ASSESSMENT OF GROWTH, YIELD AND FRUIT QUALITY OF CHERRY TOMATO (JHUMKA) AT VARIOUS MATURITY STAGES IN RESPONSE TO APPLICATION OF HUMIC ACID

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JUNE, 2021

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REG. NO. : 14-05979

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

MASTER OF SCIENCE (MS)
IN
HORTICULTURE

SEMESTER: JANUARY-JUNE, 2021

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CERTIFICATE

*This is to certify that the thesis entitled, **"ASSESSMENT OF GROWTH, YIELD AND FRUIT QUALITY OF CHERRY TOMATO (JHUMKA) AT VARIOUS MATURITY STAGES IN RESPONSE TO APPLICATION OF HUMIC 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 **Auruna Begum**, Registration number: **14-05979** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dated: June, 2021
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DEDICATED

TO

MY BELOVED PARENTS

ACKNOWLEDGEMENTS

*All praises are due to the **Almighty Allah**, Who has enabled the author to complete the research work and to prepare this thesis for the degree of Master of Science (M.S.) in Horticulture. One of the satisfied snapshots of composing this note of acknowledgement is to think back the whole voyage of my investigation and recollect every one of the general population, beginning from supervisor, co-supervisor to course instructors, friends and family.*

*The author devote an extraordinary pleasure and respect to express her ardent appreciation, most profound feelings of gratefulness, best respects and significant obligation to her reverend supervisor, **Md. Dulal Sarkar,** Assistant Professor Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka-1207, without whom author would not have been able to come this far. He did not only supervise this thesis but also guide the author immensely to successfully accomplish this research work.*

*The author feels proud to express her deepest respect, sincere appreciation and immense indebtedness to her co-supervisor, **Dr. M A Goffar,** Principle Scientific Officer, Olericulture Division, Horticulture Research Center, Bangladesh Agricultural Research Institute, Joydebpur ,Gazipur-1701, for his scholastic and continuous guidance during the entire period of course, research work and preparation of this thesis.*

The author is glad to stretch out her heartfelt thanks on account of the considerable number of resources of the Department of Horticulture, SAU, for their important instructions, recommendations and consolation amid the time of the examination.

The author would like to extend her thankfulness towards Dr Mohammad Mainuddin Molla, SSO, BARI; and Md. Rezaul Karim, SA, BARI; who helped the author a lot during data collection by giving countless suggestion and accompany despite their busy schedule.

The author also thankful to all the field staff of Horticulture Department, SAU, Dhaka-1207 for their help and cooperation during the experimental period.

The Author

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ABSTRACT

The field experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka during October 2019 to April 2020 to find out the response of humic acid on growth, yield and nutritional quality of tomato fruit at different maturity stages. Four different doses of humic acid viz., H_0= 0 ppm (control), H_1= 25 ppm, H_2= 50 ppm, H_3= 75 ppm and four maturity stages viz, MS_1=green mature, MS_2=breakers stage, MS_3= pink stage MS_4= red stage were used to conducting this experiment. The experiment was laid out in Randomized Complete Block Design having two factors.The effect of humic acid on maturity stages showed significant variations with most of the parameters studied. The maximum number of flowers per plant (305.78), number of fruit per plant (194.94), yield of fruits per plant (1.6 kg) were found at 75 ppm humic acid treatment while the lowest result found in control. The highest total soluable solid (5.86 %), pH (4.01) and *B*-carotine content (27.58 mg/100g) in fruit were found in 75 ppm humic acid with red stage. The highest yield of fruits per hectare (68.99 tones) was obtained from 75 ppm humic acid was sprayed. So, the application of 75 ppm humic acid and red stage would be the best option to maintain better growth, yield and to have better quality tomato.

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LIST OF ABBREVIATIONS

BARI = Bangladesh Agricultural Research Institute

cm = Centimeter

$_{0}$C = Degree Centigrade

DAT = Days after transplanting

et al. = and others (at elli)

Kg = Kilogram

Kg/ha = Kilogram/hectare

g = gram (s)

LSD = Least Significant Difference

MP = Muriate of Potash

m = Meter

PH = Hydrogen ion conc.

RCBD = Randomized Complete Block Design

TSP = Triple Super Phosphate

t/ha = ton/hectare

% = Percent

ml = mili liter

MS = maturity stage

HA = humic acid

CHAPTER I
INTRODUCTION

Tomato (*Solanum lycopersicon*) is the most common and significant climacteric fruit crops. BARI tomato-11 (Jhumka), is one of the promising cherry tomato varieties grown in Bangladesh on a small scale rather than other verities, particularly as table fruits and for commercial use. Owing to the large amounts of lycopene, Beta-carotine and sugars than conventional tomatoes, the economic value of cherry tomato fruits has been greatly increased globally (Raffo *et al.*, 2002). These properties are primarily dependent on harvesting time by the stage of maturity and the regulation of pre-and post-harvest factors which are optimal for ensuring fruit quality (Kader, 2008; Beckles, 2012).The maturity stages affects directly in the postharvest quality of tomato fruits including peel colour, lycopene content, and soluble solids (Caron *et al.,* 2013). The use of humic acid (HA) as plant biostimulants represents a possible method for enhancing agro-environmental perfomance in fields. It is an active natural compound obtained from organic soil and compost that can improve crop yield and quality parameters, nutrient performance, horticultural crop physiology and abiotic stress tolerance (Calvo *et al*. 2014). Foliar applications of biostimulants have been widely recognized for enhancing plant production, yield and physiological processes of horticultural crops. When applied at different plant phenological stages of development, HA increases fruit weight, color and improves grape fruit quality (Ferrara and Brunetti 2010).

It might favor berry quality profile such as color, aroma, flavor and firmness at various stages of maturity of cherry tomatoes. However, to maintain their nutritional and organoleptic quality along considering the amplification of the marketing period, the harvest should be optimized to a maturity stage. Although, several studies have been carried out using plant growth regulators and biostimulants associated or not with other pre-harvest and post-harvest condition in conventional tomatoes, while the potential of humic acid (HA) for BARI tomato-11 cherry fruits has received little research attention. Hence, the purpose of this study is to evaluate the cherry fruit quality of BARI tomato-11 at several stages of maturity using humic acid as a biostimulant in order to sustainable yield and quality. The objectives of the study were:-

- To study the efficacy of HA in plant growth and physiological activities.
- To assess the fruit quality attributes at different maturity stages.

CHAPTER II

REVIEW OF LITERATURE

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

2.1 Effect of humic acid

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

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

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

Asri *et al*. (2013) stated that, humic acids (HA) provide formation of the organomineral in soil, thus they improve nutrient concentration of tomato leaves and agricultural production. The objective of this study was to find effects of soil HA applications on yield, fruit quality and nutrient concentration of processing tomato. Humic acid was sprayed on soil at the rate of 0, 40, 80, 120, 160 and 200 L ha-1 soil along with uniform dose of nitrogen-phosphorus-potassium (NPK) (180-60-210 kg ha-1) was applied through drip irrigation. The experiment was conducted according to randomized complete block design with 4 replicates in 2011-2012 years. The humic acid applications caused a significant increase of yield. Titratable acidity, fruit weight and fruit diameter showed increase by ascending humic acid levels.

Results showed that N, P, K, Ca, Zn and Mn concentration of leaves was increased by humic acid, especially 80 L ha-1 humic acid level provided the most important progress in the first year. In the second year, N, P, K, Fe and Mn concentration of leaves was positive changed by humic acid and high levels of humic acid caused decline. Therefore, mid-levels (80 and 120 L ha-1) were found more effective.

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

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

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

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

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

2.2 Effect of different maturity stages

K.M. Moneruzzaman *et al.* (2008) were conducted an experiment was carried out to evaluate the biochemical characteristics of tomato in different maturity stages and ripening conditions. Tomato (Lycopersicon esculentum Mill) fruits (cv. Ruma VF) were harvested at the three maturity stages viz., mature green, half ripen and full ripen. The highest value of reducing sugar percentage total sugar percentage and TSS percentage were shown by full ripe tomatoes, non-reducing sugar percentage, TSS and acidity ratio by mature green tomatoes and vitamin-C and titrable acidity by half ripe tomatoes at final day observation (15 or 12 days of storage).

Tilahun A. Teka (2013) was conducted an experiment on analysis of the effect of maturity stage on the postharvest biochemical quality characteristics of tomato (Lycopersicon esculentum mill.). Quality characteristics of tomato fruit will be affected by a number pre- and post harvest factors. In this study, the effect of maturity stage on post harvest quality characteristics of tomato was investigated. Tomato fruits of the same farmers‟ variety were harvested at mature-green, medium ripe and full-ripe stages. After harvesting, tomato samples were sliced and homogenized in blender for preparation of juice. The experiment was laid out using completely randomized design on juice samples. As response parameters, pH, titratable acidity, total soluble solids, sugar (total, reducing, and non-reducing sugar), and firmness were measured with three replications. Results indicated that maturity stage at harvest significantly ($p<0.05$) affected quality attributes of tomato fruit.

Noriko Takahashi *et al. (*2013) were conducted an experiment was carried out evaluation of tomato fruit color change with different maturity stages and storage temperatures using image analysis. The effects of storage duration and temperature on the tomato fruit color change and quality with different maturity stages tomato were investigated in this study. Tomatoes were grown hydroponically in high technology greenhouse. Tomato fruit samples with green to red were stored in cool incubator for 48 h. The storage temperature was adjusted at 15 °C and 20 °C. The maturity stage of tomato fruit was evaluated with chiromaticity by image analysis. Little tomato fruit color change with storage was observed in large maturity stage (red fruit) regardless of storage temperature. Chromaticity in small maturity stage (green fruit) was increased with storage time. The sugar content of fruit was increased and fruit firmness was decreased with storage at both temperatures for 15 °C and 20 °C regardless of maturity stage.

X Wang *et al*. (2011) were conducted an experiment was carried out vision-based judgment of tomato maturity under growth conditions. To determine the picking time of tomato and design the control strategy for the harvesting robot, the judgment of tomato maturity under natural conditions is required. Tomato samples were collected based on the fruit growth conditions which were divided into five different stages in this article: breakers, turning, pink, light-red, and red stages. The visible CCD camera VS-880HC was adopted to shoot visible images, while the near-infrared images at a wavelength of 810 nm were screened by MS-3100 multi-spectral camera. The tests indicated that with the changes in maturity, the hue-mean of tomato decreased and the red-green color difference image mean increased. The intermediate divisions of five different maturity stages, which were divided by red-green color-difference image mean, were 0, 23.5, 42.5 and 70. The judgment errors of the two methods are mainly caused by the recognition of tomatoes at the pink stage.

M. Hatami *et al. (*2013) were conducted an experiment was responses of different maturity stages of tomato fruit to different storage conditions. In tomato as a climacteric fruit, fruit ripening can be completed after harvest. Provided that appropriate storage condition for a given harvesting stage is implemented, fruits are endowed with proper quality for the market. In order to study the effects of maturity stage on fruit storage life, tomato fruits were harvested at three ripening stages. They were stored at three storage temperature conditions including 5, 13°C, and a simulated condition (SC) of the interval between harvest and consumption by the consumer. Fruit color, lycopene, firmness, titratable acidity (TA), total soluble solids (TSS), ascorbic acid, weight loss, and chilling injury (CI) were measured and evaluated during the experiment. Results showed that at the end of the storage at 13°C, mature green fruits had relatively similar values of color, lycopene content, TA, TSS, and firmness compared to the red ones; however, ascorbic acid did not accord. While storage of different maturity stages of tomatoes at 13°C developed normal ripening, storage at 5°C and SC disturbed the normal ripening process.

Md.Shahidul Islam *et al.* (1996) were conducted an experiment was effect of carbon dioxide enrichment on physico-chemical and enzymatic changes in tomato fruits at various stages of maturity. The influence of CO2 enrichment on fruit growth, firmness and colour, together with its effect on the concentrations of ascorbic acid, organic acids and sugars, and the activities of sucrose synthase (SS) (UDP glucose: D-fructose 2-glucosyltransferase, E. C. 2. 4. 1. 13) and sucrose phosphate synthase (SPS) (UDP glucose: D-fructose-6-phosphate 2-glucosyltransferase, E. C. 2. 4. 1. 14) were determined at various stages of maturity in fruits of tomato (Lycopersicon esculentum Mill. cv. Momotaro). CO2 enriched tomatoes had lower amounts of citric, malic and oxalic acids, and higher amounts of ascorbic acid, fructose, glucose and sucrose synthase activity than the control. Elevated CO2 enhanced fruit growth and colouring during development. Citric acid was the primary organic acid followed by malic and oxalic acids. The concentration of organic acids (mg g^{-1} fresh weight) and of ascorbic acid (mg $100g^{-1}$ fresh weight) increased with the maturity of fruits; their maximum concentrations were found at the pink stage of ripening, but declined slightly at the red stage. The amount of reducing sugars (mg g^{-1} fresh weight) increased with the advancement of maturity, with fructose being the predominant sugar. The decrease in SS activity was accompanied by an increase in the concentrations of reducing sugars.

CHAPTER III

MATERIALS AND METHODS

The present research work was carried out at Sher -e- Bangla Agricultural University during 2019-2020 to study the "**Assessment of growth, yield and fruit quality of cherry tomato (Jhumka) at various maturity stages in response to application of humic acid**." The chapter deals with the materials and methods during conducting experiment.

3.1 Experimental site

The experiment was conducted at the Horticulture farm of Sher-e-Bangla Agricultural University, Dhaka, during the period from mid October 2019 to March 2020. The location of the site in 23°74" N latitude and 90°35" E longitude with an elevation of 8.2 meter from sea level (Appendix-I).

3.2 Climate

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

3.3 Soil

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

3.4 Plant materials

The tomato variety used in the experiment was BARI Tomato11(Jumka). This is a high yielding , indeterminate type cherry tomato.

3.5 Treatments of the experiment

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

Factor A: Humic Acid

a. HA_0: 0ppm
b. HA_1: 25ppm
c. HA_2: 50ppm
d. HA_3: 75ppm

Factor B: Maturity Stages of tomato

a. MS_1: Green mature
b. MS_2: Breakers
c. MS_3: Pink
d. MS_4: Red

Treatment combinations: HA_0MS_1, HA_0MS_2, HA_0MS_3, HA_0MS_4, HA_1MS_1, HA_1MS_2, HA_1MS_3, HA_1MS_4, HA_2MS_1, HA_2MS_2, HA_2MS_3, HA_2MS_4, HA_3MS_1, HA_3MS_2, HA_3MS_3, HA_3MS_4.

3.6 Experimental design and layout

It was a two-factorial experiment laid out in a Randomized Complete Block Design (RCBD) with three replications. The experimental area was divided into three equal blocks. Every replication had sixteen plots where 16 treatments were allotted at randomly. The total number of plots were 48. The size of each plot was 2 m × 1.8 m. The distance between two blocks and two of plots both were l.0 m. The spacing between row to row is 60 cm and plant to plant is 40 cm.

3.7 Land preparation

The selected land for the experiment was opened 10 October, 2019 with the help of a power tiller and kept open to sun for 4 days prior to further ploughing. The land was prepared well by ploughing and cross ploughing followed by laddering at 12 October, 2019. Weeds and stubble were removed and the basal dosed of fertilizers were applied and mixed thoroughly with the soil before final land preparation. The unit plots were prepared by keeping lm spacing in between two plots and 50 cm drain was dug around the land. The space between each blocks and plots were made as drain having a depth of about 30 cm.

3.8 Seedbed preparation

The seedlings of cherry tomato were raised in a 3 m × 1 m size seedbed which situated on a relatively high land at the Horticulture Farm, SAU, Dhaka. The soil was well prepared with the help of spade and made into loose friable and dried mass to obtain fine tilth. All weeds and stubbles were removed and 5 kg well rotten cowdung was applied at seedbed during seedbed preparation. The seeds were sown on 15 October, 2019 and after sowing, seeds were covered with light soil. Heptachlor 40 WP was applied @ 4 kg/ha around each seedbed as precautionary measure against ants and worm. The germination of the seedlings took place within 5 to 6 days after sowing. Necessary shading by polythene was provided over the seed bed to protect the young seedlings from scorching sun or heavy rain. Weeding, mulching and irrigation were done from time to time as and when required and no chemical fertilizer was used in the seedbed.

3.9 Application of manures and fertilizers

Following doses of manures and fertilizers were commended for cherry tomato (Jumka) production fertilizer recommendation guide 2018, BARC. Cow dung -10t, Urea-550kg, Mop-450kg, TSP-450kg.Half of cow dung and all of TSP were applied as basal during final land preparation. Remaining cow dung was applied in pits before planting of seedlings. Urea and MoP were applied in two equal splits at 15 and 35 days after transplanting as ring method under moist soil condition and mixed thoroughly with the soil as soon as possible for better utilization.

3.10 Transplanting of seedlings

The transplanting of the seedlings was performed in main field. Healthy and uniform 28 days old seedlings were uprooted separately from the seed bed to transplant in the afternoon of 12 November 2019. The row to row and plant to plant distance were maintained at 60 and 40 cm, respectively. The seedbed was watered one hour before uprooting the seedlings to minimize the damage to the roots of the seedlings. Nine plants were transplanted in each unit plot. The seedlings were watered immediately after transplanting. Watering was continued until the seedlings were well established and it was required for 6 days.

3.11 Application of humic acid and maintain maturity stages

Humic acid in distinctive concentrations have been prepared and spraying at 25, 50 ,and 75 days after transplanting in step with the treatments. Green mature,beakers,pink and red maturity stages are maintained.

3.12 Intercultural operations

After transplanting the seedlings, numerous varieties of intercultural operations have been achieved for higher growth and development of the plants, that are as follows.

3.12.1 Weeding

Weeding turned into executed each time important to hold the crop loose from weeds.

3.12.2 Shoot pruning and stalking

For right boom and improvement of the plant life the principle stems have been controlled upward with the aid of using hand and with the assist of bamboo stick. So, the wet and stormy climate couldn't harm the developing stems of the plant life.

3.12.3 Irrigation

The experiment turned into completed in rabi season. So, irrigation turned into given whilst it turned into necessary. Sometimes rain turned into provided enough water then irrigation turned into no need. When irrigation turned into carried out then it turned into given thru drains of the plots.

3.12.4 Plant protection

Tomato is a completely touchy plant to diverse insect pests and diseases. So, diverse safety measures have been taken. Melathion fifty-seven EC and Ripcord changed into applied @ 2 ml in opposition to the insect pests like beetle, fruit fly, fruit borer and other. The insecticide software changed into made fortnightly from 10 days after seed sowing to per week earlier than first harvesting. During cloudy and warm climate precautionary measures in opposition to viral sickness changed into taken through spraying. Furadan five G changed into additionally applied @ 6 g/pit in the course of pit instruction as soil insecticide.

3.13 Harvesting

Fruits were harvested when the green fruits had been attained in marketable stage. Fruits had been additionally harvested while turning colour began out to growing on the factor in which plant life are dropped.

3.14 Data collection

Data collected on the subsequent parameters.

3.15 Data collection procedure

3.15.1 Plant height (cm)

Plant hight were measured at 25 DAT, 50 DAT and 75 DAT which measured in centimeter from floor stage to tip of the primary stem from every plant of every treatment and mean value were calculated.

3.15.2 Total dry matter

Total dry mater of plant at harvest were calculated via way of means of aggregating the dry matter weight of leaves, stems, roots and different immature reproductive parts maintaining proper procedure.

3.15.3 Number of flowers per pant

Number of flower consistent with plant became counted from plant. Number of flower consistent with plant were recorded for every treatment.

3.15.4 Number of fruits per plant

Number of fruits were counted from first harvest level to final harvest. Number of fruit consistent with plant were recorded for every treatment.

3.15.5 Fruit length and diameter (cm)

Fruit length and diameter taken through vernier scale in centimeter. Diameter i.e. breath of fruit turned into measured on the center part of end result from every plot and their common turned into taken. Average length of same fruit turned into additionally taken.

3.15.6 Weight of individual fruit (g)

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

3.15.7 Weight of fruits per plant (kg)

Top load scale balance was used to take the weight of fruits per plant. It was measured by total fruit weight of harvested from the individual plant and was recorded in kilogram (kg).

3.15.8 Yield of fruits

To estimate yield, all the 9 plants in every plot and all the fruits in every harvest were considered. Thus, the average yield per plot was measured. The yield per hectare was calculated considering the area covered by the plants**.**

3.16 Evaluation of Color Value

The color of each fruit was measured according to the International Commission on Illumination (CIE, Paris, France, 1978). using a Konica Minolta® CM 2002 spectrophotometer (Konica Minolta, Osaka, Japan). Three measurements were made for each fruit. The values were then recorded as L* (lightness; black = 0, white = 100), a*(redness > 0, greenness < 0), b*(yellowness > 0, blueness < 0) were quantified for each sample. The ratio was also calculated for each measurement. The mean value for each parameter was derived from all three measured locations on each tomato. Three fruits were used for each treatment from each respective maturity stage.

3.17 Analysis of ascorbic acid:(vit-C)

Ascorbic acid analysis was performed using HPLC method (*Sp´ınola et al*. 2012) with some modifications. Fresh tomatoes were ground into a fine paste and 5 g of paste was extracted with a 5% metaphosphoric acid solution. Then, after centrifugation and filtration (through a 0.20 μm syringe filter), the aliquot (10 μL) was analyzed using a 1260 Infinity HPLC system equipped with an Acquity UPLCHSS T3 (2.1 × 100 mm, 1.8 μm, Waters) column and diode array detector at a wavelength of 254 nm. The mobile phase consisted of an isocratic aqueous 0.1% (v/v) formic acid solution at a flow rate of 0.3 mL/min for separation of the ascorbic acid peak. An authentic L-ascorbic acid standard at various concentrations (0–50 ppm) was used for the identification and quantification of the peak. The content of ascorbic acid(vit-C) was calculated on the basis of the calibration curve and results were expressed as mg/100 g fw (fresh weight).

3.18 Analysis of carotenoids (lycopene and B-carotene):

Carotenoid analyses were performed using the modified HPLC method (*Jo et al*. 2014). Freeze-dried and powdered samples (10 mg) were extracted for 30 min in 5.0 ml of extraction solution (chloroform: MeOH, 1: 1, v/v), centrifuged, filtered through a 0.45 μm syringe filter, and stored in a 1.5 mL amber vial. Sample preparations were performed under dimmed room light to minimize carotenoid degradation, as light causes loss of carotenoids.Subsequently, the aliquot (10 μL) was analyzed using a 1260 Infinity HPLC system equipped with a Nova-Pak C18 4 μm (3.9 ×150 mm) column and a diode array detector at 470 nm. An isocratic mobile phase composed of 100% methanol, at a flow rate of 1.5 ml/min, was used for the separation of carotenoid peaks. Authentic standards of lycopene, and β-carotene at various concentrations (0.0–50.0 ppm) were used for the identification and quantification of the peaks, and results were expressed as mg/100 g dw (dry weight).

3.19 Determination of pH:

The pH of the tomato juice was determined by the method described by *Rangana et al.*1979. The fruits were chopped into small pieces, mashed by an electrical blender for 10 minutes and tomato juice was prepared using waring blender.Then the pH meter was standardized with pH 4.0 and 7.0 buffer solutions. After standardization, 10 ml of tomato juice was added in to 50 ml beaker and then the pH of each juice sample was measured by using Microcomputer pH meter with a glass electrode.

3.20 Total soluble solid (TSS):

A total soluble solid (TSS in °Brix) of the tomato juice was measured by the method described by *Tigchelaar et al.*1986. Tomato juice was prepared by blending tomato fruit using waring blender for 10 minutes. Five mL of the juice was taken and centrifuged using at 5000rpm. The clear supernatant (1-2 ml) was taken and filtered using a syringe fitted with a 0.45 µm pore diameter filter, and two drops of the filtrate were then carefully applied on the refractometer using plastic dropper and the reading was obtained directly as percentage soluble solids concentration (ºBrix range 0 -95% at 22 °C) using bench-top scale based Abbe- refractometer .

3.21 Determination of sugar content:

A common colorimetric procedure for the analysis of the total sugar determination in fruit juice; the Anthrone method was used. The reducing sugar content was estimated by determining the volume of unknown sugar solution of tomato pulp required for complete reduction of standard Fehling"s solution using titration method.The non reducing sugar(sucrose) content was calculated by subtracting reducing sugar from total sugar.

3.22 Determination of calcium:

Calcium is precipitated as calcium oxalate.The precipitate is dissolve in hot dilute sulfuric acid and tritrated with standard potassium permanganate.It is calculated in percentage.

3.23 Determination of magnesium:

In alkaline solution from which calcium and iron have been removed, magnesium is precipitated as magnesium ammonium phosphate. The precipitate is dissolved in acid and the amount of phosphorus is determined colorimetrically. Magnesium is then calculated. It is calculated in percentage.

3.24 Determination of phosphorus:

Phosphorus reacts with molybdic acid to from a phosphomolybdate complex.It is then reduced with amino naphtholsulphonic acid to the complex molybdenum blue which is measured colorimetrically. It is calculated in percentage.

3.25 Determination of potassium:

Potassium in solution is atomized into an oxyhydrogen or oxyacetylene flame.The flame excites atoms of potassium causing them to emit radiations at specific wavelenths. The amount of radiation emitted is measured qn a spectrophotometer.Under standard conditions, it is proportional to the concentration of -potassium in solution. It is calculated in percentage.

3.26 Determination of iron:

The iron in food is determined by converting the iron to ferric from using oxidizing agents like potassium persulphate or hydrogen peroxide and treating thereafter with potassium thiocyanate to from the red ferric thiocyanate which is measured colorimetrically at 480 nm. It is calculated in ppm.

3.27 Determination of dry matter (oven drying method)

100g fresh tomato pulp were taken and dried over-night into the oven. Next dried tomato pulp weight were taken. The final weight is dry matter of tomato fruit and reduced weight is moisture of tomato fruit.

3.28 Statistical analysis:

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

CHAPTER IV

RESULTS AND DISCUSSION

This chapter comprises the presentation and discussion of the results of the experiment. The experiment was conducted to determine the response of humic acid on growth and yield on different stages of maturity along with nutritional quality of cherry tomato. Some of the findings have been presented in tables and in figures for ease of discussion, comparison and understanding. The results and discussion have been mentioned under the following headings.

4.1 Plant height (cm)

The effect of humic acid was significant on plant height at 25, 50 and 75 days after transplanting (DAT). The tallest plant (90.38 ,111.08 and 147.67 cm at 25, 50 and 75 DAT, respectively) was produced by HA_3 (75 ppm humic acid) and the shortest plant (53.24, 85.71 and 105.37 cm at25, 50 and 75 DAT, respectively) was produced by HA_0 (control) treatment (Table 1 and Appendix iv). The plant height was increased with increasing in concentration of humic acid significantly up to a certain level.

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

Treatments	Plant height (cm)		
	25 DAT	50 DAT	75DAT
HA_0	53.24±0.92d	85.71±0.89d	105.37±1.67d
HA_1	63.15±1.20c	94.82±0.69c	120.17±0.70c
HA_2	75.08±0.85b	101.82±0.45b	128.51±1.64b
HA_3	90.38±1.36a	111.08±1.59a	147.67±2.01a
LSD (0.05)	1.25	1.02	1.15
P-value	0.00	0.00	0.00
CV (%)	2.13	1.25	1.10

Means with the same letter did not significantly differ from each other at $p<0.05$. Abbreviations are as follows HA_0 = 0, HA_1 = 25 ppm, HA_2 = 50 ppm, HA_3 = 75 ppm of humic acid. DAT = days after transplanting. Values are mean ± SE.

4.2 Floral attributes of tomato

The humic acid showed significant variation on floral attributes of tomato. Number of flower cluster plant-1,number of flower cluster-1 and number of flower plant-1 highest in HA_3 (75 ppm humic acid) 11.70, 23.79 and 305.78 respectively. HA_0 (control) treatment produced the lowest floral attributes of tomato (Table 2 and Appendix v).

Table 2. Effect of humic acid on floral attributes of tomato

Treatments	Number of flower cluster /plant	Number of flower /cluster	Number of flower /plant
HA_0	10.33±0.26b	19.13±0.27c	197.75±5.81 c
HA_1	11.42±0.26 a	20.34± 0.35b	231.96±6.01 b
HA_2	11.32±0.40 a	20.69± 0.23b	236.65±9.61 b
HA_3	11.70± 0.26a	23.79±0.49 a	305.78±10.88 a
LSD (0.05)	0.89	0.76	21.57
P-value	0.02	0.00	0.00
CV (%)	9.58	4.38	10.67

Means with the same letter did not significantly differ from each other at $p<0.05$. Abbreviations are as follows HA0 = 0, HA1 = 25 ppm, HA2 = 50 ppm, HA3 = 75 ppm of humic acid. Values are mean ± SE

4.3 Fruit yield and yield contributing characters of tomato

The humic acid showed significant variation on berry yield and yield contributing characters of tomato. Number of fruits /cluster, number of fruits/ plant, single fruit weight (g), fruit diameter (cm), fruit yield/ plant and fruit yield/ ha maximum in HA_3 treatment (16.69, 194.94, 8.28, 2.66,1.61 and 66.99 respectively) (Table 3).

Table 3. Effect of humic acid on berry yield and yield contributing characters of tomatos

Treatments	Number of fruits/ cluster	Number of fruits /plant	Days to maturity	Single fruit weight (g)	Fruit diameter (cm)	Fruit yield/ plant	Fruit yield/ ha
HA0	14.12±0.31c	145.80±4.83c	72.01±1.30a	8.72±0.20ab	1.61±0.06d	1.26±0.02d	52.57±0.82d
HA1	14.71±0.24b	167.90±4.48b	71.67±1.18ab	8.64±0.18ab	1.90±0.10c	1.45±0.03c	60.24±1.35c
HA2	15.20±0.18b	171.99±6.32b	71.45±1.19ab	9.07±0.30a	2.28±0.13b	1.54±0.01b	64.11±0.60b
HA3	16.69±0.33a	194.94±4.52a	70.67±1.12b	8.28±0.12b	2.66±0.09a	1.61±0.02a	66.99±0.81a
LSD (0.05)	0.58	14.58	1.02	0.59	0.26	0.05	1.99
P-value	0.00	0.00	0.07	0.08	0.00	0.00	0.00
CV (%)	4.60	10.31	1.72	8.24	14.94	3.89	3.92

Means with the same letter did not significantly differ from each other at $p<0.05$. Abbreviations are as follows HA0 = 0, HA1 = 25 ppm, HA2 = 50 ppm, HA3 = 75 ppm of humic acid. Values are mean ± SE.

Table 4. Fruit yield and yield contributing characters of tomato at various maturity stages

Treatments	Number of fruits /cluster	Number of fruits/ plant	Days to maturity	Single fruit weight (g)	Fruit diameter (cm)	Fruit yield /plant	Fruit yield/ ha
MS1	14.75±0.25b	163.34±7.25b	65.67±0.25d	8.83±0.25a	1.91±0.13b	1.42±0.04b	59.48±1.69b
MS2	14.77±0.35b	163.92±7.68b	70.73±0.45c	8.83±0.28a	2.06±0.13b	1.43±0.05b	59.73±2.25b
MS3	15.38±0.47a	172.78±6.91ab	73.37±0.35b	8.76±0.17a	2.14±0.16ab	1.51±0.05a	62.71±1.93a
MS4	15.83±0.39a	180.60±6.05a	76.04±0.33a	8.28±0.16a	2.33±0.16a	1.49±0.03a	61.98±1.36a
LSD (0.05)	0.58	14.58	1.02	0.59	0.26	0.05	1.99
P-value	0.00	0.07	0.00	0.20	0.02	0.00	0.00
CV (%)	4.60	10.31	1.72	8.24	14.94	3.89	3.92

Means with the same letter did not significantly differ from each other at $p<0.05$. Abbreviations are as follows MS_1 = green stage, MS_2 = breaker stage, MS_3 = pink stage, MS_4 = red stage. Values are mean ± SE

Application of humic acid upto various maturity stages varied significantly in fruit of tomato. Results showed that humic acid on berry yield and yield contributing characters of tomato at various maturity stages maximum at HA_3MS_4 treatment (75 ppm humic acid at red stage) (Table 5).

Table 5. Effect of humic acid on berry yield and yield contributing characters of tomato at different maturity stages.

Treatments	Number of fruits cluster-1	Number of fruits plant-1	Days to maturity	Single fruit weight (g)	Fruit diameter (cm)	Fruit yield plant	Fruit yield ha-1
HA0MS1	13.68±0.32fg	132.17±4.13e	65.36±0.35h	8.37±0.41ab	1.60±0.10f	1.24±0.04h	51.48±1.45h
HA0MS2	13.78±0.44fg	142.37±6.46de	71.72±0.64efg	8.50±0.36bcd	1.60±0.15f	1.21±0.00h	50.23±0.22h
HA0MS3	13.33±0.33g	142.00±1.00de	74.32±0.85bcd	8.83±0.17a-d	1.57±0.18f	1.26±0.02gh	52.26±0.87gh
HA0MS4	15.67±0.33bcd	166.67±11.39cd	76.63±0.39a	8.17±0.42cd	1.67±0.07f	1.35±0.03f	56.32±1.17f
HA1MS1	14.62±0.31def	165.49±1.33cd	66.24±0.38h	8.40±0.15bcd	1.70±0.20f	1.39±0.02ef	57.91±0.98ef
HA1MS2	14.00±0.58efg	158.67±11.62cde	70.54±1.36fg	8.50±0.51bcd	1.80±0.15ef	1.34±0.03fg	55.74±1.51fg
HA1MS3	15.00±0.58b-e	169.67±3.28bcd	73.58±0.30cde	8.33±0.17abc	1.87±0.13def	1.58±0.01abc	65.94±0.34abc
HA1MS4	15.23±0.23bcd	177.80±14.03abc	76.33±0.67ab	8.33±0.33bcd	2.23±0.22cde	1.47±0.06de	61.35±2.63de
HA2MS1	15.03±0.03b-e	170.36±18.13bcd	65.71±0.33h	9.13±0.85a-d	2.00±0.31c-f	1.53±0.03cd	63.55±1.40cd
HA2MS2	15.30±0.30bcd	158.56±16.63cde	70.68±0.71fg	8.83±0.73a	2.33±0.22bcd	1.54±0.04cd	63.97±1.79cd
HA2MS3	15.80±0.42bc	178.04±7.81abc	73.23±0.62cde	8.70±0.47a-d	2.30±0.30cde	1.54±0.02cd	64.24±0.97cd
HA2MS4	14.67±0.33c-f	181.00±7.81abc	74.19±0.81ab	8.60±0.25bcd	2.47±0.24abc	1.55±0.03bcd	64.70±1.20bcd
HA3MS1	15.67±0.33bcd	185.33±7.42abc	65.37±0.87h	8.43±0.22bcd	2.33±0.20bcd	1.56±0.02bcd	64.99±0.86bcd
HA3MS2	16.00±0.58b	196.07±8.22ab	69.97±0.95g	8.47±0.26bcd	2.50±0.00abc	1.66±0.02a	68.99±0.76a
HA3MS3	17.37±0.20a	196.41±8.61a	72.35±0.68def	8.17±0.17cd	2.83±0.03ab	1.64±0.04ab	68.42±1.62ab
HA3MS4	17.74±0.63a	196.94±13.49ab	75.00±0.58abc	9.03±0.34d	2.97±0.03a	1.97±0.05abc	69.55±2.11abc
LSD (0.05)	1.16	29.17	2.04	1.19	0.52	0.09	3.98
P-value	0.01	0.85	0.93	0.39	0.83	0.00	0.00
CV (%)	4.60	10.31	1.72	8.24	14.94	3.89	3.92

Means with the same letter did not significantly differ from each other at $p<0.05$. Abbreviations are as follows HA0 = 0, HA_1 = 25 ppm, HA_2 = 50 ppm, HA_3 = 75 ppm of humic acid; MS_1 = green stage, MS_2 = breaker stage, MS_3 = pink stage, MS_4 = red stage. Values are mean ± SE.

4.4 Dry matter content

Humic acid had significant influence on the dry matter content of fruit. Highest dry matter content at control condition (Figure 1-3).

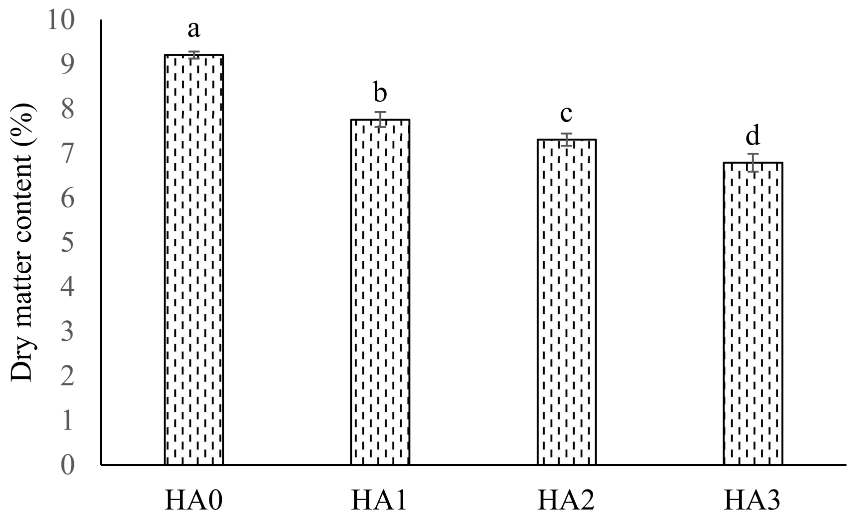

Figure 1. Effect of humic acid on dry matter content of tomato

Means with the same letter did not significantly differ from each other at p<0.05. Abbreviations are as follows HA0 = 0, HA1 = 25 ppm, HA2 = 50 ppm, HA3 = 75 ppm of humic acid. Vertical bars indicate standard errors

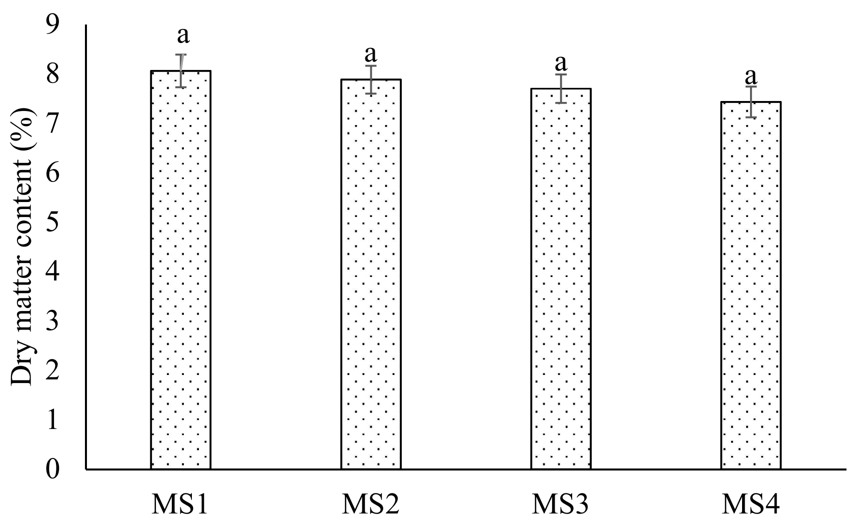

Figure 2. Dry matter content of tomato at various maturity stages

Means with the same letter did not significantly differ from each other at p<0.05. Abbreviations are as follows MS1 = green stage, MS2 = breaker stage, MS3 = pink stage, MS4 = red stage. Vertical bars indicate standard errors

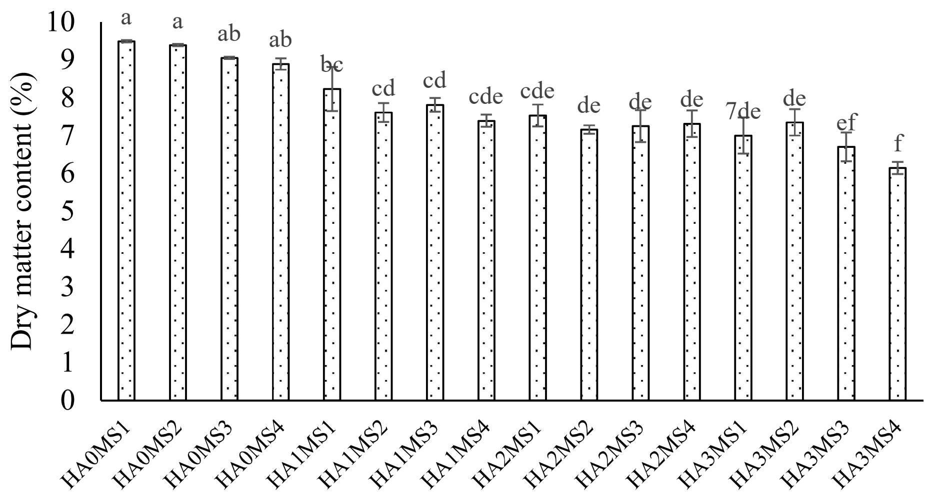

Figure 3. Effect of humic acid on dry matter content of tomato at various maturity stages.

Means with the same letter did not significantly differ from each other at $p<0.05$. Abbreviations are as follows HA0 = 0, HA1 = 25 ppm, HA2 = 50 ppm, HA3 = 75 ppm of humic acid; MS1 = green stage, MS2 = breaker stage, MS3 = pink stage, MS4 = red stage. Vertical bars indicate standard errors

4.5 Color

Table 6. Effect of humic acid on berry lightness (L*), green–red chromaticity (a*), and blue–yellow chromaticity (b*) of tomato

Treatments	L	a	b
HA_0	55.41±0.90a	-7.65±1.03a	24.33±1.10a
HA_1	54.69±0.74ab	-7.68±1.11a	25.21±0.92a
HA_2	54.05±1.48b	-7.97±1.03a	21.99±0.65b
HA_3	54.90±1.25ab	7.21±0.73a	24.43±0.96a
LSD (0.05)	1.24	1.02	2.26
P-value	0.19	0.51	0.04
CV (%)	2.73	16.08	11.34

Means with the same letter did not significantly differ from each other at $p<0.05$. Abbreviations are as follows HA0 = 0, HA1 = 25 ppm, HA2 = 50 ppm, HA3 = 75 ppm of humic acid. Values are mean ± SE.

The values were then recorded as L* (lightness; black = 0, white = 100), a*(redness > 0, greenness < 0), b*(yellowness > 0, blueness < 0) were quantified for each sample.In HA_3

treatment L* value is lower then control which indicate redness higher then control, a* value is higher then control and b* value is also higher then control which showed the best color.

Table 7. Berry lightness (L*), green–red chromaticity (a*), and blue–yellow chromaticity (b*) of tomato at various maturity stages

Treatments	L	a	b
MS_1	60.05±0.54a	-4.47±0.25c	21.51±0.61b
MS_2	55.25±0.20b	5.29±0.30c	24.39±1.16a
MS_3	52.57±0.47c	8.67±0.46b	24.60±0.81a
MS_4	51.19±0.68d	-12.07±0.50a	25.45±0.87a
LSD (0.05)	1.24	1.02	2.26
P-value	0.00	0.00	0.01
CV (%)	2.73	16.08	11.34

Means with the same letter did not significantly differ from each other at $p<0.05$. Abbreviations are as follows MS1 = green stage, MS_2 = breaker stage, MS_3 = pink stage, MS_4 = red stage. Values are mean ± SE.

Table 8. Effect of humic acid on berry lightness (L*), green–red chromaticity (a*), and yellow chromaticity (b*) of tomato at different maturity stages.

Treatments	L	a	b
HA0MS1	59.80±1.62ab	-4.94±0.88ef	23.90±1.43a-e
HA0MS2	55.43±0.29cd	-5.22±0.47ef	26.34±4.06abc
HA0MS3	53.72±0.53c-f	7.85±1.23cd	23.69±2.05b-e
HA0MS4	52.70±0.19ef	-12.60±1.36a	23.38±1.12cde
HA1MS1	58.34±0.54b	-4.25±0.43f	21.00±0.53de
HA1MS2	55.07±0.29cde	-4.10±0.39f	24.41±1.15a-e
HA1MS3	53.02±0.48def	10.11±0.48b	28.17±0.21ab
HA1MS4	52.37±0.68fg	-12.27±0.74a	27.24±1.14abc
HA2MS1	61.43±0.60a	-4.10±0.38f	20.57±0.96e
HA2MS2	54.77±0.18c-f	6.34±0.52de	21.70±1.91de
HA2MS3	50.20±0.53gh	8.23±0.58bcd	22.80±1.12cde
HA2MS4	49.80±1.81h	-13.21±0.26a	22.88±1.34cde
HA3MS1	60.64±0.68ab	-4.60±0.28ef	20.58±1.07e
HA3MS2	55.73±0.64c	5.52±0.28ef	25.11±1.57a-d
HA3MS3	53.33±0.44c-f	8.51±1.07bc	23.75±0.14b-e
HA3MS4	49.90±1.68gh	10.20±0.67b	28.29±1.12a
LSD (0.05)	2.49	2.04	4.52
P-value	0.03	0.05	0.15
CV (%)	2.73	16.08	11.34

same letter did not significantly differ from each other at $p<0.05$. Abbreviations are as follows HA0 = 0, HA1 = 25 ppm, HA2 = 50 ppm, HA3 = 75 ppm of humic acid; MS1 = green stage, MS2 = breaker stage, MS3 = pink stage, MS4 = red stage. Values are mean ± SE.

Best color found in HA_3MS_4 treatment (Table 8).

4.6 Biochemical composition in fruit of tomato

Biochemical composition in fruit of tomato varied significantly at different concentration of humic acid. Results showed that reducing sugar, beta-carotene, lycopene, TSS, pH and vitamin C are maximum in HA_3 (75 ppm humic acid) treatment (Table 9).

Biochemical composition in berry of jhumka tomato influenced significantly by various maturity stages.It was found that reducing sugar, beta-carotene, TSS, pH and vitamin C increased with the advancement of maturity of fruit (Table 10). The highest value was observed in red stage of maturity.

The combined effect of humic acid at various stages of maturity found significant (Table 11). The highest reducing sugar, beta-carotene, TSS, pH and vitamin C content were recorded in HA_3MS_4 (75ppm humic acid with red stage).

Table 9. Biochemical composition in fruit of tomato under the effect of humic acid.

Treatments	Reducing sugar	Non-reducing sugar	Beta-carotene	Lycopene	TSS	pH	Vitamin C
HA0	0.84±0.01c	1.23±0.01a	15.33±0.42d	0.14±0.01c	5.38±0.08c	3.91±0.02c	23.22±0.60d
HA1	0.88±0.01bc	1.25±0.02a	17.08±0.50c	0.21±0.01b	5.46±0.07bc	3.97±0.02b	28.68±1.80c
HA2	0.92±0.01b	1.23±0.02a	19.20±0.46b	0.22±0.01ab	5.51±0.08b	3.95±0.02bc	35.92±0.77b
HA3	1.22±0.06a	1.07±0.04b	23.27±1.10a	0.24±0.01a	5.86±0.07a	4.01±0.01a	40.95±0.93a
LSD (0.05)	0.07	0.08	0.59	0.03	0.09		0.94
P-value	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CV (%)	8.22	7.70	3.82	15.11	1.92	1.16	3.52

Means with the same letter did not significantly differ from each other at $p<0.05$. Abbreviations are as follows HA0 = 0, HA1 = 25 ppm, HA2 = 50 ppm, HA3 = 75 ppm of humic acid. Values are mean ± SE.

Table 10. Biochemical composition in fruit of tomato influenced by different maturity stages.

Treatments	Reducing sugar	Non-reducing sugar	Beta-carotene	Lycopene	TSS	pH	Vitamin C
MS1	0.90±0.02b	1.16±0.02a	16.94±0.56d	0.20±0.02a	5.31±0.07d	3.92±0.02c	28.59±1.91c
MS2	0.98±0.07a	1.17±0.05a	18.12±0.98c	0.21±0.02a	5.45±0.06c	3.9±0.01bc	31.42±2.60b
MS3	0.96±0.04ab	1.22±0.01a	19.43±1.24b	0.19±0.01a	5.55±0.08b	3.97±0.01a	32.14±2.03b
MS4	1.02±0.07a	1.23±0.04a	20.40±1.27a	0.20±0.01a	5.90±0.05a	4.01±0.02a	36.62±2.04a
LSD (0.05)	0.07	0.08	0.59	0.03	0.09	0.04	0.94
P-value	0.01	0.17	0.00	0.50	0.00	0.00	0.00
CV (%)	8.22	7.70	3.82	15.11	1.92	1.16	3.52

Means with the same letter did not significantly differ from each other at $p<0.05$. Abbreviations are as follows MS_1 = green stage, MS_2 = breaker stage, MS_3 = pink stage, MS_4 = red stage. Values are mean ± SE.

Table 11. Biochemical composition in fruit of tomato under the effect of humic acid at different maturity stages.

Treatments	Reducing sugar	Non-reducing sugar	Beta-carotene	Lycopene	TSS	pH	Vitamin C
HA0MS1	0.84±0.00d	1.18±0.01abc	13.90±0.36j	0.11±0.00d	5.17±0.04j	3.85±0.02e	22.90±0.51h
HA0MS2	0.83±0.00d	1.25±0.02ab	15.56±0.70i	0.12±0.01d	5.18±0.02j	3.89±0.01de	20.58±0.28i
HA0MS3	0.85±0.00d	1.23±0.01abc	14.58±0.04ij	0.16±0.01cd	5.40±0.06ghi	3.95±0.02cd	23.68±0.66h
HA0MS4	0.86±0.01d	1.24±0.02abc	17.28±0.36gh	0.16±0.01cd	5.77±0.07bcd	3.95±0.04cd	25.72±0.65g
HA1MS1	0.87±0.02d	1.21±0.02abc	18.32±0.32fg	0.23±0.02ab	5.27±0.03ij	3.93±0.02cd	22.16±1.17hi
HA1MS2	0.86±0.01d	1.20±0.04abc	14.63±0.42ij	0.22±0.02ab	5.43±0.07ghi	3.95±0.02cd	26.86±0.91fg
HA1MS3	0.90±0.03cd	1.25±0.03abc	16.84±0.41h	0.15±0.03cd	5.30±0.06hij	3.97±0.02bc	27.62±1.10f
HA1MS4	0.89±0.01cd	1.33±0.01a	18.54±0.43f	0.22±0.01ab	5.83±0.03bc	4.03±0.04ab	38.08±0.31bc
HA2MS1	0.90±0.01cd	1.14±0.04b-e	17.61±0.60fgh	0.24±0.01a	5.17±0.12j	3.93±0.06cd	32.54±0.28e
HA2MS2	0.92±0.03cd	1.24±0.05abc	19.85±0.35e	0.24±0.01a	5.47±0.12fgh	3.92±0.01cde	34.79±1.05d
HA2MS3	0.93±0.02cd	1.25±0.01ab	21.15±0.17d	0.22±0.01ab	5.57±0.03efg	3.95±0.02cd	37.89±0.46bc
HA2MS4	0.93±0.02cd	1.31±0.03a	18.20±0.40fg	0.18±0.01bc	5.83±0.03bc	3.99±0.03bc	38.48±0.30bc
HA3MS1	1.00±0.03c	1.10±0.09cde	17.93±0.30fgh	0.23±0.02ab	5.63±0.09def	3.96±0.02bcd	36.77±0.62c
HA3MS2	1.31±0.16a	0.99±0.16e	22.42±0.22c	0.24±0.02a	5.70±0.00cde	3.98±0.01bc	43.45±0.21a
HA3MS3	1.16±0.04b	1.16±0.03bcd	25.16±0.65b	0.23±0.02ab	5.93±0.03b	4.03±0.01ab	39.38±0.31b
HA3MS4	1.39±0.05a	1.02±0.04de	27.58±0.37a	0.25±0.04a	6.17±0.03a	4.07±0.01a	44.20±0.37a
CV (%)	8.22	7.70	3.82	15.11	1.92	1.16	3.52

4.7 Nutritional status of tomato

Significant variation among the tomato fruits of different concentration of humic acid were recorded in respect of nutrient balance of the fruit pulp. It estimated that calcium (Ca), magnesium (Mg), potassium (K), phosphorus (P) and iron (F) were increased with the advancement of humic acid. The highest value found at HA_3 (75 ppm humic acid) (Table 12).

Table 12. Nutritional status in fruit of tomato under the effect of humic acid.

Treatments	Ca	Mg	K	P	Fe
HA_0	1.94±0.04c	1.08±0.12c	1.27±0.04d	0.33±0.01d	127.50±1.88d
HA_1	2.06±0.10bc	0.93±0.06d	1.64±0.04c	0.39±0.01c	140.50±1.63c
HA_2	2.17±0.09b	1.93±0.05b	1.83±0.02b	0.50±0.02b	162.76±3.04b
HA_3	2.79±0.05a	2.29±0.03a	2.31±0.04a	0.65±0.01a	189.47±4.98a
LSD (0.05)	0.20	0.12	0.09	0.02	5.96
P-value	0.00	0.00	0.00	0.00	0.00
CV (%)	10.88	9.15	5.88	4.37	4.62

Means with the same letter did not significantly differ from each other at $p<0.05$. Abbreviations are as follows HA_0 = 0, HA_1 = 25 ppm, HA_2 = 50 ppm, HA_3 = 75 ppm of humic acid. Values are mean ± SE.

Significant variations among different maturity stages of tomato fruits were recorded in respect of nutritional status of the tomato pulp. Tomatoes of all stages of maturity were found to increase in quantity of calcium (Ca), magnesium (Mg), potassium (K), phosphorus (P) and iron (F) at MS_4 (red stage) (Table 13).

Table 13. Nutritional status of tomato influenced by maturity stages.

Treatments	Ca	Mg	K	P	Fe
MS_1	2.27±0.12a	1.46±0.20bc	1.66±0.11c	0.44±0.03c	146.37±6.51c
MS_2	2.13±0.09a	1.39±0.18c	1.73±0.12bc	0.45±0.03c	151.35±6.59bc
MS_3	2.27±0.13a	1.56±0.19b	1.79±0.12b	0.48±0.04b	156.04±6.84b
MS_4	2.29±0.15a	1.82±0.16a	1.88±0.11a	0.52±0.04a	166.47±9.43a
LSD (0.05)	0.20	0.12	0.09	0.02	5.96
P-value	0.34	0.00	0.00	0.00	0.00
CV (%)	10.88	9.15	5.88	4.37	4.62

Means with the same letter did not significantly differ from each other at $p<0.05$. Abbreviations are as follows MS_1 = green stage, MS_2 = breaker stage, MS_3 = pink stage, MS_4 = red stage. Values are mean ± SE.

There was a significant interaction between humic acid and maturity stages in respect of nutrient balance of fruit pulp. Result showed that the 75 ppm humic acid at red stage tomatoes contained the maximum nutrient balance while it was minimum in control condition at green stage (Table 14).

Table 14. Nutritional status in fruit of tomato under the effect of humic acid at various maturity stages.

Treatments	Ca	Mg	K	P	Fe
HA_0MS_1	1.83±0.03d	0.79±0.06h	1.15±0.01h	0.31±0.01i	119.61±0.97k
HA_0MS_2	1.96±0.05d	0.84±0.01gh	1.26±0.08gh	0.33±0.01hi	125.93±0.73jk
HA_0MS_3	1.88±0.04d	0.93±0.07gh	1.27±0.09gh	0.34±0.01hi	129.08±1.80ijk
HA_0MS_4	2.08±0.10d	1.74±0.14ef	1.41±0.08fg	0.36±0.00gh	135.39±2.84hij
HA_1MS_1	2.07±0.04d	0.83±0.09gh	1.54±0.00ef	0.38±0.01fg	136.69±3.04hij
HA_1MS_2	2.00±0.11d	0.86±0.18gh	1.56±0.10ef	0.38±0.01fg	138.96±3.33hi
HA_1MS_3	2.23±0.04cd	0.98±0.08gh	1.70±0.04de	0.40±0.01ef	142.32±4.09gh
HA_1MS_4	1.94±0.42d	1.05±0.11g	1.77±0.04cd	0.43±0.01e	144.01±2.27gh
HA_2MS_1	2.50±0.28bc	1.94±0.03de	1.78±0.02cd	0.45±0.02d	152.44±4.40fg
HA_2MS_2	1.96±0.06d	1.70±0.12f	1.81±0.04cd	0.46±0.01d	158.76±5.61ef
HA_2MS_3	2.01±0.05d	1.99±0.01cd	1.85±0.02cd	0.54±0.02c	166.90±3.14de
HA_2MS_4	2.22±0.03cd	2.11±0.06bcd	1.89±0.01c	0.56±0.02c	172.95±4.57cd
HA_3MS_1	2.70±0.12ab	2.26±0.03ab	2.16±0.13b	0.61±0.01b	176.74±4.32bcd
HA_3MS_2	2.59±0.04abc	2.19±0.05abc	2.29±0.07ab	0.63±0.00b	181.74±4.89bc
HA_3MS_3	2.95±0.03a	2.33±0.01ab	2.35±0.04a	0.64±0.01b	185.86±6.18b
HA_3MS_4	2.96±0.06a	2.39±0.01a	2.44±0.01a	0.71±0.01a	213.54±7.53a
LSD (0.05)	0.41	0.24	0.17	0.03	11.92
P-value	0.16	0.00	0.88	0.02	0.05
CV (%)	10.88	9.15	5.88	4.37	4.62

Means with the same letter did not significantly differ from each other at $p<0.05$. Abbreviations are as follows HA_0 = 0, HA_1 = 25 ppm, HA_2 = 50 ppm, HA_3 = 75 ppm of humic acid; MS_1 = green stage, MS_2 = breaker stage, MS_3 = pink stage, MS_4 = red stage. Values are mean ± SE.

CHAPTER V

SUMMARY AND CONCLUSION

The field experiment was conducted at Sher-e-Bangla Agricultural University Farm, Dhaka, Bangladesh during October 2019 to April 2020 to find the response of humic acid and maturity stages on growth, yield and nutritional quality of tomato. Four different doses of humic acid, viz., HA_0= 0 ppm, HA_1= 25ppm, HA_2= 50ppm, HA_3= 75 ppm and four stages of maturity viz. MS_1= Green Stage, MS_2= Breaker Stage, MS_3= Pink Stage, MS_4= Red Stage were used to conduct this experiment. The experiment was laid out in Randomized Complete Block Design (RCBD) having two factors and replicated three times. Data were taken on growth; yield contributing characters, yield and the collected data were statistically analyzed for evaluating of the treatment effects. The summary of the results has been described in this chapter.

The effect of humic acid was significant on plant height at 25, 50 and 75 day after transplanting (DAT). The tallest plant (90.38, 111.08, and 147.67cm at 25, 50 and 75 DAT, respectively) was produced by HA_3 (75 ppm humic acid). The maximum number of flower cluster per plant (11.70) was produced by HA_3 treatment. The humic acid showed significant variation in the number of flower per cluster. The maximum number of flower per cluster (23.70) was produced by HA_3 treatment. The maximum number of flowers per plant (305.78), and maximum number of fruit per plant (194.94) was produced by HA_3 treatment. The highest fruit diameter (2.66 cm) was produced by HA_3. The earliest fruit maturity obtain (70.67 DAT) at HA_3 treatment.The largest individual fruit weight (9.07 g) was produced by HA_2. The humic acid had significant effect on the yield of fruits per plant. The maximum yield of fruits per plant (1.61 kg) was produced by HA_3 treatment. The different humic acid had significant effect on the yield of fruits per hectare. The maximum yield of fruits per hectare (66.99 tones) was obtained HA_3 (75 ppm) treatment and the minimum yield of fruits per hectare (52.57 tones) was obtained from HA_0 treatment.

Colour of tomato was influenced by humic acid. The best color of fruit (lightness L*, green-red chromaticity a*and blue-yellow chromaticity b* were 54.90, 7.21 and 24.43 respectively) found at HA_3 treatment.

Biochemical composition in tomato fruit was influenced by humic acid. The highest total soluable solid percentage in tomato (5.86) was obtained from HA_3. The highest reducing sugar percentage in tomato (1.22) was obtained from HA_3 treatment. The highest non reducing sugar percentage in tomato (1.25) was obtained from HA_1 treatment. The highest pH in tomato (4.01) was obtained from HA_3 treatment. The humic acid show significant variation in case of vit C content in tomato fruit which is examined by sampling it in proper way. The higher amount vit C (40.95 mg/100 g) found in HA_3 treatment. The highest amount of lycopene content in fruit (0.24 mg/100 g) found in HA_3. The higher amount of Beta-carotene content in fruit (23.27 mg/100 g) found in HA_3.

Nutrient balance in berry of jhumka tomato was influenced by humic acid. The highest calcium, magnesium, potassium and phosphorus percentage in tomato (2.79, 2.29, 2.31 and 0.65 respectively) was obtained from HA_3 treatment. The highest iron contain in tomato (189.47 ppm) was obtained from HA_3 treatment.

The maximum number of fruits per plant (180.60) was produced by MS_4 treatment. The highest fruit diameter (2.33 cm) was produced by MS_4.The largest individual fruit weight (8.83 g) was produced by MS_2(breaker stage). The maturity stages had significant effect on the yield of fruits per plant. The maximum yield of fruits per plant (1.51 kg) was produced by MS_4(red stage) treatment. The different maturity stages had significant effect on the yield of fruits per hectare. The maximum yield of fruits per hectare (62.71 tones) was obtained MS_4 treatment and the minimum yield of fruits per hectare (59.48 tones) was obtained from MS_1 treatment.

Color of tomato was influenced by maturity stages. The best color of berry (lightness L*, green-red chromaticity a*and blue-yellow chromaticity b* were 51.19, 12.07 and 25.45 respectively) found at MS_4 treatment.

Biochemical composition in tomato fruit was influenced by maturity stages. The highest total soluable salt percentage in tomato (5.90) was obtained from MS_4. The highest reducing sugar percentage in tomato (1.02) was obtained from MS_4 treatment. The highest non reducing sugar percentage in tomato (1.23) was obtained from MS_4 treatment. The highest pH in tomato (4.01) was obtained from MS_4treatment. The maturity stages show significant variation in case of vit C content in tomato fruit which is examined by sampling it in proper way. The higher amount vit C (36.62 mg/100 g) found in MS_4 treatment. The higher amount of lycopene content in fruit (0.21 mg/100 g) found in MS_2(breaker stage). The higher amount of Beta-carotene content in fruit (20.40 mg/100 g) found in MS_4.

Nutrient content in tomato was influenced by maturity stages.The highest calcium, magnesium, potassium and phosphorus percentage in tomato (2.29, 1.82, 1.88 and 0.52

respectively) was obtained from MS_4 treatment. The highest iron contain in tomato (166.47 ppm) was obtained from MS_4 treatment.

The effect of different doses of humic acid and various maturity stages indicated a significant variation in all parameter. The maximum number of fruits per plant (201.41) was produced by HA_3MS_3(75 ppm humic acid with pink stage) treatment. The highest fruit diameter (2.97 cm) was produced by HA_3MS_4.The largest individual fruit weight (9.37 g) was produced by HA_0MS_1 (0 ppm humic acid with green stage). The maximum yield of fruits per plant (1.66 kg) was produced by HA_3MS_2 (75 ppm humic acid with breaker stage) treatment. The maximum yield of fruits per hectare (68.99 tones) was obtained HA_3MS_4(75 ppm humic acid with red stage) treatment and the minimum yield of fruits per hectare (50.23 tones) was obtained from HA_0MS_2 (0 ppm humic acid with breaker stage) treatment.

The highest total soluable salt percentage in tomato (6.17) was obtained from HA_3MS_4. The highest reducing sugar percentage in tomato (1.39) was obtained from HA_3MS_4 treatment. The highest non reducing sugar percentage in tomato (1.33) was obtained from HA_1MS_4 (25 ppm humic acid with red stage) treatment. The highest pH in tomato (4.07) was obtained from HA_3MS_4 treatment. The higher amount vit C (44.20 mg/100 g) found in HA_3MS_4 treatment. The higher amount of lycopene content in fruit (0.25 mg/100 g) found in HA_3MS_2. The higher amount of Beta-carotene content in fruit (27.58 mg/100 g) found in HA_3MS_4.

The highest calcium, magnesium, potassium and phosphorus percentage in tomato (2.94, 2.39, 2.44 and 0.71 respectively) was obtained from HA_3MS_4 treatment. The highest iron contain in tomato (213.54 ppm) was obtained from HA_3MS_4 treatment.

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

Conclusion and suggestions-

From the above discussion, it may be concluded that-

- In the experiment humic acid effect at different maturity stages gave a better performance for growth and yield.
- During the investigation, the treatment combination (HA_3MS_4) of 75 ppm humic acid with red stage was the best due to the highest gross yield.

- Considering the findings of the experiment, further studies might be conducted for confirming the results.

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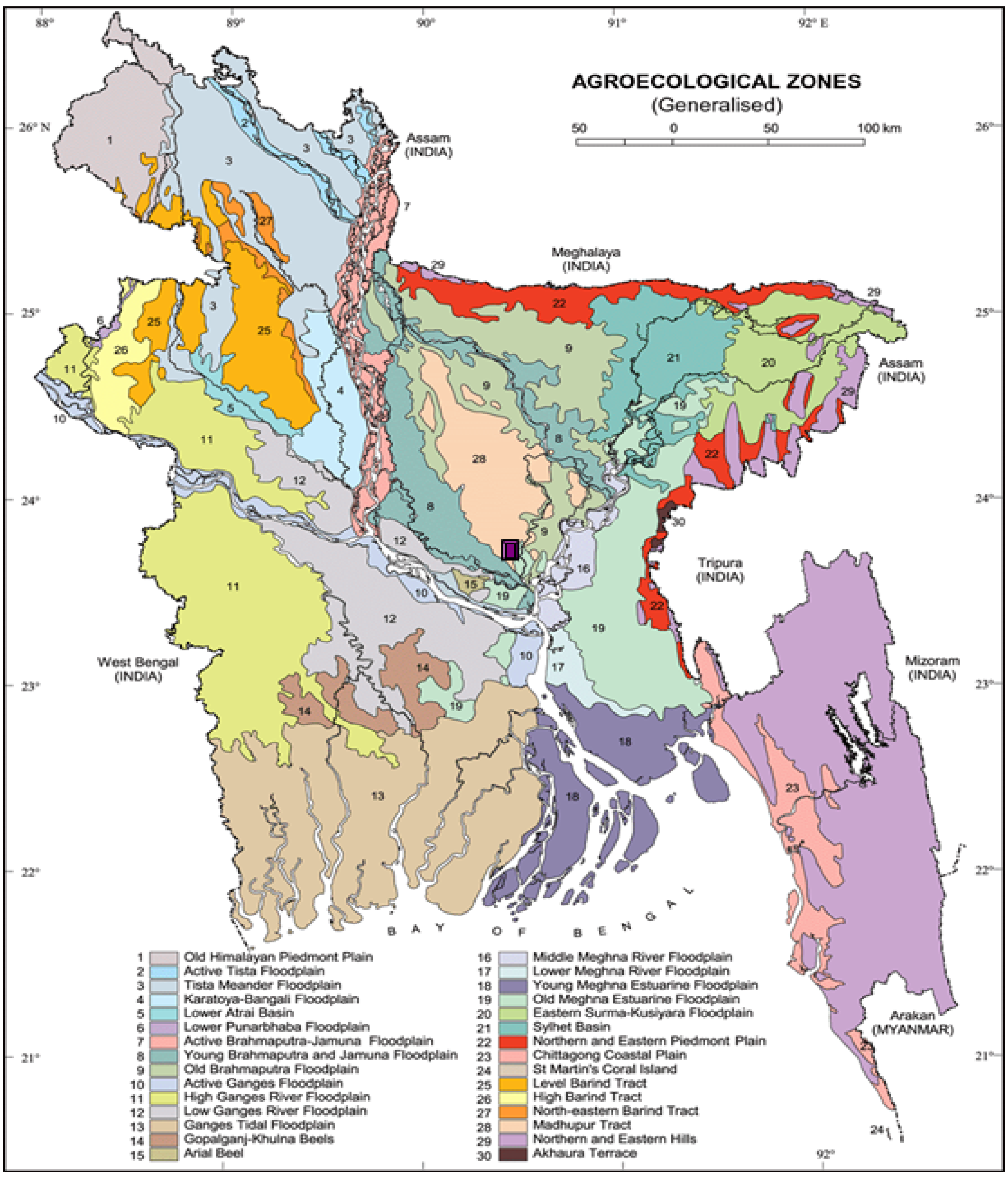
APPENDICES

Appendix i. Map showing 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 2019 to March 2020

Year	Month	Average Air temperature (^0C)			Total rainfall (mm)	Average RH (%)	Total Sun shine hours
		Maximum	Minimum	Mean			
2019	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
2020	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: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1212

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

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

Appendix iv: Analysis of variance on data with the humic acid at various maturity stages on yield and yield contributing characters of tomato

Source of variation	Degrees of freedom	Mean square of				
		Number Fruit per plant	Fruit diameter (cm)	Individual fruit weight (g)	Yield per plant (kg)	Total yield per hectare (ton)
Factor A	3	4863.07**	2.49 **	1.265*	0.268**	468.744**
Factor B	3	805.73*	0.376**	0.8316ns	0.0180**	31.219**
AB	9	158.08*	0.055ns	0.560ns	0.0119**	20.58**
Error	32	307.54	0.099	0.510	0.003	5.714

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

Appendix v: Analysis of variance on data with the humic acid at various maturity stages on color of fruits, total soluble solid, and pH of tomato

Source of variation	Degrees of freedom	Mean square of				
		Color			Total soluble solid	pH
		l*	a*	b*		
Factor A	3	3.8ns	1.193ns	23.21*	0.536**	0.020**
Factor B	3	183.14**	144.8**	35.16**	0.7644**	0.021**
AB	9	5.64*	3.300*	11.95ns	0.025*	0.0007ns
Error	32	2.234	1.505	7.39	0.01138	0.01138

**: 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 on dry matter content and sugar content on fruit of tomato at various maturity stage

Source of variation	Degrees of freedom	Dry matter Content (%)	Reducing sugar percentage on fruit	Non-reducing sugar percentage on fruit
Factor A	3	12.85**	0.352**	0.086**
Factor B	3	0.865*	0.0288**	0.0148ns
AB	9	0.206ns	0.020**	0.010ns
Error	32	0.261	0.006	0.008

**: 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 on vit-C and lycopene content on fruit of tomato at various maturity stages

Source of variation	Degrees of freedom	Mean square of		
		Vitamin C contnent (mg/100g)	Lycopene content (mg/100g)	B-carotine content(mg/100g)
Factor A	3	0.849*	9**	140.467**
Factor B	3	2.476**	0.037**	27.448**
AB	9	3.539**	0.028**	15.964**
Error	32	0.207	0.003	0.512

**: 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 on nutrient balance in berry of jhumka tomato at various maturity stages

Source of variation	Degrees of freedom	Mean square of				
		Calcium (Ca)	Magnesium (Mg)	Potassium (K)	Phosphorus (P)	Iron (Fe)
Factor A	3	1.74633**	5.20437**	2.24268**	0.22647**	8859.63**
Factor B	3	0.06934ns	0.42357**	0.10283**	0.01445**	881.93**
AB	9	0.09502*	0.10614**	0.00513ns	0.00112*	112.53**
Error	32	0.05940	0.02034	0.01078	0.00042	51.40

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

Appendix ix: Pictorial view of research work

Plate 1. Seed bed preparation

Plate 2. Germinated seedlings on seedbed

Plate 3. Land preparation for transplanting

Plate 4. Transplanted seedlings on experimental plot

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Plate 5. Vegetative stage of tomato plant

Plate6. 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

Appendix x: Pictorial view of harvested tomato with different treatment

Plate 9. Pictorial view of harvested tomato with different treatment

In picture H_0R_1: HA_0MS_1 (control at green stage), H_0R_2: HA_0MS_2 (control at beakers stage), H_0R_3: HA_0MS_3 (control at pink stage), H_0R_4: HA_0MS_4 (control at red stage), H_1R_1: HA_1MS_1(25 ppm humic acid at green stage), H_1R_2: HA_1MS_2 (25 ppm humic acid at beakers stage), H_1R_3: HA_1MS_3 (25 ppm humic acid at pink stage), H_1R_4: HA_1MS_4 (25 pppm humic acid at red stage), H_2R_1: HA_2MS_1 (50 ppm humic acid at green stage), H_2R_2: HA_2MS_2 (50 ppm humic acid at beakers stage), H_2R_3: HA_2MS_3 (50 ppm humic acid at pink stage), H_2R_4: HA_2MS_4 (50 ppm humic acid at red stage), H_3R_1: HA_3MS_1 (75 ppm humic acid at green stage), H_3R_2: HA_3MS_2 (75 ppm humic acid at beakers stage), H_3R_3: HA_3MS_3 (75 ppm humic acid at pink stage), H_3R_4: HA_3MS_4 (75 ppm humic acid at red stage).

Plate 10. Pictorial view of harvested tomato