53^{bcd}
H_2S_0	0.53^{bcd}
H_2S_1	0.56^{bcd}
H_2S_2	0.55^{bcd}
H_2S_3	0.43^{ef}
H_3S_0	0.51^{cde}
H_3S_1	0.59^{bc}
H_3S_2	0.75^{a}
H_3S_3	0.60^{b}
$LSD_{(0.05)}$	0.08
P-value	0.00
CV (%)	10.25

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 = 30 ppm, H_2 = 60 ppm, H_3 = 90 ppm of humic acid and S_0 = 0, S_1 = 40 ppm, S_2 = 80 ppm, S_3 = 120 ppm of salicylic acid.

4.22 Protein percentage on fruit

Humic acid affected the amount of protein in fruit. The H_2 treatment produced the highest protein content on fruit (2.88 %), whereas the H_0 (control) treatment produced the lowest (1.96 %). (Appendix ix and Figure 31)

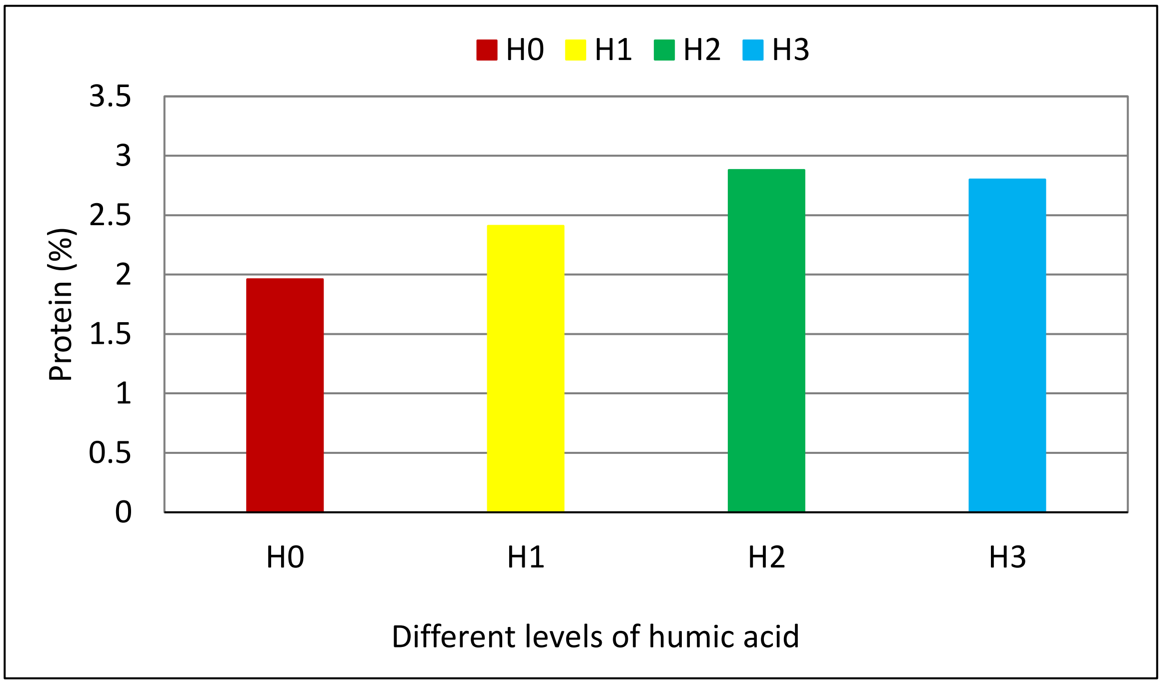


Figure 31. Effect of humic acid on protein (%) of tomato

Note:

H_0: Control

H_1: 30 ppm humic acid

H_2: 60 ppm humic acid

H_3: 90 ppm humic acid

The amount of protein in fruit was considerably altered by various SA dosages. It was clear from the data that the S_3 treatment produced the fruit with the highest protein content (2.58 %), whereas the S_0 treatment produced the fruit with the lowest protein content (2.44 %). (Figure 32 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 (2.94) was found from H_3S_0, while the lowest Protein percentage on fruit (1.74) was recorded from H_0S_0 (Table 25 and Appendix ix).

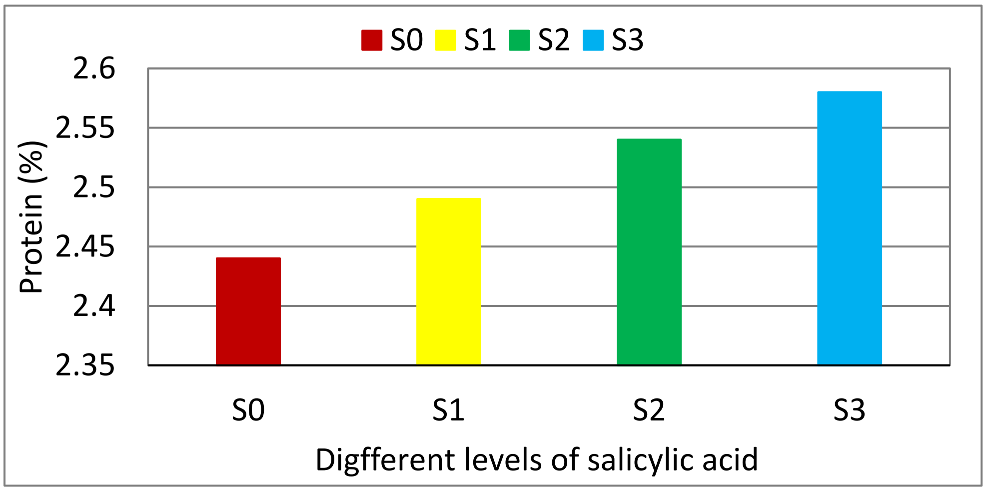


Figure 32. Effect of salicylic acid on protein (%) of tomato fruit

Note:

S_0: Control

S_1: 40 ppm salicylic acid

S_2: 80 ppm salicylic acid

S_3: 120 ppm salicylic acid

Table 25: Combined effect of humic acid and salicylic acid on (protein %) of tomato

Treatments	Protein(%)
H_0S_0	1.74^{j}
H_0S_1	2.15^{h}
H_0S_2	2.00^{i}
H_0S_3	1.98^{i}
H_1S_0	2.16^{h}
H_1S_1	2.16^{h}
H_1S_2	2.58^{g}
H_1S_3	2.75^{e}
H_2S_0	2.93^{b}
H_2S_1	3.01^{a}
H_2S_2	2.82^{c}
H_2S_3	2.78^{d}
H_3S_0	2.94^{b}
H_3S_1	2.67^{f}
H_3S_2	2.76^{de}
H_3S_3	2.83^{c}
$LSD_{(0.05)}$	0.02
P-value	0.00
CV (%)	0.71

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 = 30 ppm, H_2 = 60 ppm, H_3 = 90 ppm of humic acid and S_0 = 0, S_1 = 40 ppm, S_2 = 80 ppm, S_3 = 120 ppm of salicylic acid.

4.23 Sodium percentage (mg/100g) on fruit

Humic acid had a considerable significant impact on the sodium content of fruit. The H_3 treatment, which was statistically identical to other treatments, produced the highest sodium percentage on fruit (6.82), whereas the H_0 treatment produced the lowest (5.80). (Appendix ix and Figure 33).

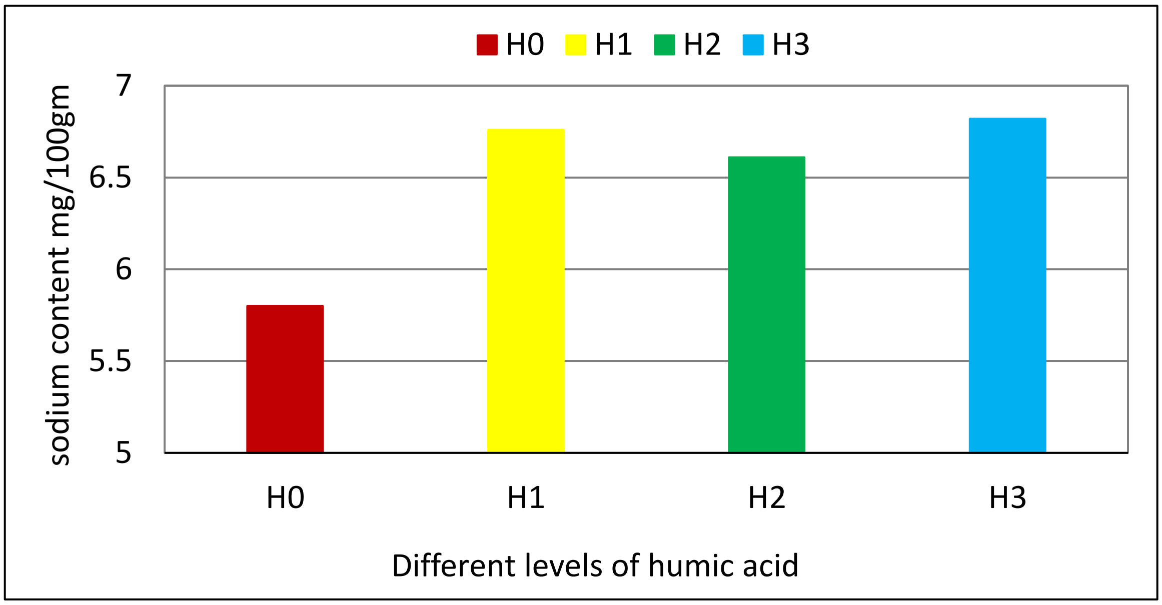


Figure 33. Effect of humic acid on sodium content of tomato

Note:

H_0: Control

H_1: 30 ppm humic acid

H_2: 60 ppm humic acid

H_3: 90 ppm humic acid

Different SA doses had significant impact on how much sodium was in the fruit. The S_2 treatment produced the highest total sodium percentage on fruit (6.76), whereas the S_0 treatment produced the lowest (6.28) and was statistically equivalent to other treatments (Figure 34 and Appendix ix).

Combination effect of humic acid and SA showed statistically significant variation on Sodium percentage on fruit (Table 26 and Appendix ix). The highest Sodium percentage on fruit (7.28) was found from H_3S_2, while the lowest sodium percentage on fruit (4.92) was recorded from H_0S_0..

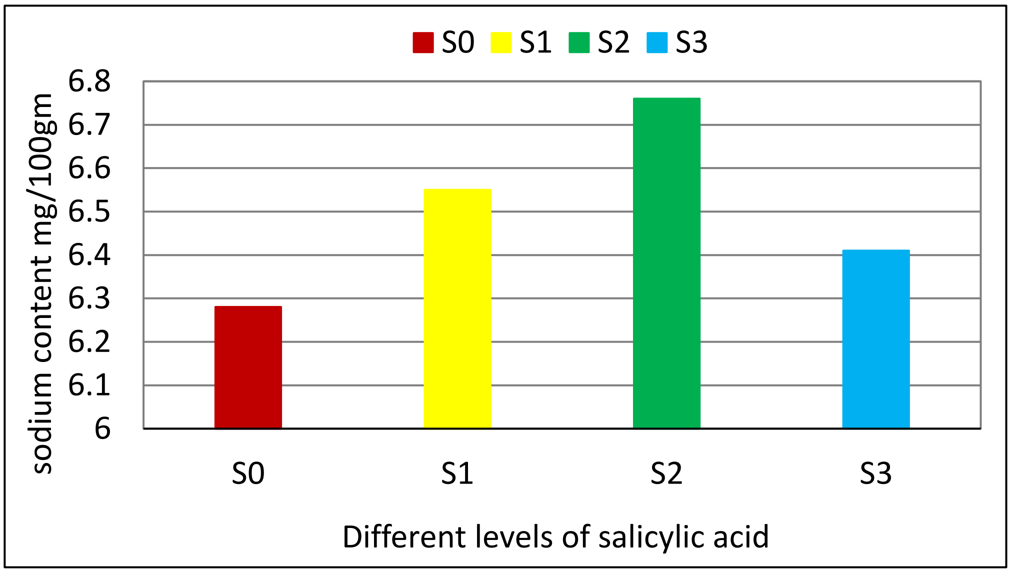


Figure 34. Effect of salicylic acid on sodium content of tomato

Note:

S_0: Control

S_1: 20 ppm salicylic acid

S_2: 80 ppm salicylic acid

S_3: 120 ppm salicylic acid

Table 26: Combined effect of humic acid and salicylic acid on sodium content of tomato

Treatments	Sodium content mg/100gm
H_0S_0	4.92[g]
H_0S_1	5.86[f]
H_0S_2	6.26[de]
H_0S_3	6.16[ef]
H_1S_0	6.66[bc]
H_1S_1	6.93[ab]
H_1S_2	6.95[ab]
H_1S_3	6.49[cde]
H_2S_0	6.95[ab]
H_2S_1	6.33[cde]
H_2S_2	6.54[cde]
H_2S_3	6.62[bcd]
H_3S_0	6.59[bcd]
H_3S_1	7.06[a]
H_3S_2	7.28[a]
H_3S_3	6.36[cde]
LSD $_{(0.05)}$	0.38
P-value	0.00
CV (%)	3.57

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 = 30 ppm, H_2 = 50 ppm, H_3 = 90 ppm of humic acid and S_0 = 0, S_1 = 20 ppm, S_2 = 80 ppm, S_3 = 120 ppm of salicylic acid.

CHAPTER V

SUMMARY AND CONCLUSION

To determine how humic acid and salicylic acid affected tomato growth, yield, and nutritional quality, a field experiment was carried out at the Sher-e-Bangla Agricultural University Farm in Dhaka, Bangladesh from October 2020 to April 2021. In this experiment, four distinct dosages of humic acid H_0= 0 ppm, H_1= 20 ppm, H_2= 40 ppm, and H_3= 80 ppm as well as four doses of salicylic acid S_0= 0 ppm, S_1= 30 ppm, S_2= 70 ppm, and S_3= 110 ppm—were utilized. The experiment was designed using a three-replication Randomized Complete Block Design (RCBD) with two components. Data on growth, yield-contributing factors, and yield were collected. The acquired data underwent statistical analysis to determine the treatment's effects. This chapter has provided a summary of the findings.

At 30,70, and100 days following sowing, humic acid had a substantial impact on plant height and the number of leaves per plant (DAS). The tallest plant was created by H_3 and measured 14.84, 41.88 and 94.37 cm at 30, 70, and 100 DAS, respectively (80 ppm humic acid). The H_3 treatment resulted in the highest number of leaves per plant (8.04, 20.25, and 34.83 at 30, 70, and 100 DAS, respectively). At 70 and 100 DAS, the humic acid revealed a substantial change in the number of branches per plant. The H_3 treatment resulted in the highest number of branches per plant (3.82 and 6.92 at 70, and 100 DAS, respectively). The H_1 plant recorded the highest total dry weight per plant (41.72 g). H_3 treatment was the first in blossoming of flowers. H_3 treatment is the earliest in fruit set and the number of days required for the number first fruit set is (45.83 days). H_3 treatment resulted in the highest number of flowers (53.67) and fruits (34.58) per plant. H_1 produced fruit with the largest thickness and diameter (6.31 cm and 6.89 cm, respectively). H_3 treatment yielded the largest individual fruit weight (86.02g). H_2 treatment led to the highest yield of fruits per plant (2.97 kg). The fruit output per hectare was significantly impacted by the various humic acids. The highest fruit harvested per hectare was 123.38 tons in H_3 treatment. The H_0 treatment produced the smallest fruit production per hectare (91.48 tons).

Humic acid affected the tomato's ash content. The maximum tomato ash percentage (0.61) were found in H_3 and greatest protein percentage (2.88) was found in H_2 treatment. The H_3 treatment produced the tomato with the greatest brix % (4.57). The H_2 treatment produced the greatest total sugar content in tomato (5.62). The H_3 treatment produced the tomato with the highest salt content (6.82). When tomato fruit is properly sampled and its vitamin- C content is measured, the humic acid shows a large fluctuation. The H_3 treatment had more vitamin C (14.85 mg/100 g). Fruit with a greater lycopene concentration (4.57 mg/100 g) was found in H_3 treatment. H_3 treatment produced the highest shelf-life (25.83) of tomato fruits.

At 30, 70, and 100 DAS, plant height was noted. The effect of the varied salicylic acid fertilizer levels on plant height at 30, 70, and 100 DAS was significant. The S_2 (110 ppm salicylic acid) treatment resulted in the plants with the largest plant heights (13.26, 39.62, and 83.43 cm at 30, 70, and 100 DAS, respectively) and leaf counts (7.59, 17.87, 21.82 and 35.35 at 30, 70, and 100 DAS, respectively). The S_2 had the most branches per plant (3.70 at 70 DAS and 6.64 at 100 DAS, respectively). The plant with the most total dry matter per plant (41.39 g) was in S_0 treatment. First flowering was discovered to be delayed (49.60 days) in the S_0 treatment and to be earliest (46.32 days) in the S_2 treatment. The S_3 treatment had the earliest (68.71 days) fruit set. The number of blooms per plant and the number of fruits per plant varied significantly across the salicylic acid fertilizers. The S_2 treatment produced the most fruit per plant (34.20) and the most flowers per plant (54.43). Fruits from S_0 had the longest length (5.96 cm) and longest diameter (6.68 cm) was produced in S_3 treatment. The biggest fruit (weighing 84.83 g) came from the S_2 treatment. From the S_2 treatments, the highest fruit output per plant (2.90 kg) was attained. S_2 provided the largest fruit production (120.84 t/ha), while S_0 provided the lowest yield (96.75 t/ha).

The amount of ash in the fruit was not significantly impacted by different SA dosages. It was clear from the data that the fruit with the highest ash content (0.59) came from S_2

and the greatest protein content of any fruit (2.58 %) came from S_3 treatment. S_2 had the highest brix percentage (4.62), and total salt percentage (6.76) for fruit. S_3 had the highest total sugar % (5.46). Different salicylic acid levels were to blame for the difference in vitamin C content of tomato fruit. The S_2 treatment had more vitamin C (15.24 mg/100 g). Fruit with a greater lycopene content (4.55 mg/100 g) was detected in the S_2 treatment and S_1 treatment produced the highest shelf-life (25.85) of tomato fruits.

The combined impact of various humic acid and salicylic acid doses revealed a considerable variance in every parameter. H_3S_2 (90 ppm humic acid with 80 ppm salicylic acid) was found to have the tallest plants (16.99, 43.62, and 106.11 cm at 30, 70, and 100 DAS, respectively), as well as the most leaves per plant (8.73, 25.97 and 41.15 at 30, 70, and 100 DAS, respectively) and highest number of branches per plant (3.92 and 7.28 at 70 and 100 DAS, respectively). H_1S_0 produced the most total dry matter per plant (61.93 g), while H_3S_2 had the shortest days to first blossom (41.47 days). H_3S_2 therapy was observed to shorten the time it took for the first fruit to ripen (62.71 days). H_3S_2 had the greatest number of flowers per plant (59.26) and most fruit production per plant (36.67). H_1S_0 had the fruit with the largest length (6.86 cm) and diameter (7.26 cm). The fruit with the heaviest weight (89.82 g) was discovered in H_3S_2 treatment. The H_3S_2 treatment produced the maximum fruit output per plant (3.29 kg) and per hectare (137.06 tons). The H_0S_0 treatment produced the lowest fruit output per hectare (72.92 tons).

H_3S_2 treatment was shown to have the greatest ash percentage on fruit (0.75), H_3S_0 has the highest protein content of any fruit (2.94 %). The fruit with the highest ^{0}brix content (4.75) was recorded in H_3S_2 treatment. Fruit from H_3S_0 had the greatest total sugar content (5.83). Fruit with the highest content (7.28) came from H_3S_2. The H_3S_2 treatment combination produced the highest level of vitamin-C (16.93 mg/100 g) C content. Fruit with H_3S_2 treatment combined had the highest lycopene concentration (4.72 mg/100 g) highest shelf-life (25.96) was found in H_3S_3 treatment. Before making any recommendations, more research may be conducted in Bangladesh's various agro-ecological zones.

Conclusion:

Considering the above result of the present experiment the following conclusion can be drawn:

- The maximum number of flowers per plant, number of fruits per plant, yield of fruits per plant were found at H_3 (90 ppm) humic acid treatment while the lowest result found in control.
- The maximum number of flowers per plant, number of fruits per plant and yield of fruits per plant were found in S_2 (80 ppm) salicylic acid treatment.
- The highest vitamin – C content, sodium content, ^{0}brix content and lycopene content in fruit were found in 90 ppm humic acid with 80 ppm salicylic acid (H_3S_2) treatment.
- The highest yield of fruits per hectare (137.06 tones) was obtained from 90 ppm humic acid with 80 ppm salicylic acid (H_3S_2) treatment.

REFERENCES

Abdellatif, I. M., Abdel-Ati, Y. Y., Abdel-Mageed, Y. T. and Hassan, M. A. (2017). Effect of humic acid on growth and productivity of tomato plants. *J. of Hort. Res.*, **25**(2), 59-66.

Abida, S., Nazmul, H., and Kumar, B. S. (2020). Influence of salicylic acid and micronutrients on yield attributes of tomato in summer. *Inter.J.of Multi. Pers.,* **1**(2), 19-26.

Abreu, M. E., and Munné, B. S. (2009). Salicylic acid deficiency in NahG transgenic lines and sid 2 mutants increases seed yield in the annual plant *Arabidopsis thaliana*. *J. Exp. Bot.,* **60**:1261-1271.

Agamy, R. A., Sayed E. l. Hafez and Taha T.H. (2013). Acquired resistant motivated by salicylic acid applications salt stressed tomato (*Lycopersicon esculentum Mill.*). *American-Eurasian J Agric and Environm Sci.,* **13**: 50-57.

Akinremi, O., Janzen, H. H., Lemke, R. L. and Larne, F. J. (2000). Response of canola wheat and green beans to leonardite additions. *Canadian Journal of Soil science.,* **80**: 437-443.

Alaey, M., Babalar, M.,Naderi, R. and Kafi, M. (2011). Effect of pre- and postharvest salisylic acid treatment on physio chemical attributes in relation to vase-life of Rose cut flowers. *Postharvest Biol Technol*, **61**: 91–94.

Alenazia, M. M., and Khandakerb, M.M. (2021). Responses of tomato hybrid cultivars to soil application of humic acid under greenhouse conditions. *Brazilian Journal of Biology*, **84**. Retrieved from https://doi.org/10.1590/1519-6984.252573

Amira, A., and Helaly. (2021). Enhancing the Productivity and Quality of Tomato using Magnetized Water and Humic Acid as Bio-stimulant Agents. *Indian Journal of Agricultural Research,* **55,** 645-655. Retrieved from doi:/:10.18805/IJARe.A-616

Ananieva, E. A., Christov, K. N. and Popova, L.P. (2004). Exogenous treatment with salicylic acid leads to increased antioxidant capacity in leaves of barley plants exposed to paraquat. *J. Plant Phys.*, **161**,319-328.

Asri, F. O., Demirtas, E.I. and 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.

Atkinson, N. J. and Urwin, P. E. (2012). The interaction of plant biotic and abiotic stresses: from genes to the field. *J. Exper. Bot.*, **63**, 3523-3543.

Bramley, P. M. (2000). Is lycopene beneficial to human health? *Phytochem*, **54**, 233-235.

Breusegem, F.V., Vranova, E., Dat, J.F. and Inze, D. (2001). The role of active oxygen species in plant signal transduction. *Plant Sci.,* **161**, 405-414.

Chavan, R. F., and Sakhale, B.K. (2020). Studies on the effect of exogenous application of salicylic acid on post-harvest quality and shelf life of tomato fruit. Cv. Abhina. *Food Research,* **4**(5), 1444-1450.

Chen, Y., M. De N. and T. Aviad. (2004). Stimulatory effects of humic substances on plant growth. In: Magdoff F, Weil RR, editors. Soil organic matter in sustainable agriculture. *Boca Raton: CRC Press,* 103-130.

Cimrin, K. M., and Yilmaz, I. (2005). Humic acid applications to lettuce do not improve yield but do improve phosphorus availability. *Acta Agriculturae Scandinavica, Section B, Soil and Plant Science,* **55**, 58-63.

Dunoyer, A. A., Castillo F. C. and Camargo J.M. (2022). Effect of humic acid on the growth of seedling tomato (Solanum. Ambiente & Água - An Interdisciplinary. *Journal of Applied Science.* Retrieved from doi:doi:10.4136/ambi-agua.2808

Dursun, A., Guvenc, I., and Turan, M. (2002). Effects of different levels of humic acid on seedling growth and macro and micronutrient contents of tomato and eggplant. *Acta Agro botanica,* ***56,*** 81-88.

Faried, H. N., Ayyub, C.M., Amjad, M., Ahmed, R., Wattoo, F.M., Butt, M.and Bashir, M. (2017). Salicylic Acid Confers Salt Tolerance in Potato Plants by Improving Water Relations, Gaseous Exchange, Antioxidant Activities and Osmoregulation. *J. Sci. Food Agric,* ***97***, 1868-1875.

Ferrara, G., and Brunetti, G. (2010). Effects of the times of application of a soil humic acid on berry quality of table grape (Vitis vinifera L.) cv *Italia. Spanish J. Agric. Res.,* **8,** 817-822.

Galambos, N., Compant, S., Moretto, M., Sicher, C., Puopolo, G., Wäckers, F., Sessitsch, A., Pertot, I. and Perazzolli, M. (2020). Humic acid enhances the growth of tomato promoted by endophytic bacterial strains through the activation of hormone-, growth-, and transcription-telated Processes. 582267. doi:10.3389/fpls.2020.582267

Ghabbour, E. A., and G. Davies. (2001). Humic substances: Structures, models and functions. *Royal Soc. Chem., Cambridge, UK,* **1.** Front. Plant Sci., 11

Gunes, A., Inal, A., Alpaslan, M., Cicek, N., Guneri, E., Eraslan, F. and Guzelordu, T. (2005). Effects of exogenously applied salicylic acid on the induction of multiple stress tolerance and mineral nutrition in maize (*Zea mays L.*). *Arc. Agron. Soil Sci,* **51**(6), 687-695.

Ibrahim, A., Abdel-Razzak, H., Wahb-Allah, M., Alenazi, M., Alsadon, A. and Dewi, Y.H. (2019). Improvement in Growth, Yield, and Fruit Quality of Three Red Sweet Pepper Cultivars by Foliar Application of Humic and Salicylic Acids. *Hort. Technology*, **29,** 170-178.

Islam, M. Z., Mele, M. K., Baek, J. P. and Kang, H. M. (2018). Salicylic Acid in Nutrient Solution Influence the Fruit Quality and Shelf Life of. *Sains Malaysiana*, **47**(3), 537-542. Retrieved from http://dx.doi.org/10.17576/jsm-2018-4703-14

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., N. Akbari. (2016). Salicylic acid at different plant growth stages affects. *Adv. Hort. Sci.*, **30**(3), 151-157. doi:10.13128/ahs-20277

Jayakannan, M. J., Bose, O., Babourina, Z., Rengel, and S. Shabala, (2015). Salicylic acid in plant salinity stress signaling and tolerance. P*lant Growth Regulat*, **76**, 25-40.

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

Kesba, H. H. and El-Beltagi, S.H. (2012). Biochemical changes in grape rootstocks resulted from humic acid treatments in relation to nematode infection. *Asian Pacific J. Tropical Biomedicine*, **2**(4), 287-293.

Khalil, H. (2014). Effects of pre-and postharvest salicylic acid application on quality and shelf life of 'Flame seedless' grapes. *European J. Hortic. Sci.*, **79**, 8-15.

Khan, M. I., M. Fatma, T.S., Per, N. A., Anjum, and N.A. Khan. (2015). Salicylic acid induced abiotic stress tolerance and underlying mechanisms in plants. *Front. Plant Sci.,* **6**, 1-17.

Khan, N. A., Syeed, S., Masood, A., Nazar, R., and Iqbal, N. (2010). Application of salicylic acid increases contents of nutrients and antioxidative metabolism in mungbean and alleviates adverse effects of salinity stress. *Int. J. Plant Biol.*, **1**(1), 1-8.

Khan, W., Prithiviraj, B., and Smith, D.L. (2003). Photosynthetic responses of corn and soybean to foliar application of salicylates. *J. Plant Physiol.*, **160**, 485-492.

Korkmaz, A. (2005). Inclusion of acetyl salicylic acid and methyl jasmonate into the priming solution improves low-temperature germination and emergence of sweet pepper. *Hort. Sci.*, **40**(1), 197-200.

Kumar, H., R. A. Kaushik., K. D. Ameta., Regar, A. L. Singh and Kumari, P. (2017). Effect of humic acid and nutrients mixture on quality parameter of Tomato (*Lycopersicon esculentum* Mill.) under polyhouse condition. *Journal of Applied and Natural Science*, **9**(3), 1369-1372.

Kumar, S., and Verma, D.K. (2004). Effect of micro-nutrients and NAA on yield and quality of litchi cv. Dehradun. International Seminar on Recent Trend in Hi-tech Horticulture and Post Harvest Technology, 193.

Kumar, U. (2017). Effect of Saline Water Irrigation, Humic Acid and Salicylic Acid on Soil Properties, Yield Attributes and Yield of Tomato (*Lycopersicon esculentum Mill*.). *Environment & Ecology*, **35**(1B), 449-453.

Mady, M. A. (2009). Effect of foliar application of salisylic acid and vitamin e on growth anf productivity of tomato (*Lycopersicon esculentum, Mill*.) plant. **34**(4), 6715 - 6726.

Mahmood, N., Abbasi, N. A., I. Hafiz, I. Ali, and S. Zakia. (2017). Effect of biostimulants on growth, yield and quality of bell pepper cv. Yolo Wonder. *Pakistan J. Agr. Sci.*, **54**, 311-317.

Malik, Z. A. and Lal, E.P., (2018). Effect of salicylic acid and indole acetic acid on growth, yield, lycopene and soluble sugar content of tomato (Lycopersicum esculentum) varieties under cadmium and salinity stressed environment. *Annals of Plant and Soil Research*, **20**(4), 396-400.

Manas, D., P.K. Bandopadhyay, Chakravarty, S., Pal, and A. Bhattacharya. (2014). Effect of foliar application of humic acid, zinc and boron on biochemical changes related to productivity of pungent pepper (Capsicum annuum L.). *Afr. J. Plant Sci.*, **8,** 320-335.

Mandal, D., Pautu L., Hazarika T. K., Nautiyal B.P. and Shukla A. C. (2016). Effect of Salicylic acid on physico-chemical attributes and shelf life of tomato fruits at refrigerated storage. *International Journal of Bio-resource and Stress Management*,**7**(6),1272-1278.

Moustafa, F. M., Mohamed H. I., Mahmoud, A., Elkelish, A., Misra, A. N. and Guy, K. M. (2020). Salicylic acid stimulates antioxidant defense and osmolyte metabolism to alleviate oxidative stress in watermelons under excess boron. **9**, 724. Retrieved from https://doi.org/10.3390/plants9060724

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

Naeem, M., Basit A., Ahmad, I., Heba, I. Mohammed and Wasila H. (2020). Effect of Salicylic Acid and Salinity Stress on the Performance of Tomato Plants. Springer-Verlag GmbH Deutschland, ein Teil von Springer Nature. Retrieved from https://doi.org/10.1007/s10343-020-00521-

Paradikovic, N. (2011). Effect of natural biostimulants on yield and nutritional quality:An example of sweet yellow pepper (Capsicum annuum L.) plants. *J. Sci. Food Agr.*, **91**, 2146–2152.

Perez-Jimenez. M., M. Pazos-Navarrob, J. Lopez-Marina, A. Galvez, P. Var O. and F.M. del Amora. (2015). Foliar application of plant growth regulators changes the nutrient composition of sweet pepper (Capsicum annuum L.). *Scientia Hort.*, **194**, 188-193.

Qadir, I., Anjum M.K., Nawaz, A., Ejaz, S., Altaf M. A., Shahid and R. Hassan, (2019). Growth of cherry tomato in response to salicylic acid and glycinebetaine under water stress condition. *Middle East Journal of Agriculture*, **8**(3), 762-775.

Rivas-sun, V. M., and Plasencia J. (2011). Salicylic acid beyond defence: its role in plant growth and development. *J. Exper. Bot.*, ***62*,** 3321-3338.

Saharkhiz, M., Mohammadi, S., Javanmardi, J. and Tafazoli, E. (2011). Salicylic acid changes physio-morphological traits and essential oil content of catnip (Nepeta cataria L.). *Zeitschrift für Arznei- und Gewurzpflanzen*, ***16***(2), 75-77.

Sahu, G. K. (2013). Salicylic acid: Role in plant physiology and stress tolerance. *Molecular stress physiology of plants*, 217-239.

Saied, A. J. I., and Gulli, W. G. (2019). Effect of humic acid, number of clusters and cultivars on growth flowering and yield of tomato plants (*Lycopersicon esculantum L.*) under plastic house condition. *Journal of University of Duhok,* **22**(2), 1-14. Retrieved from https://doi.org/10.26682/cajuod.2020.22.2.1

Sakhabutdinova, A. R., Fatkhutdinova, D. R., Bezrukova, M. V. and Shakirova, F.M. (2003). Salicylic acid prevents the damaging action of stress factors on wheat plants. *Bulg. J. Plant Physiol.,* 314-3`19.

Salehi, S. A. K. (2011). Growth of Tomato as Affected by Foliar Application of Salicylic Acid and Salinity. *American-Eurasian J. Agric. & Environ. Sci.,* **11**(4), 564-567.

Sarinana, A.O.,Sanchez C. E., Fortis, M., Gonzalez, F. J. A., Moreno, A. and Rojas, D. A. (2020). Improvement of the nutraceutical quality and yield of tomato by application of salicylic acid. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca, **48***(2), 882-892. doi:10.15835/nbha48211914

Serenella, N., Pizzeghelloa, D., Muscolob, A., & Vianello, A. (2002). Physiological effects of humic substances on higher plants. *Soil Biology & Biochemistry, **34***, 1527-1536.

Shi, Q., Bao, Z., Zhu, Z., Ying, Q., and Qian, Q. (2006). Effects of different treatments of salicylic acid on heat tolerance, chlorophyll fluorescence, and antioxidant enzyme activity in seedlings of *Cucumis sativa L. Plant Growt. R*., **48**, 127-135.

Singh, B., and Usha, K. (2003). Salicylic acid induced physiological and biochemical changes in wheat seedlings under water stress. *Plant Grow. Regul.,* **39**, 137-141.

Sofy, M. R., Seleiman, M.F., Alhammad, B.A., Alharbi, B.M. and Mohamed H.I. (2020). Minimizing adverse effects of pb on maize plants by combined treatment with jasmonic, salicylic acids and proline. *Agronomy*, **10**, 699. Retrieved from https://doi.org/10.3390/agronomy

Stefani, D. E., Oreggia, F., and Boffetta, P. (2000). Tomatoes, tomato-rich foods, lycopene and cancer of the upper aero digestive tract:. *A case control in Uruguay. Oral Oncol*, **36**, 47-53.

Stevens, J., Senaratna, T., Sivasithamparam, K., (2006). Salicylic Acid Induces Salinity Tolerance in Tomato (Lycopersicon esculentum cv. Roma): Associated Changes in Gas Exchange, Water Relations and Membrane Stabilisation. *Plant Growth Regul.*, **49**, 77-83.

Tchiadje, N. F. T. (2007). Strategies to reduce the impact of salt on crops (rice, cotton and chilli) production. *A case study of the tsunami-affected area on India,* **206**, 524-530.

Tommonaro, G., DE, P. R., Abbamondi, G.R., Marzocco, S., Saturnino, C., Poli, A. and Nicolause B. (2012). Evaluation of antioxidant properties, total phenolic content, and biological activities of new tomato hybrids of industrial interest. *J. Med. Food, **15***, 483-489.

Ullah, A., khan, N. A., Shah, S. M., Amin, F., Khan, S. and Ullah, Z. (2019). Influence of foliar application of bio-stimulants on growth, yield and chemical composition of tomato. *International Journal of Biosciences* | IJB |, **14**(1), 309-316. Retrieved from http://dx.doi.org/10.12692/ijb/14.1.309-316.

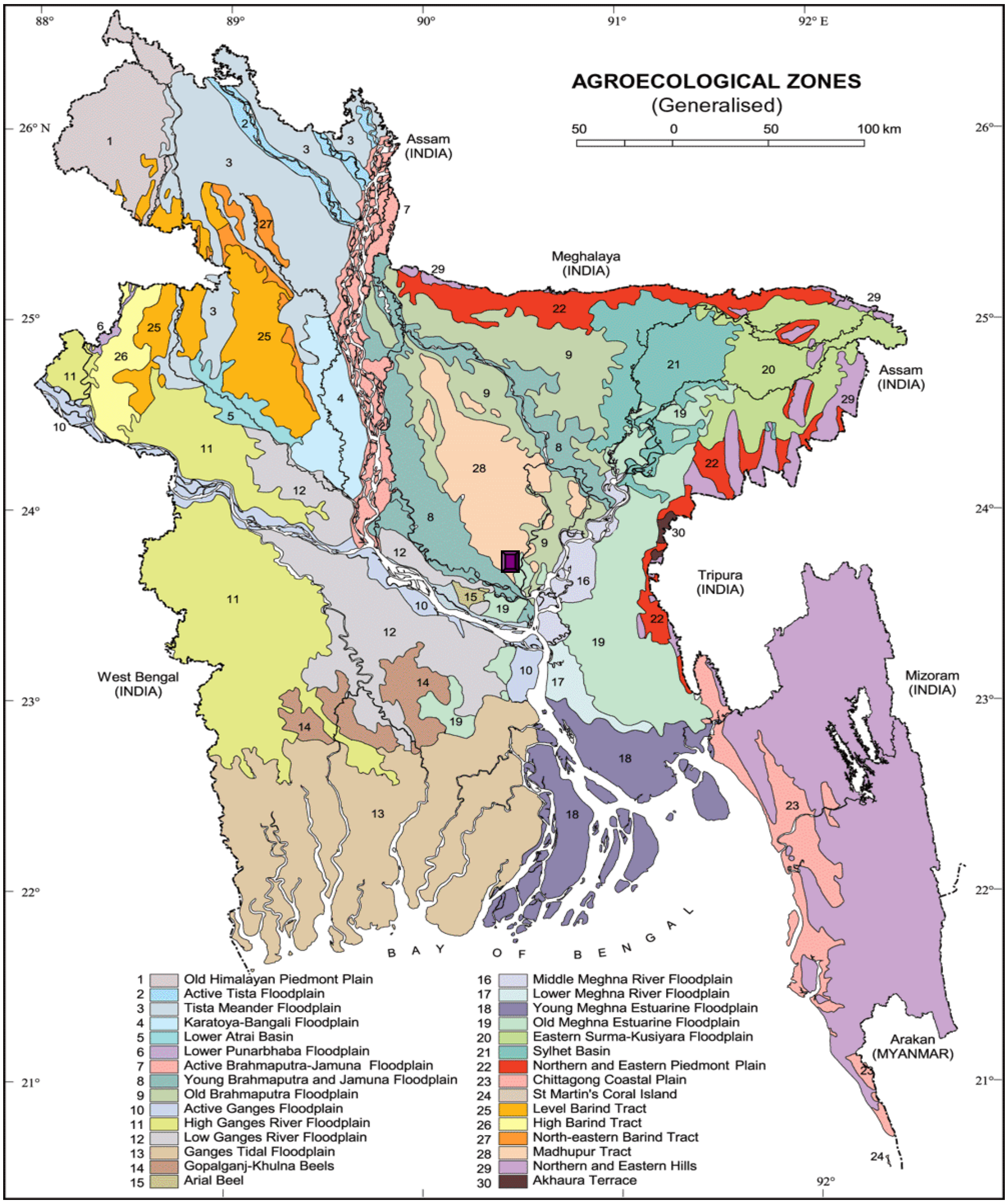
Yildirim, E. and Dursun, A. (2009). Effect of foliar salicylic acid applications on plant growth and yield of tomato under greenhouse conditions. *J. Acta Horticulturea,* **807,** *395-400.*

Zahra, S., Amin, B., and Mehedi, Y. (2010). The salicylic acid effect on the tomato (*lycopersicum esculentum Mill.*)germination, growth and photosynthetic pigment under salinity stress (NaCl). *Journal of Stress Physiology & Biochemistry*,**6**(3),4-16.

Zaky, M. H., Zoah, E.L. and Ahmed, M.E. (2006). Effects of humic acids on growth and productivity of bean plants grown under plastic low tunnels and open field. *Egypt. J. Appl. Sci.,* **21**(4B), 582-596.

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 (^0C)			Total rainfall (mm)	Average RH (%)	Total Sun shine hours
		Maximum	Minimum	Mean			
2020	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
2021	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	4.010^{**}	7.869^{**}	302.007^{**}
Factor B	3	4.444^{**}	9.338^{**}	266.065^{**}
AB	9	3.696^{**}	2.351^{**}	40.505^{ns}
Error	30	0.854	0.670	31.678

**: 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	7.728^{**}	46.220^{**}	31.957^{**}
Factor B	3	1.594^{*}	74.698^{**}	32.836^{**}
AB	9	0.499^{ns}	41.380^{**}	19.670^{**}
Error	30	0.436	5.612	3.623

**: 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, 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	Plant total dry weight (g)
Factor A	3	1.741**	3.486**	14.477**
Factor B	3	0.824**	0.654**	73.660*
AB	9	0.334**	0.651**	12.810**
Error	30	0.0529	0.035	1.631

**: 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	33.212**	26.597**	239.870**	48.355**
Factor B	3	27.624**	24.920**	302.046**	12.922*
AB	9	7.093**	7.452**	47.731**	10.894**
Error	30	1.409	1.715	9.134	2.716

**: 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 length (cm)	Individual fruit weight (g)	Yield per plant (kg)	Total yield per hectare (ton)
Factor A	3	3.420^{**}	1.010^{**}	381.070^{**}	1.236^{**}	2144.42^{**}
Factor B	3	0.336^{**}	0.034^{ns}	333.618^{**}	0.765^{**}	1328.76^{**}
AB	9	0.868^{**}	0.556^{**}	9.571^{*}	0.039^{*}	68.82^{*}
Error	30	0.009	0.103	3.762	0.0153	26.71

**: 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	3.116^{**}	0.056^{**}	2.117^{**}	0.036^{**}	2.684^{**}
Factor B	3	0.809^{**}	0.044^{**}	0.043^{**}	0.089^{**}	0.501^{**}
AB	9	0.754^{**}	0.010^{*}	0.127^{**}	0.008^{**}	0.499^{**}
Error	30	0.131	0.002	0.000	0.001	0.053

**: 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	3.977**	1.741**	0.479**
Factor B	3	1.597**	0.804**	0.160**
AB	9	0.652**	0.340**	0.105**
Error	30	0.048	0.053	0.022

**: 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

Sources of variation	Degress of freedom	Mean square of	
		Vit-C content on fruit (mg/100 gm)	Lycopene content on fruit (mg/100 gm)
Factor A	3	4.782**	0.039**
Factor B	3	8.897**	0.031**
AB	9	2.154*	0.022**
Error	30	0.994	0.001

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

Appendix xii: pictorial view of research work

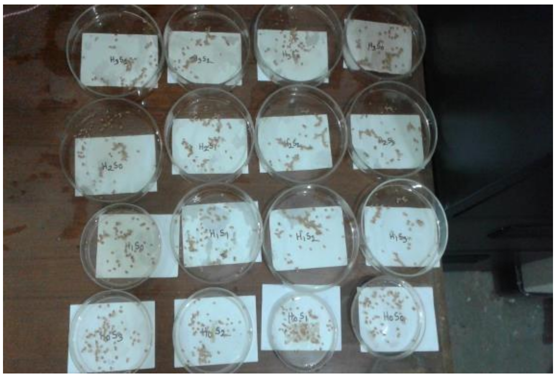


Plate 1. Seed soaked on different Treatment combination

Plate 2. Germinated seedlings on seedbed

Plate 3. Land preparation for transplanting

Plate 4. Transplanted seedlings on experimental plot

Plate 5. Vegetative stage of tomato plant

Plate 6. Flowering stage of tomato plant

Plate 7. Fruiting stage of tomato plant

Plate 8. Fruit cluster on tomato plant

Plate 9. Ripening stage of tomato

Plate 10. Determination of nutritional attributes of tomato in BCSIR laboratory

Plate 11. Harvested fresh tomato