EFFECT OF SALT WATER ON GROWTH, YIELD, AND QUALITY OF HYDROPONICALLY GROWN TOMATO

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CERTIFICATE

*This is to certify that thesis entitled, "**EFFECT OF SALT WATER ON GROWTH, YIELD, AND QUALITY OF HYDROPONICALLY GROWN TOMATO**" 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 (MS) in HORTICULTURE**, embodies the result of a piece of bonafide research work carried out by **Md. Mamunur Rashid**, **Registration no. 19-10171** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dated:
Place: Dhaka, Bangladesh

Dr. Md. Jahedur Rahman
Professor
Supervisor

Dedicated to

My

Beloved Parents

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The Author

EFFECT OF SALT WATER ON GROWTH, YIELD, AND QUALITY OF HYDROPONICALLY GROWN TOMATO

ABSTRACT

Tomatoes grow faster in hydroponics than they do in soil. Therefore a pot experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka during the period from September-2019 to February-2020, to investigate the effect of salt water on growth, yield, and quality of hydroponically grown tomatoes. The experiment consisted of two factors, and followed completely randomized design (CRD) with three replications. Factor A: Tomato variety denoted as V: V_1 = BARI tomato-8, V_2 = BARI tomato-9, V_3 = BARI tomato-10, and Factor B: Salt water denoted as S: S_0 = 0 ml L^{-1} + standard solution, S_1 = 0.5 ml L^{-1} + standard solution, S_2 = 0.75 ml L^{-1} + standard solution and S_3 = 1 ml L^{-1} + standard solution. Experimental result revealed that in among different varieties, cultivation of BARI tomato-8 (V_1) in hydroponic system, had the highest number of flower clusters plant^{-1} (13.17), fruits cluster plant^{-1} (4.51), fruits plant^{-1} (50.00), fruit polar length (3.90 cm), fruit radial length (3.68 cm), individual fruit fresh weight (45.64 g), fruit dry weight (2.59 g) yield plant^{-1} (4.13 kg), volume (195.0 cc) and pH value (4.41). In case of different concentration of salt water application the highest yield plant^{-1} (4.19 kg) was recorded in S_0 (0 NaCl ml L^{-1} + standard solution) treatment. In case of combination, BARI tomato-8 (V_1) along with (S_0) no salt water application (0 NaCl ml L^{-1} + standard solution) affected plant growth, yield and quality parameters, leading to the maximum plant yield (4.33 kg) than compared to other treatment combination. Therefore, it was concluded that the BARI toamto-8 variety in conjunction with non-salt water concentrations outperformed other treatment combinations for achieving higher yield and quality tomato production in a hydroponic cultivation system.

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ABBREVIATIONS

Full word	Abbreviations
Agriculture	Agr.
Agro-Ecological Zone	AEZ
Bangladesh Bureau of Statistics	BBS
Biology	Biol.
Biotechnology	Biotechnol.
Botany	Bot.
Cultivar	Cv.
Dry weight	DW
Editors	Eds.
Emulsifiable concentrate	EC
Entomology	Entomol.
Environments	Environ.
Food and Agriculture Organization	FAO
Fresh weight	FW
International	Intl.
Journal	J.
Least Significant Difference	LSD
Liter	L
Triple super phosphate	TSP
Science	Sci.
Soil Resource Development Institute	SRDI
Technology	Technol.
Serial	Sl.

CHAPTER I

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) belongs to the family Solanaceae and is normally a self-pollinated annual crop. Tomato is a universally known vegetable and is one of the widest grown vegetables in the world and ranked third in respect of vegetable production in the world next to potato and sweet potato (Yasmin *et al*., 2022). According to Guan *et al.* (2018), FAO (2017) claimed to produced 170 million tons fresh and processed tomato globally in 2014. Among the vegetables tomato is important for vitamin A, C and minerals (Bhowmik *et al*., 2012). Nutritive elements are almost double compared to apple which proved superiority in regard to food values (Ibrahim *et al*., 2017). Due to its phytonutrients mainly antioxidant elements such as lycopene and β carotene, it prevents cancer and many human diseases (Islam *et al*., 2021). It occupies an area of 0.15 million hectares with annual production of about 0.45 million tons in Bangladesh (BBS, 2021). Although the total cultivated area and production of tomato in our country have been increased gradually over the last few years, the productivity is still very low (9.4 t/ha) compared to the average yield (26.29 t ha^{-1}) of the world (Mazed *et al*., 2015).

The use of improved varieties, proper management, high-quality seed, knowledge of improved production technologies like hydroponics, and even conventional breeding techniques, which may increase production level and quality under the current environmental conditions, are just a few of the factors that affect tomato production. The cultivation of hybrid tomato varieties has grown significantly around the world and offers numerous benefits over open pollinated species. There are many tomato cultivars with great yield potential and extended harvest times that have been released by BARI and other seed companies (Yasmin, *et al*., 2022).

Hydroponic is a modern technology in Bangladesh to cultivate leafy vegetables (Alam, 2022). Hydroponic tomato are grown in a nutrient solution rather than soil, although they are typically placed in a non soil material that can support their roots and hold the nutrients. Growing tomatoes hydroponically allows the grower to raise them in a controlled environment with less changes of disease, faster growth and greater fruit yield

(Cardoso *et al*., 2018). Although tomato can grow under a wide range of climatic conditions, but sensitive to a number of environmental stresses, especially extreme temperature, drought, salinity and inadequate moisture stresses (Krishna *et al.,* 2019).

The salinized areas are increasing at an annual rate of 10% for various reasons (Gorji *et al*., 2020) and more than 50% of the arable land would be salinized by the year 2050 (Shrivastava and Kumar, 2015). The area under saline land in the coastal belt of Bangladesh is also increasing day by day and is being affected with varying levels of salinity ranging from 3.63-27.67 dS m^{-1}. Shrivastava and Kumar (2015) also reported that the productivity of most crops is significantly reduced by soil salinity when the value of electric conductivity approaches 4.0 dS m^{-1}. About 58.5% of the cultivated land of the coastal and offshore regions of Bangladesh is affected above this threshold level of salinity 4.01- >16 dS m^{-1}.

In the short term, salinity stress causes osmotic stress due to a decrease in water availability, and in the long term, ion toxicity due to an imbalance of cytosol nutrients (Sheteiwy *et al*., 2019). A high concentration of exogenous salt causes an ionic imbalance in the cells which leads to ion toxicity and osmotic stress (Chakraborty *et al*., 2018), nutrient imbalances, membrane damage, and reduced photosynthetic activities (Chourasia *et al*., 2021), and alteration of NO_3^- uptake by plants, which affect plant growth and yield (Yasuor *et al*., 2017).

Tomato is moderately sensitive to salinity (Zushi and Matsuzoe, 2017), and cannot endure or tolerate with very low yields. Salinity level above 3-5.5 dS m^{-1} markedly reduces leaf area index, total chlorophyll and also reduces tomato yield by 12-32% (Zhai *et al*., 2015). Salt stress influences a series of major physiological processes such as photosynthesis, ion partitioning as well as Na^+: K^+ ratio, Reactive Oxygen Species (ROS), and hydraulic conductivity which affects the bioenergetic processes of the electron transport chain (Almeida *et al*., 2017). Furthermore, salt stress seems to affect root anatomy and morphology parameters (Robin *et al.*, 2016). Earlier researchers investigated the response of salinity on different vegetables (Raza *et al*., 2017), where they observed stressed plants with significantly reduced the biomass, leaf area, and growth. Root and shoot weight, taproot length, chlorophyll content, and transpiration rate are some of the morph-physiological traits that can be employed to develop salt-tolerant cultivars (Taibi *et al.*, 2016).

Although many previous studies have reported the effect of salt water and high temperature on tomato yield and quality, little information is available on the precise interaction between them on tomato growth in hydroponic system. Therefore, this study aimed to investigate the following objectives-

i. To identify the effect of salt water on growth and quality of tomato
ii. To investigate the growth, yield and quality of different varieties of tomato growing in hydroponic system with various salt water content.

CHAPTER II

REVIEW OF LITERATURE

In order to gather information useful for carrying out the current study, an effort was made to compile and research pertinent material about the investigation of the effect of salt water on growth, yield, and quality of hydroponically grown tomato.

2.1 Effect of variety

Shah *et al*. (2021) carried out a study to know the performance of tomato cultivars transplanted on various dates under the agro-climatic conditions of district Buner and reported that among different cultivars Anna resulted in tallest plant (258.37 cm), more branches plant^{-1} (41.73), fruits plant^{-1} (80.58), fruit weight (133.43 g), fruit diameter (5.00 cm), yield (95.16 tons ha^{-1}), lowest fruit drop (4.87 %) and disease incidence (2.30 %).

Hoque *at el.* (2020) reported that the combination of organic and inorganic fertilizers has a substantial impact on tomato growth and yield. The results indicated that the variety BARI-2 (Ratan) showed superior performance than BARI-15 tomato varieties on different fertilizer combination regarding growth and yield of tomato.

Sanjida *et al*. (2020) conducted a field research to examine the effect of different levels of boron (B) on physico-chemical quality of different summer tomato (*Lycopersicon esculentum* Mill.). Experimental results showed that the longest fruit length (41.87 mm) and maximum fruit width (48.0 mm) were recorded from V_2 (BARI hybrid tomato 8) while the shortest fruit length (33.07 mm) and minimum fruit width (34.60 mm) were observed from V_3(BARI hybrid tomato 10) variety. The marked differences in fruit length and fruit width might be due to the different genetic makeup of the summer tomato varieties. Significant variations ($p<0.05$) were observed in case of total soluble solids (TSS) and pH content of summer tomato varieties. The highest TSS (5.41%) was found from V_2 (BARI hybrid tomato 8) which was statistically similar with V_3 (BARI hybrid tomato 10) (5.23%) while the lowest TSS (4.97%) was obtained from V_1 (BARI hybrid tomato 4). The highest (3.88) and lowest (3.71) pH were found from V_3 (BARI hybrid tomato 10) and V_1 (BARI hybrid tomato 4), respectively. Varietal character might influence the variations of TSS and pH in summer tomato.

Das *et al.* (2019) reported that height of a plant is determined by genetical character and under a given set of environment different variety will acquire their height according to their genetic makeup.

Prakash *et al.* (2019) performed an experiment with twenty six genotypes of tomato and revealed that the genotype TOINDVAR-3 (4.91) recorded highest mean performance for fruit yield per plant, while, genotype TOINDVAR-5 showed lowest fruit yield.

Devkota *et al.* (2018) studied hybrid genotypes of tomato for fruit yield and fruit quality traits and revealed that the hybrids HRA-14× HRD-7, HRA-13× HRD-7, HRA-20× HRD-1 and HRA-20× HRD-6 were high yielder and with good quality as compared to check variety Srijana.

Rajolli *et al.* (2018) conducted an experiment to evaluate performance of eighteen genotypes of tomato at Bhubaneshwar during rabi season of 2017-18. The overall performance on vegetative parameters of eighteen diverse determinate tomato genotypes indicated superiority of 2016/TODVAR-12 and Pusa 120 as compared to other tested genotypes.

Kerketta *et al.* (2018) studied performance of twenty diverse genotypes of tomato for growth, yield and quality traits at Allahabad during Rabi season of 2015-16. On the basis of present research study they concluded that the genotype Arka Abha (165.66cm) is the highest the plant height, days to first flower open (29.15) and flower per cluster (9.66), lycopene (4.23mg/100gm), shelf life (5.66 days) in Kashi Sharad. The heighest fruit set per cluster (5.33), number of fruits per plant (87.50), fruit index (1.43), TSS (7.61^0Brix) in Pusa Cherry and the average weight of fruit (84.50gm), fruit yield per plant (4 kg) in genotype Kashi Aman.

Kiran *et al.* (2018) investigated twenty two genotypes of tomato for yield and quality attributes at Horticultural Research Farm, IGKV, Raipur (CG) during 2016-17. On the basis of the investigation they revealed that genotype 2014/TOLCVRES-3 was recorded maximum values for the traits number of flowers per cluster, pericarp thickness, number of fruits per cluster and TSS. The variety H-86 recorded as a high yielding variety with 4.06 kg per plant fruit yield, 659.72 quintal per hectare total yield, 107.33 g average fruit weight and 6.00 percent dry matter of fruit.

Biswas *et al.* (2017) reported that the genotype C-41 produced the highest number of fruits (48.00 plant^{-1}) but its corresponding individual fruit weight was the lowest (34.33 g). The lowest number of fruits plant^{-1} was harvested from the line WP-10 (22.33 plant^{-1}), and it had the highest individual fruit weight (66.67 g). Significant variation was observed in weight of fruit plant^{-1}. The highest fruit yield plant^{-1} was recorded from the genotype HT-025 (2.02 kg plant^{-1}) and the lowest was recorded from the line FP-5 (1.17 kg plant^{-1}). The variation in different characters of tomato might be due to difference in cultivars used.

Khondakar *et al.* (2017) reported that the differences in number of branches might be due to the different genetic makeup of the summer tomato varieties.

Spaldon and Hussain (2017) conducted an experiment to analyze the performance of the tomato genotypes for yield, quality and biotic reaction against biotic stress. Pusa Ruby recorded the highest fruits per plant (30.82), estimated maximum marketable yield in hybrid Tokita (5.07 kg/plot). With respect to the quality traits, maximum pericarp thickness (6.86mm) was found in genotype Anand. Arka Vikas reported highest fruit pH (4.49) and beta-carotene content (7.06mg/100g). They concluded that the genotypes Tokita, US-3383, Pusa Ruby were high yielding and good for fresh marketing purpose. Arka Vikas, Aditya, and Arka Meghali genotypes were classified as suitable for processing.

Ali *et al.* (2016) conducted an experiment to Evaluate various tomato (*Lycopersicon esculentum* Mill.) cultivars for quality, yield and yield component under agro-climatic condition of Peshawar and found significant variation in respect of total soluble solids in different genotypes of tomato and maximum TSS (4.98 %) and minimum TSS (3.70 %) were observed in Bambino and Money maker tomato varieties respectively.

Dunsin *et al.* (2016) performed an experiment to assess the Performance of five Tomato cultivars under Controlled Environment Condition of the Southern Guinea Savannah. They found that the Nemoneta cultivar, performed better than rest of the cultivars with respect to plant height (8.3cm), highest shelf life of 14 days followed by Delicious with 7 days, while Small Cherry was better for number of fruits per plant with an average of 8.733/plant. But Delicious cultivar gave the highest values in terms of marketable fruit weight (9.33kg) and highest pH values (4.07). In terms of fruit quality, Large Cherry cultivar contains the highest values for lycopene (1467.30mg/100g), vitamin A & B (56.7mg/100g & 0.62 mg/100g, respectively) and potassium content (0.62%).

Kanaujia and Phom (2016) studied the performance of various tomato genotypes of tomato and revealed that the genotype 2013/TODVAR-1 recorded maximum fruit yield (32.59 t/ha) and vitamins C content (74.58 mg/ 100g of fruit). The maximum TSS content (6.45^{o} Brix) was recorded in genotype 2012/TODVAR-3.

Khan *et al.* (2016) carried out an experiment to know the effect of different mulching materials on weeds and yield of chili cultivars and reported that in production of branches the differences among the cultivars might be due to their hereditary composition.

Helal *et al.* (2016) reported that higher number of branches/plant is the result of genetic makeup of the crop and environmental conditions which play a remarkable role towards the final yield of the crop.

Biswas *et al.* (2015) investigated BARI tomato varieties to study growth and yield responses of tomato varieties and revealed that the variety BARI Tomato-7 recorded tallest plant, maximum number of leaves and branches. The maximum number of flowers, number of clusters and number of fruits were recorded in BARI Tomato-9 and Maximum fruit diameter, yield, number of locules, individual fruit weight were also recorded in BARI Tomato-7.

Bhati and Kanaujia (2014) evaluated the performance of nine tomato varieties for their growth, yield and quality characters in the experiment. TODVAR-8 was found superior variety and recorded maximum plant height, number of leaves per plant, branches per plant, fresh weight of fruit, fruit length, fruit diameter, fruits per plant, total soluble solids, yield per hectare ascorbic acid content.

Mehraj *et al.* (2014) conducted an experiment to evaluate the performance of twenty (V_1 -V_{20}) coded tomato cultivars grown in the summer. The cultivar Mini Anindyo Red (V8) and Hybrid Tomato US440 (V_{18}) showed maximum leaves and plant height. Cultivar BARI Tomato 6 (V_{19}) has observed maximum days to flower bud appearance chlorophyll content, and days to flowering. Maximum number of number of flower bud per plant, branches per plant, flowers per plant, bunch per plant, fruit weight, number of flower per bunch, number of fruits per plant, fruit length, fruit diameter, yield per plant, yield per plot and fruit yield per hectare were detected from Mini Chika (V_{10}) cultivar. Thus the cultivar Mini Chika (V_{10}) was found suitable for summer cultivation.

Ngullie and Biswas (2014) conducted an experiment at krishi vigyan Kendra, Mokokchung, Nagaland to evaluate five tomato cultivars for their growth and fruit yield. Observation were taken on growth parameters and yield components including plant height, number of branches, fruit length, fruit girth, fruit weight, and total fruit yield per hectare. They found that highest fruit yield per hectare was found in Megha-1 followed by Sel-1, Punjab Chhuhara and Sel-2. While, the lowest fruit yield was obtained in Pusa Ruby than rest of the cultivars.

Kiran (2014) studied the twelve qualitative and quantitative characters of forty-five genotypes at AICRP on vegetable crops at O.U.A.T. Bhubaneshwar. She found that the genotypes BT-22-4(V7), BT-442-2 (V1), BT-3 (V28), BT-17-2 (V18) and BT- 437-1-2 (V2) were good yielders among all the genotypes in Odisha conditions.

Aoun *et al*. (2013) reported that tomato quality parameters can be verified by both physical and chemical characteristics of the fruit.

Jilani *et al.* (2013) reported minimum stem diameter (9.11 mm) in tomato cultivar Nema-1200 while the maximum stem diameter (14.95 mm) in tomato cultivar Vegnesh during comparison. He also reported that cultivar Nandi and Vegnesh took least days to flowering.

Singh *et al.* (2013) studied the performance of different tomato hybrids under greenhouse conditions in 2008 to 2009 and 2009 to 2010 at Hissar and reported that Avinash-23 recorded maximum yield per plant of 2.90 kg followed by Richa with a yield of 2.88 kg.

Tyeb *et al.* (2013) reported that the variation in plant height is due to the effect of varietal differences. The variation of plant height is probably due to the genetic make-up of the cultivars.

According to Mehmood *et al.* (2012) the tomato germplasm BINA Tomato-6 took maximum time to first flower appearance when compared with the other twenty one germplasms.

Ali *et al.* (2012) found maximum fruit diameter (5.19 cm) and minimum fruit diameter (4.50 cm) in tomato hybrids T-7010 and PTM-1603 respectively during studying the performance of various tomato hybrids.

Islam *et al.* (2012) studied the genetic variability of eleven inbred lines of cherry tomato and reported that line CH155 (5.7%) had the highest total soluble solids followed by CLN1555A (4.9%).

Naz *et al.* (2012) found that number of flower clusters plant^{-1} had significant variation among the tomato varieties.

Chapagain *et al*. (2011) assessed the performance of tomato varieties under plastic house for two successive years from 2009 to 2010 in Nepal. The highest marketable yield was recorded from All Rounder (86.6 t ha-1) followed by Srijana (80.8 t ha^{-1}).

Olaniyi *et al*. (2010) carried out an experiment where the assessment of seven varieties of tomatoes was done. He evaluated the growth, fruit yield and quality of the varieties. The results showed that DT97/162A(R) gave the highest height compared to Ogbomoso local variety. This shows that the yield and the quality of tomato depend on the variety.

2.2 Effect of salt water

Habibi *et al.* (2021) reported that salinity stress creates serious problems for tomato production in dry climate regions like Southeast Asia. They were conducted two sets of experiments , where the initial experiment was on effects of salinity on seed germination and seedling characteristics in the laboratory and the second experiment was to evaluate the effects of salinity on growth, physiological and biochemical responses of tomato. The experiment was designed in complete randomized design with 4 salt treatments (50, 100, 150, and 200 mM), and control (no sodium chloride). In the initial experiment, it was found that the germination rate, shoot and root length were significantly reduced under saline conditions. In the second experiment, it was observed that salinity, at the rates tested, decreased plant height, root length, the number of flowers, photosynthetic rate, transpiration rate, and stomatal conductance, but it increased leaf temperature. Moreover, sugars decreased under salinity, while organic acids, MDA and proline content increased. Proline and MDA are produced in response to salt stress. Accordingly, fruit yield was reduced under salinity as compared to control.

Ahmad *et al*. (2019) stated that number of fruits plant^{-1} decrease with increasing salinity level.

Rahman *et al.* (2018) conducted a pot experiment to observe the effects of NaCl-salinity on tomato (*Lycopersicon esculentum* Mill.) plants. Morphological properties and yield of five varieties of Bangladesh Agricultural Research Institute tomato (BARI-T 1, BARI-T 2, BARI-T 3, BARI-T 4, and BARI-T 5) plants were exposed to NaCl-salinity (2, 4, 6 and 8 dS m^{-1}) through irrigation. Results showed that morphological properties of all studied tomato plants were affected by increasing NaCl salinity and confirmed that NaCl-salinity significantly affects the growth of five varieties of BARI tomato plants and reported that under moderate salinity stress (>4 dS m^{-1}), none of the studied tomato plants (BARI-T 1 to 5) is suitable for cultivation.

Khanbabalo *et al.* (2018) carried out an experiment using four varieties (Stone, Lesto, Super Chief and Falat) of tomato under normal and salt stress (3, 6 and 9 dS m^{-1}) hydroponic conditions. Results revealed 10 fold reduction in yield compared to control in variety Lesto and highest yield in variety Super Chief among all four varieties.

A glasshouse experiment accompanied by El Mogy *et al.* (2018) to determine the influence of different salt concentrations (0, 25, 50, 75, 100 or 150 mM sodium chloride) on yield parameters of cherry tomato (*Solanum lycopersicum* L), cv. West Virginia 106 grown in peatmoss substrate. The NaCl treatments of 75, 100 and 150 mM salt resulted in shorter plants, decreased stem width, a lower plant dry weight, fewer flowers, and smaller leaf area, while yield was reduced by treatment with concentrations of 50 mM NaCl and above. Average fruit weight and fruit number were also negatively affected by treatment with 50 mM salt and above.

Al Daej (2018) conducted a study to determine the salt tolerance of two tomato cultivars ("Rams", "C10") under laboratory conditions using different levels of salinity *viz.*, 0, 20, 40, 60, 80 and 100 mM NaCl concentrations. The results showed that the cultivar Rams performed better than C10 for all the physiological parameters *i.e.*, germination (%), plant length, fresh and dry matter yield under control treatment.

Islam *et al.* (2018) who found that TSS of tomato was increased with increased in salinity.

Umar *et al.* (2018) also indicated that the number of leaves plant^{-1} was reduced under high salinity conditions.

An experiment on effects of salinity stress on growth, yield, fruit quality and water use efficiency of tomato under hydroponics system conducted by Zhang *et al.* (2017) showed that salinity reduces tomato root elongation rate and lateral root growth due to restriction of root cell growth and increased root lesion. Tomato leaf, shoot height and stem diameter reduced under salinity stress. Total yield of tomato is significantly reduced at salinity equal and above 5 dS m^{-1}, and a 7.2 % yield reduction per unit increase in salinity.

A screen house experiment was conducted by Rani *et al.* (2017) to investigate the effect of different saline environments on yield and quality of tomato. Four levels of saline water irrigation (2, 4, 6 and 8 dS m^{-1}) plus fresh water as control were applied at sowing time. Results revealed the overall reduction of fresh fruit yield as compared to non- saline conditions and found >50% yield reduction at 8 dS m^{-1} in chloride salinity.

An experiment on the effect of irrigation with different levels of saline water was carried out by Helay *et al*. (2017) on husk tomato plants to test the growth ability of salt tolerance with best fruit yield and their quality under saline condition. The results showed that the saline water treatments significantly decreased the vegetative growth parameters, total chlorophyll content, NPK in husk tomato leaves, early and total yield. On the contrary, irrigation with saline water significantly increased sodium and proline contents in husk tomato leaves, fruit firmness, total soluble solids and total sugars as compared with the control. The fruit yield productivity was decreased, while the fruit quality was increased under saline irrigation.

A study taken by Ahmed *et al.* (2017) using different levels of saline irrigation water (fresh water, 4, 6, 8 and 10 dS m^{-1}) where the plants irrigated with fresh water gave the highest fruit yield per plant (1.52 kg) whereas the lowest fruit yield per plant (0.667 kg) was obtained from the higher level of saline water treatment of 10 dS m^{-1}.

Ahmad *et al.* (2017) carried out a study to assess the influence of salt stress on two cultivars of lowland tomato (Pearl and MT1) treated with sodium chloride (NaCl) at 70 and 140 mM. Results showed that plant height, fruit cluster $plant^{-1}$, fresh fruit weight, fruit number and yield of both cultivars were reduced under salinity stress. In comparison, Pearl was more tolerant to the salinity than MT1 in terms of growth and yield in both medium and high level of NaCl.

Huang *et al*. (2016) mentioned that increasing TSS plays a role in adaptation of plants to salinity. Our present study suggested that the TSS of the fourth cluster was higher than that of first cluster fruits and this result could be due to increasing salinity stress with a prolonged stress period which forces the plant to accumulate more TSS in tissues to adapt to the salinity level.

Zhang *et al*. (2016) reported that salt added to nutrient solution is an easy method that can improve tomato fruit quality, but plant growth and flower production were negatively affected. Salinity reduces tomato root elongation rate and lateral root growth due to restriction of root cell growth and increased root lesion. Tomato leaf, shoot height and stem diameter reduced under salinity stress caused by photosynthesis reduction, tissues expansion reduction and cell divided inhibition. Salinity also reduces leaf chlorophyll content, stomatal resistance and photosynthetic activities. Total yield of tomato is significantly reduced at salinity equal and above 5 dS m^{-1}, and a 7.2% yield reduction per unit increase in salinity. Salinity can decrease root water uptake through its osmotic effect, and subsequently induce water stress. Fruit quality is the only parameter which is positively affected with increased salinity.

Ramin *et al*. (2015) carried a research in order to study the salinity effects on growth and physiological characteristics of tomato plant cultivars Super strain–B and Red clud using five levels of salinity treatments including, zero (control), 40, 80, 120 and 160 mM of NaCl. The results showed that salt stress significantly reduces shoot and root dry weight, number of leaves, leaf area and stress index (Fv/Fm) of both cultivars. Specific leaf area (SLA) in both cultivars decreased due to salinity treatment however, this reduction was not significant in Red clud cultivar. The results were suggestive of the relative resistance of tomato plant cultivar Red clud in comparison with Super strain-B to salinity conditions.

A study undertaken by Khursheda *et al.* (2015) showed that salt stress significantly affects morphology, physiology and fruit weight of tomato. Plant height, leaf number and branch number/plant were decreased with increased levels of salinity at 6 and 8 dS m^{-1} while reduced shoot dry weight, leaf area, leaf chlorophyll content and fruit weight per plant at 8 dS m^{-1}.

Liu *et al.* (2014) found that tomato cultivars of Tainan ASVEG No. 19, Hualien ASVEG No. 21 and Taiwan Seed ASVEG No. 22 under 150 mM NaCl stress condition showed 73%, 83.3% and 79.3% in number of marketable fruits per plant and 59%, 66.4% and 61.4% in fruit set, respectively, less than those in the 0 mM NaCl condition.

Giannakoula and Ilias (2013) reported that the negative effect of salt stress on tomatoes is a result of retarded plant growth due to decline in photosynthetic rate which leads to a reduction in fruit size and total yield per plant, which are the most important factors for tomato producers.

Gumi *et al.* (2013) investigated the response of *Solanum lycospersicum* (L.) to varied concentrations (0, 50, 75, 100 mM) of salinity stress. The plant exhibited a decline in number of leaves, length of leaf and dry matter accumulation measured. The number of flowers increased at 50 mM NaCl concentration.

Moniruzzaman *et al*. (2013) observed that the plant height decreased with increasing salinity level. Salinity affects plant growth by disturbing the water balance, causing an imbalance in plant nutrition and affecting plant physiological and biochemical processes.

Salwa *et al.* (2012) carried out an experiment on salinity levels of the three used soils were 7.55, 9.20 and 12.5 dS m^{-1}. They resulted that soil pH of the cultivated three soils was decreased with increasing salinity level. Similarly those decreased were found with soil EC, where the high reduction was recorded with 12.5 followed by that of 9.20 dS m^{-1}. They also reported that little decreased of soluble ions in soils was found. The predominant soluble cations in the three soils were Na+ followed by Ca^{2+} or Mg^{2+}. On the other hand the predominant soluble anions were Cl^- followed by $SO4^{2-}$.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka to investigate the effect of salt water on growth, yield, and quality of hydroponically grown tomato. Materials used and methodologies followed in the present investigation have been described in this chapter.

3.1 Experimental period

The experiment was conducted during the period from September-2019 to February-2020.

3.2.1 Geographical location

The experiment was carried out at Sher-e-Bangla Agricultural University's horticulture farm (SAU). The experimental site is located 8.6 meters above sea level at a latitude and longitude of 23°77 N and 90°33 E, respectively. In Appendix I Map of Bangladesh's AEZ, the experimental site has been highlighted for easier understanding.

3.2.2 Climate and weather

The experimental site's climate was subtropical, with the winter season lasting from November to February, the pre-monsoon period, also known as the hot season, lasting from March to April, and the monsoon season lasting from May to October (Farukh *et al.*, 2019). Appendix-II contains meteorological information about the temperature, relative humidity, and rainfall during the experiment period that was gathered from the Bangladesh Meteorological Department's Climate Division in Sher-e-Bangla Nagar, Dhaka.

3.3 Experimental materials

As planting materials, BARI tomato-8, BARI tomato-9 and BARI tomato-10 were chosen. The seeds of these tomatoes were obtained from Krishibid Seed Limited. The other substrates were gathered from Hatibandha upazilla Lalmonirhat, and (Khoa+ cocopean) was collected from an agargoan in Dhaka.

3.4 Experimental treatment

There were two factors in the experiment namely Tomato variety and Salt water as mentioned below:

Factor A: Tomato variety denoted as V:

V_1 = BARI tomato-8
V_2 = BARI tomato-9
V_3 = BARI tomato-10

Factor B: Salt water denoted as S:

S_0 = 0 ml L^{-1} NaCl+ standard solution
S_1 = 0.5 ml L^{-1} NaCl + standard solution
S_2 = 0.75 ml L^{-1} NaCl + standard solution
S_3 = 1 ml L^{-1} NaCl + standard solution

3.5 Experimental design

The experiment had two factors, three replications, and a completely randomized design (CRD). The experiment employed a total of 24 unit pots with 8 treatments.

3.6 Detail of experimental preparation

3.6.1 Preparation of the substrate

Overnight, cocopeat as substrate was immersed in a plastic container. Then the wet substrate was spread out on a polythene sheet to remove excess moisture from it. After that the growing medium was prepared for use as hydroponic culture by adding a little amount of cocopeat, khoa, and a disinfection chemical like sevin powder.

3.6.2 Selection and preparation of the pot

The pots were made of plastic and had a hole in the center of the bottom and measured 12 inches in height and diameter. The pots' upper edge diameter was 30 cm (r= 15 cm). To appropriately provide irrigation and nutrient solution, the top inch of the pot was left empty while being filled with various substrates. As a result, the upper surface's radius was 15 cm and its area was (πr^2 = 3.14x 0.015x 0.015=0.07 m^2).

3.6.3 Standard solution

Rahman and Inden (2012) nutrient solution was used as standard solution for this experiment. The NO_3-N, P, K, Ca, Mg, and S ratios for the Rahman and Inden (2012) solutions were 17.05, 7.86, 8.94, 9.95, 6.0, and 6.0 meq/L, respectively. The 17 micronutrient rates were 3.0, 0.5, 0.1, 0.03, 0.025, and 1.0 mg/L for Fe, B, Zn, Cu, Mo, and Mn, respectively. Each pot was filled with the solution according with par treatment requirement.

3.6.4 Seed bed preparation for seedling raising

To prepare the seed bed for growing tomato seedlings, a mixture of cocopeat, broken bricks (khoa), and rice husk at a ratio of 60:30:10 (v/v) was utilized. Blocks of cocopeat were steeped for 24 hours in a large bowl. After drying and washing them, they were correctly combined with khoa and rice husk. This combination was used after being put in a box made of styrofoam sheets.

3.6.5 Seed sowing

The seeds were sown in styrofoam sheet box and covered with newspaper under normal temperature for raising seedling.

3.6.6 Transplanting of tomato seedling

15 days old tomato seedlings were transferred to small pot. 4 weeks after that seedlings were transferred to 12 inch plastic pots containing cocopeat substrate. The plants were transplanted carefully to avoid the root damage. Little amount of water was applied soon after transplanting of seedling.

3.6.7 Imposed treatment for experiment

Salt water treatment was imposed on 25 days-old seedlings and the desired level of salinity were achieved in each container. Throughout the study period, a group of plants was grown in a similar type of container without saline solution for comparisons. All the containers kept in separate room maintaining treatment temperature.

3.7 Intercultural operations

3.7.1 Pruning

After transplanting, the lowest yellow leaves were cut off as needed to give the plants time to establish a strong vegetative frame before bearing fruit.

3.7.2 Irrigation

To make up for the water shortage after transplanting, a light irrigation was given to each individual pot. Each container received watering on alternate days after seedling establishment to maintain the substrate's moisture levels for the plants' regular growth and development. Irrigation was done sincere during the pre-flowering stage.

3.7.3 Weeding

No weeding was done in the experiment.

3.7.4 Stalking

Firstly, a bamboo stick was used to support tomato plant. Secondly, a small plastic pipe was cut roundly different pieces. Then it was used as a hook in plant base and plastic rope used for support the plant.

3.7.5 Insect management

Tomato plants were grown in controlled environment. So, no insecticides were applied in the experiment.

3.7.6 Diseases management

Tomato plants were grown in controlled environment in hydroponic culture and all nutrients required for plant were supplied artificially to the plants. The growing environment was clean and no disease attacked the plant.

3.8 Harvesting

Once the first bloom of red appears on the skin of the tomato then they were harvested.

3.9 Data collection

Plants per pot were tagged for recording various data. The data were recorded as described below.

i. Plant height (cm)

The plant height was recorded in centimeters from earlier selected plant from ground level to the growing tip of the main stem with the help of metalic strip tape.

ii. Number of branches plant^{-1}

The number of branches per plant counted for randomly selected five plants and average was recorded.

iii. Days of first flower initiation

Number of days required from the day of transplanting to the day on first flower initiation as recorded as days of recorded as first flower initiation.

iv. Number of flower clusters plant^{-1}

Number of flower clusters plant^{-1} were counted and averaged.

v. Number of fruits plant^{-1}

Plants was counted to compute the average number of fruits per cluster.

vi. Number of fruits plant^{-1}

Number of fruits per plant was counted at every picking, which was finally added up to work out total and average number of fruits per plant.

vii. Fruit polar length (cm)

The individual fruit polar length was measured during harvesting with the help of a large scale in centimeter unit.

viii. Fruit radial length (cm)

The individual fruit radial length was measured during harvesting with the help of a large scale in centimeter unit.

ix. Fruit yield plant^{-1} (kg)

To calculate yield per plant, the harvesting was completed when the fruit was halfway ripe. The yield was measured in grams at each picking and totaled across all pickings to determine the overall fruit production per plant. Finally, the fruit production from all the plants was combined, and the average output from plant-^{1} (kg) was recorded.

x. Average fresh weight of tomato (g)

Total weight of five randomly harvested fruits at every picking was recorded to compute the average fresh fruit weight of tomato in grams.

xi. Average dry weight of tomato (g)

Individual tomato fruit were collected for each treatment. The fruit was then cut into slices and dried in the sun for two days separately before being moved to the central laboratory oven at Sher-e-Bangla Agricultural University to finish drying. After 72 hours, it was collected and weighed using an electric balance.

xii. Individual fruit volume

The individual fruit volume was measured during harvesting by Archimidis method with the help of a 500 ml beaker in centimeter cube (cc) unit. Another name of cc unit is ml.

xiii. Total soluble solids (^{0}Brix)

The randomly taken ripe fruits of third harvest were crushed and their juice was passed through a double layer of fine mesh cheesecloth. A drop of juice was placed on the plate of hand refractometer (0-32%) ERMA, JAPAN) and the reading was recorded. A mean of five readings was taken in each treatment and every replication.

xiv. pH determination

The pH value of tomato was measured using a digital pH meter. The pH meter was first calibrated with different standard solutions for pH 4, 7 and 10. Then, the tomato was taken in a beaker and the pH meter immersed in the juice to record the value. The test was performed by triplicate per each treatment at normal temperature.

3.10 Data analysis technique

The collected data were compiled and analyzed statistically using the analysis of variance (ANOVA) technique with the help of a computer package program name Statistix 10 Data analysis software and the mean differences were adjusted by Least Significant Difference (LSD) test at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

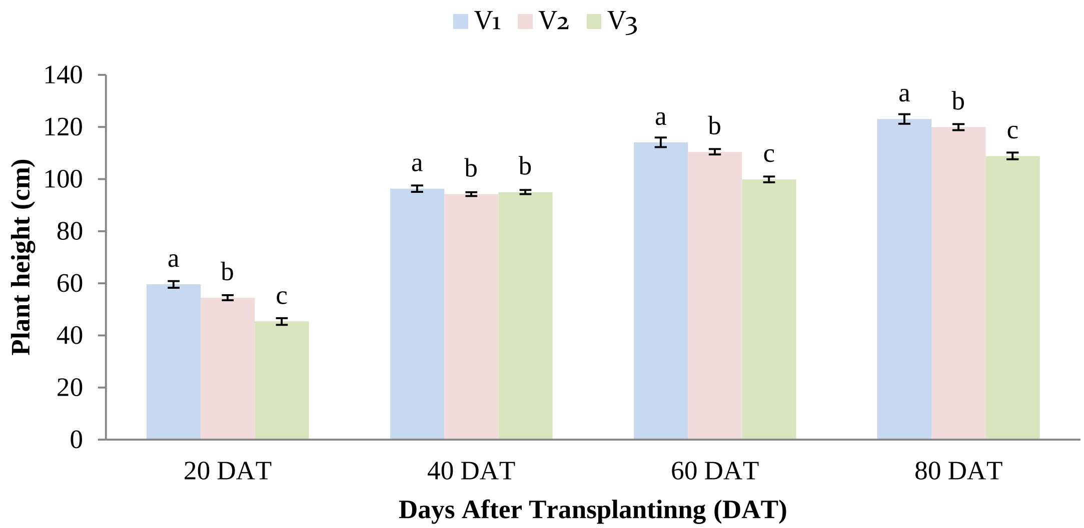
RESULTS AND DISCUSSION

This section presents and discusses the study's findings on the effect of salt water on the growth, yield, and quality of hydroponically produced tomatoes. The information was presented in various tables and graphs. The findings had been discussed, and possible interpretations were provided under the headings listed below.

4.1 Plant height (cm)

Effect of variety

Plant height is a crucial aspect of the crop plant's vegetative stage that indirectly affects crop plant yield. Different varieties had a substantial effect on tomato plant height at various days after transplanting (DAT). Height was observed to grow steadily as the crop aged up to harvest. At maturity, the plant's height achieved its peak value (Figure 1). Experimental result revealed that the highest plant height (59.63, 96.35, 114.10 and 123.10 cm) at 20, 40, 60 and 80 DAT was observed in V_1 (BARI toamto-8) treatment. Whereas the lowest plant height (45.40, 95.05, 99.92 and 108.92 cm) at 20, 40, 60 and 80 DAT was observed in V_1 (BARI tomato-10) treatment which was statistically similar with V_2 treatment (94.25 cm) at 40 DAT. The genetic makeup of the cultivar is likely to blame for the difference in plant height. Das *et al.* (2019) reported that height of a plant is determined by genetical character and under a given set of environment different variety will acquire their height according to their genetic makeup.

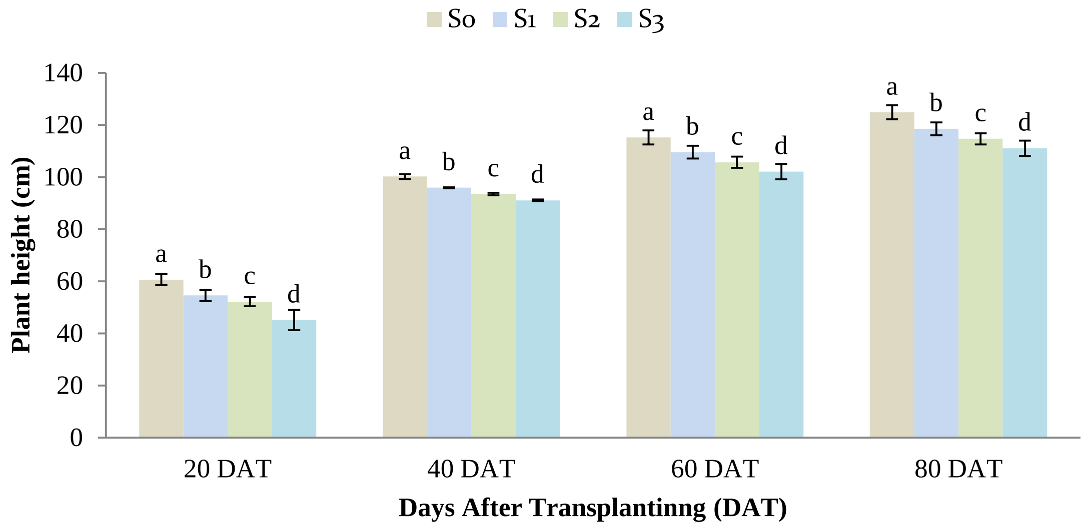


In the bar graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Vertical bars indicate standard error (SE). Here, Here, V_1 = BARI tomato-8, V_2 = BARI tomato-9, V_3 = BARI tomato-10

Figure 1. Effect of variety on plant height of tomato at different DAT

Effect of salt water

Plant height of tomato showed significant variation due to the effect of salt water treatment at different DAT (Figure 2). Experimental result showed that the highest plant height (60.70, 100.23, 115.23 and 124.90 cm) at 20, 40, 60 and 80 DAT was observed in S_0 (0 NaCl ml L^{-1} + standard solution/Control) treatment. Increasing salt water decreased plant height and the lowest plant height (45.17, 91.13, 102.13 and 111.13 cm) was observed in S_3 (NaCl 1 ml L^{-1} + standard solution) treatment. Gradual decrease in plant height might be due to the nutrient unavailability caused by increased salt water concentration or the inhibition of cell division or cell enlargement. The result obtained from the present study was similar with the findings of Habibi *et al.* (2021) who reported that increased salinity levels gradually decreased plant height. Zhang *et al.* (2016) reported that salt added to nutrient solution is an easy method that can improve tomato fruit quality, but plant growth and fruit production are negatively affected. Moniruzzaman *et al.* (2013) observed that the plant height decreased with increasing salinity level. Salinity affects plant growth by disturbing the water balance, causing an imbalance in plant nutrition and affecting plant physiological and biochemical processes.



In the bar graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Vertical bars indicate standard error (SE). Here, S_0 = 0 NaCl ml L^{-1} + standard solution, S_1 = NaCl 0.5 ml L^{-1} + standard solution, S_2 = NaCl 0.75 ml L^{-1} + standard solution and S_3 = NaCl 1 ml L^{-1} + standard solution

Figure 2. Effect of salt water on plant height of tomato at different DAT

Combined effect of variety and different salt water concentration

Different varieties along with salt water concentration significantly influenced on plant height of tomato at different DAT (Table 1). Experimental result revealed that the highest plant height (66.00, 102.70, 123.70 and 132.70 cm) at 20, 40, 60 and 80 DAT was observed in V_1S_0 treatment combination. While V_3S_3 treatment combination had the lowest plant height (31.70, 90.00, 92.00 and 101.00 cm) at 20, 40, 60 and 80 DAT which was statistically similar with V_1S_3 treatment combination (91.40 cm) at 40 DAT.

Table 1. Combined effect of variety and different salt water concentration on plant height of tomato at different DAT

Treatment Combinations	Plant height (cm)			
	20 DAT	40 DAT	60 DAT	80 DAT
V_1S_0	66.00 a	102.70 a	123.70 a	132.70 a
V_1S_1	60.50 bc	97.30 b	114.80 b	123.80 b
V_1S_2	58.70 c	94.00 c-e	112.00 bc	121.00 c
V_1S_3	53.30 d	91.40 fg	105.90 ef	114.90 e
V_2S_0	62.50 b	97.50 b	114.50 b	125.50 b
V_2S_1	53.00 de	94.50 cd	111.50 b-d	120.50 c
V_2S_2	52.00 de	93.00 d-f	107.50 de	116.50 de
V_2S_3	50.50 e	92.00 e-g	108.50 c-e	117.50 d
V_3S_0	53.60 d	100.50 a	107.50 de	116.50 de
V_3S_1	50.30 e	96.00 bc	102.50 f	111.50 f
V_3S_2	46.00 f	93.70 c-f	97.70 g	106.70 g
V_3S_3	31.70 g	90.00 g	92.00 h	101.00 h
$LSD_{(0.05)}$	2.70	2.47	4.44	2.35
CV(%)	3.00	1.53	2.42	1.18

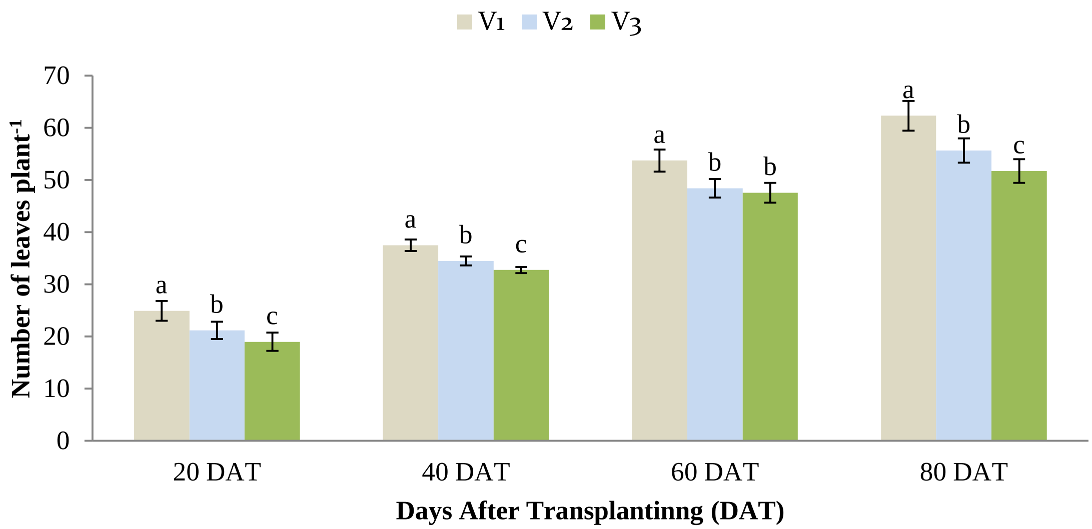
In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, V_1 = BARI tomato-8, V_2 = BARI tomato-9, V_3 = BARI tomato-10, S_0 = 0 NaCl ml L^{-1} + standard solution, S_1 = NaCl 0.5 ml L^{-1} + standard solution, S_2 = NaCl 0.75 ml L^{-1} + standard solution and S_3 = NaCl 1 ml L^{-1} + standard solution

4.2 Number of leaves plant^{-1}

Effect of variety

A leaf is the principal lateral appendage of the vascular plant stem, usually borne above ground and specialized for photosynthesis. Different tomato varieties significantly influenced number of leaves plant^{-1} at different days after transplanting (Figure 3). Experimental result showed that the highest number of number of leaves plant^{-1} (24.92, 37.50, 53.75 and 62.33) at 20, 40, 60 and 80 DAT was observed in V_1 treatment. However V_3 treatment had the lowest number of leaves plant^{-1} (19.00, 32.75, 47.58 and

51.75) at 20, 40, 60 and 80 DAT which was statistically similar with V_2 treatment (48.41) at 60 DAT. The variation in number of leaves plant^{-1} was probably due to the genetic makeup of the cultivars. Similar results were discovered by Biswas *et al.* (2015), supporting the current finding, and reported that the changes in the number of leaves on plant^{-1} may be caused by the tomato variety's characteristics.

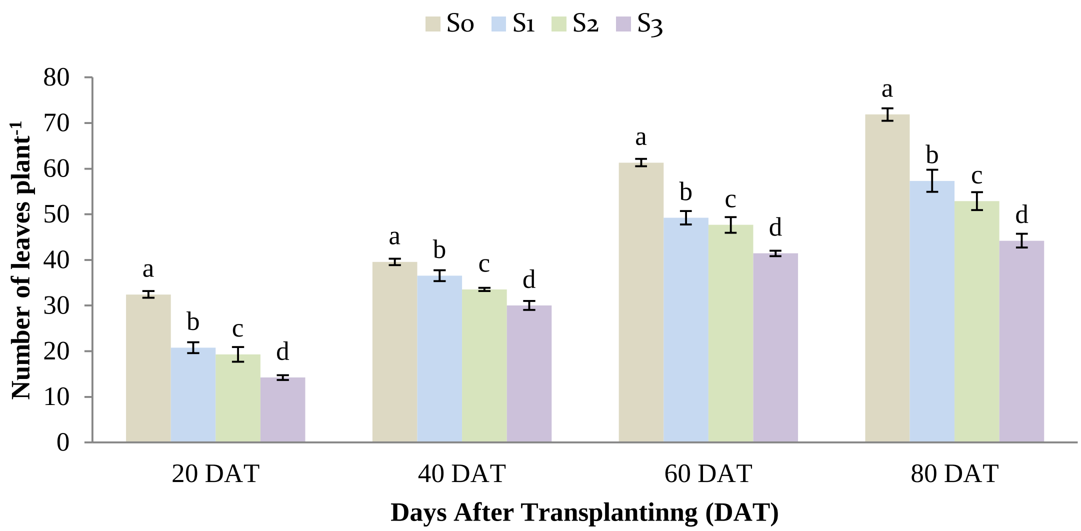


In the bar graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Vertical bars indicate standard error (SE). Here, Here, V_1 = BARI tomato-8, V_2 = BARI tomato-9, V_3 = BARI tomato-10

Figure 3. Effect of variety on number of leaves plant^{-1} of tomato at different DAT

Effect of salt water

Different salt water concentration had shown significant effect on number of leaves plant^{-1} of tomato at different DAT (Figure 4). According to the experimental findings the S_0 treatment had the highest number of leaves plant^{-1} (32.44, 39.56, 61.33 and 71.88) at 20, 40, 60 and 80 DAT. While the S_3 treatment had the lowest number of leaves plant^{-1} (14.22, 30.00, 41.44 and 44.22). Salinity-induced osmotic stress, as a result water uptake by plant is hampered and plant suffers from physiological drought. This also lead to various morphological, physiological biochemical alternations and interruption of nutrient uptake which ultimately reduce their growth and productivity result in severe reductions in leaves plant^{-1}. Umar *et al.* (2018) indicated that the number of leaves plant^{-1} was reduced under high salinity conditions.



In the bar graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Vertical bars indicate standard error (SE). Here, S_0 = 0 NaCl ml L^{-1} + standard solution, S_1 = NaCl 0.5 ml L^{-1} + standard solution, S_2 = NaCl 0.75 ml L^{-1} + standard solution and S_3 = NaCl 1 ml L^{-1} + standard solution

Figure 4. Effect of salt water on number of leaves plant^{-1} of tomato at different DAT

Combined effect of variety and different salt water concentration

Variety and different salt water concentrations had shown significant effect on the number of leaves plant^{-1} of tomato at different DAT (Table 2). The V_1S_0 treatment combination had the highest number leaves plant^{-1} (34.66, 42.00, 64.00 and 76.33) at 20, 40, 60, and 80 DAT. While V_3S_3 treatment combination had the lowest number of leaves plant^{-1} (13.33, 27.67, 39.66 and 41.00) at 20, 40, 60, and 80 DAT which was statistically similar with V_2S_3 treatment combination at different DAT.

Table 2. Combined effect of variety and different salt water concentration on number of leaves plant^{-1} of tomato at different DAT

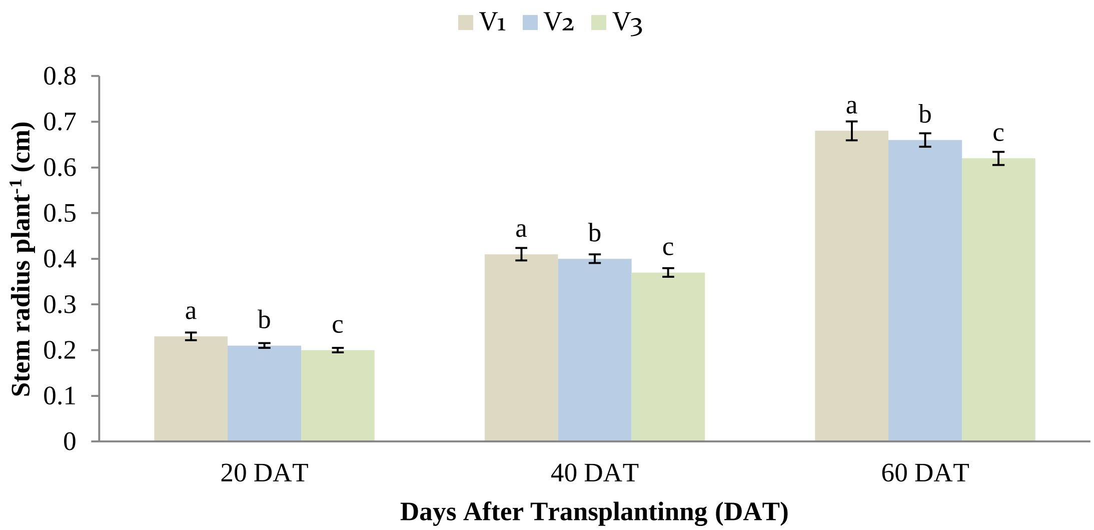
Treatment Combinations	Number of leaves			
	20 DAT	40 DAT	60 DAT	80 DAT
V_1S_0	34.66 a	42.00 a	64.00 a	76.33 a
V_1S_1	24.67 d	40.33 b	54.34 c	65.00 c
V_1S_2	24.33 d	34.33 e	53.33 c	58.66 d
V_1S_3	16.00 h	33.33 ef	43.33 e	49.33 fg
V_2S_0	32.33 b	38.67 c	60.66 b	71.00 b
V_2S_1	20.00 e	36.33 d	47.00 d	56.33 d
V_2S_2	19.00 f	34.00 e	46.33 d	53.00 e
V_2S_3	13.33 j	29.00 g	41.33 f	42.33 h
V_3S_0	30.33 c	38.00 c	59.33 b	68.33 b
V_3S_1	17.67 g	33.00 ef	46.34 d	50.67 ef
V_3S_2	14.67 i	32.33 f	43.34 e	47.00 g
V_3S_3	13.33 j	27.67 g	39.66 f	41.00 h
$LSD_{(0.05)}$	0.88	1.35	0.94	1.41
CV(%)	2.40	2.28	2.31	3.06

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, V_1 = BARI tomato-8, V_2 = BARI tomato-9, V_3 = BARI tomato-10, S_0 = 0 NaCl ml L^{-1} + standard solution, S_1 = NaCl 0.5 ml L^{-1} + standard solution, S_2 = NaCl 0.75 ml L^{-1} + standard solution and S_3 = NaCl 1 ml L^{-1} + standard solution

4.3 Stem radius plant^{-1} (cm)

Effect of variety

The results of the experiment showed that different varieties had had shown significant effect on stem radius plant^{-1} of tomato at different DAT (Figure 5). Experimental result revealed that the V_1 treatment had the highest stem radius plant^{-1} (0.23, 0.41 and 0.68 cm) at 20, 40 and 60 DAT. While the V_3 treatment showed the lowest stem radius plant^{-1} (0.20, 0.37 and 0.62 cm) at 20, 40 and 60 DAT. The diverse genetic make-up of the tomato cultivars may be the cause of the stem radius variations in plant^{-1}. The results obtained from the present study was similar with the findings of Jilani *et al.* (2013) who reported that the tomato cultivar Nema-1200 had the smallest stem diameter (9.11 mm), while tomato cultivar Vegnesh had the largest stem diameter (14.95 mm).

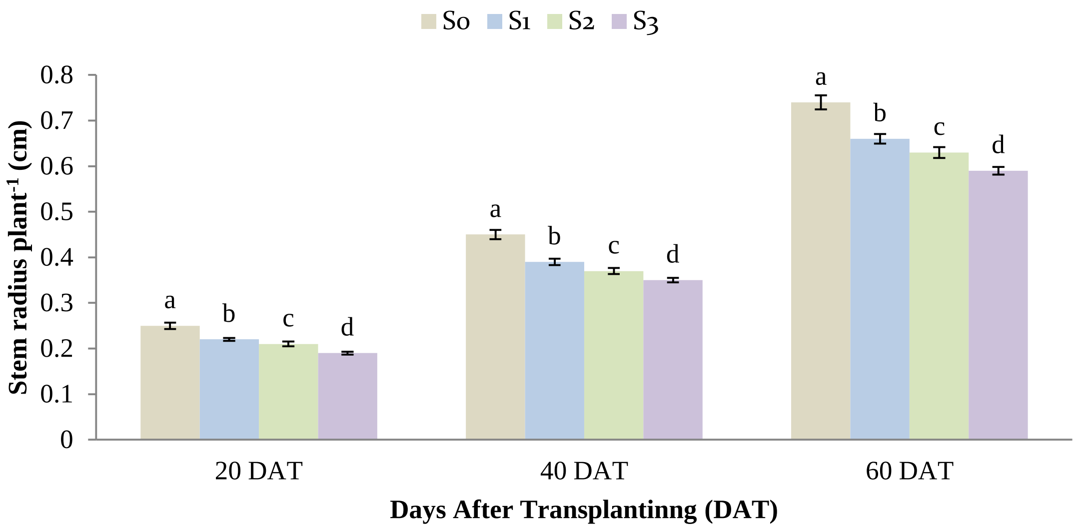


In the bar graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Vertical bars indicate standard error (SE). Here, Here, V_1 = BARI tomato-8, V_2 = BARI tomato-9, V_3 = BARI tomato-10

Figure 5. Effect of variety on stem radius plant^{-1} of tomato at different DAT

Effect of salt water

Different salt water concentration had shown significant effect on stem radius plant^{-1} of tomato at different DAT (Figure 6). Experimental result showed that the highest stem radius plant^{-1} (0.25, 0.45 and 0.74 cm) at 20, 40 and 60 DAT was recorded in S_0 (Control) treatment. With the increasing salt water concentration the stem radius plant^{-1} of tomato drastically reduced. While the S_3 treatment had the lowest stem radius plant^{-1} (0.19, 0.35 and 0.59 cm) at 20, 40 and 60 DAT. Increase of salt in the root medium can lead to a decrease in leaf water potential and, hence, may affect many plant processes. Zhang *et al.* (2017) showed that salinity reduces tomato root elongation rate and lateral root growth due to restriction of root cell growth and increased root lesion. Tomato leaf, shoot height and stem diameter reduced under increased salinity levels.



In the bar graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Vertical bars indicate standard error (SE). Here, S_0 = 0 NaCl ml L^{-1} + standard solution, S_1 = NaCl 0.5 ml L^{-1} + standard solution, S_2 = NaCl 0.75 ml L^{-1} + standard solution and S_3 = NaCl 1 ml L^{-1} + standard solution

Figure 6. Effect of salt water on stem radius plant^{-1} of tomato at different DAT

Combined effect of variety and different salt water concentration

Variety and different salt water concentrations had shown significant effect on the stem radius plant^{-1} of tomato at different DAT (Table 3). The V_1S_0 treatment combination had the highest stem radius plant^{-1} (0.27, 0.48 and 0.79 cm) at 20, 40 and 60 DAT. However V_3S_3 treatment combination had the lowest stem radius plant^{-1} (0.18, 0.33 and 0.56 cm) at 20, 40 and 60 DAT which was similar with V_3S_2 (0.19 cm) and V_1S_3 (0.19 cm) treatment combination at 20 DAT.

Table 3. Combined effect of variety and different salt water concentration on stem radius plant^{-1} of tomato of tomato

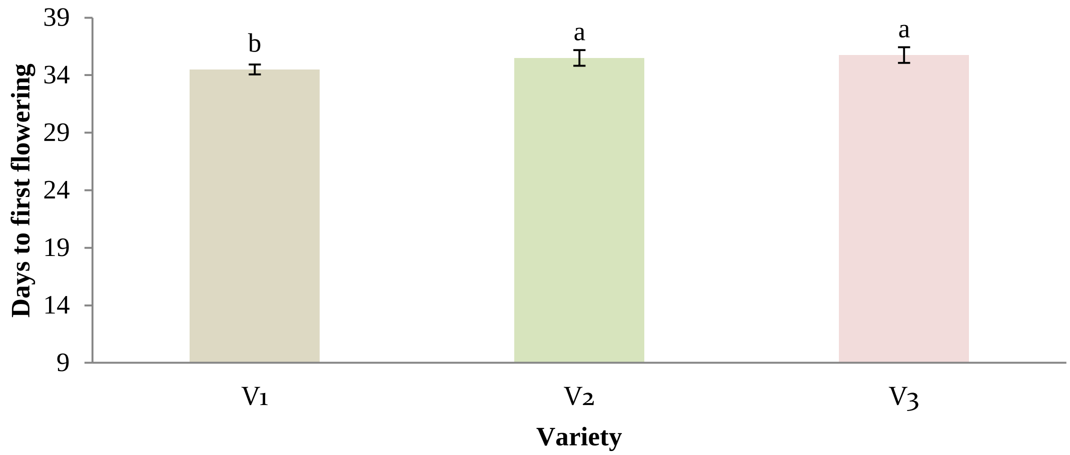
Treatment Combinations	20 DAT	40 DAT	60 DAT
V_1S_0	0.27 a	0.48 a	0.79 a
V_1S_1	0.23 bc	0.41 cd	0.69 d
V_1S_2	0.22 de	0.39 ef	0.66 f
V_1S_3	0.19 gh	0.35 i	0.59 j
V_2S_0	0.24 b	0.44 b	0.73 b
V_2S_1	0.22 cd	0.40 de	0.67 e
V_2S_2	0.21 d-f	0.38 fg	0.64 g
V_2S_3	0.20 fg	0.36 hi	0.61 i
V_3S_0	0.23 bc	0.42 c	0.70 c
V_3S_1	0.21 e-g	0.37 gh	0.63 h
V_3S_2	0.19 gh	0.35 i	0.59 j
V_3S_3	0.18 h	0.33 j	0.56 k
$LSD_{(0.05)}$	0.01	0.01	0.01
CV(%)	4.06	2.05	1.32

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, V_1 = BARI tomato-8, V_2 = BARI tomato-9, V_3 = BARI tomato-10, S_0 = 0 NaCl ml L^{-1} + standard solution, S_1 = NaCl 0.5 ml L^{-1} + standard solution, S_2 = NaCl 0.75 ml L^{-1} + standard solution and S_3 = NaCl 1 ml L^{-1} + standard solution

4.4 Days to first flowering

Effect of variety

Days to first flowering differed significantly due to different varieties (Figure 7). The highest 35.75 days required for first flowering was found in V_3 treatment. While the lowest 34.50 days required for first flowering was found in V_1. The variation in production of flower was due to the variation in genetic makeup of the cultivars. Mehmood *et al.* (2012) reported that the tomato germplasm BINA Tomato-6 took maximum time to first flower appearance when compared with the other twenty one germplasms.

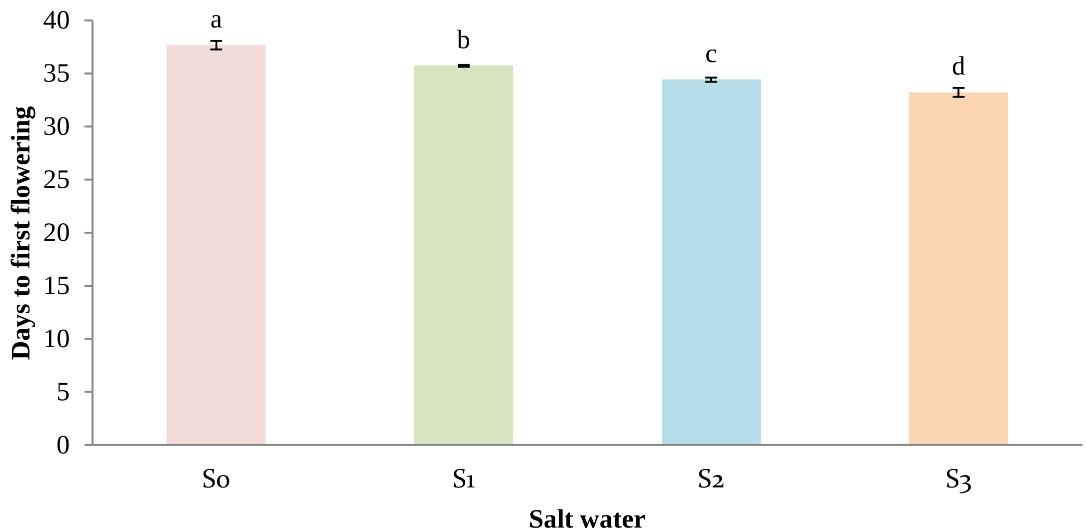


In the bar graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Vertical bars indicate standard error (SE). Here, Here, V_1 = BARI tomato-8, V_2 = BARI tomato-9, V_3 = BARI tomato-10

Figure 7. Effect of variety on days to first flowering of tomato

Effect of salt water

Tomatoes grown in hydroponic culture at various salt water concentrations differed significantly in terms of days to first flowering (Figure 8). According to the experimental results the S_0 treatment took the longest 37.66 days for first flowering. While S_3 treatment had the shortest time required for first flowering at 33.23 days. According to El Mogy *et al*. (2018), increasing salinity causes osmotic disturbance, physiological alterations in transpiration, stomatal conductance, chlorophyll concentra-tion, photosynthesis, and leaf and root expression. As a result, days to first flowering occurred early, therefore, reduction in quality of flower (size, color, length and stem thickness) and yield in cherry tomatoes.



In the bar graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Vertical bars indicate standard error (SE). Here, S_0 = 0 NaCl ml L^{-1} + standard solution, S_1 = NaCl 0.5 ml L^{-1} + standard solution, S_2 = NaCl 0.75 ml L^{-1} + standard solution and S_3 = NaCl 1 ml L^{-1} + standard solution

Figure 8. Effect of salt water on days to first flowering of tomato

Combined effect of variety and different salt water concentration

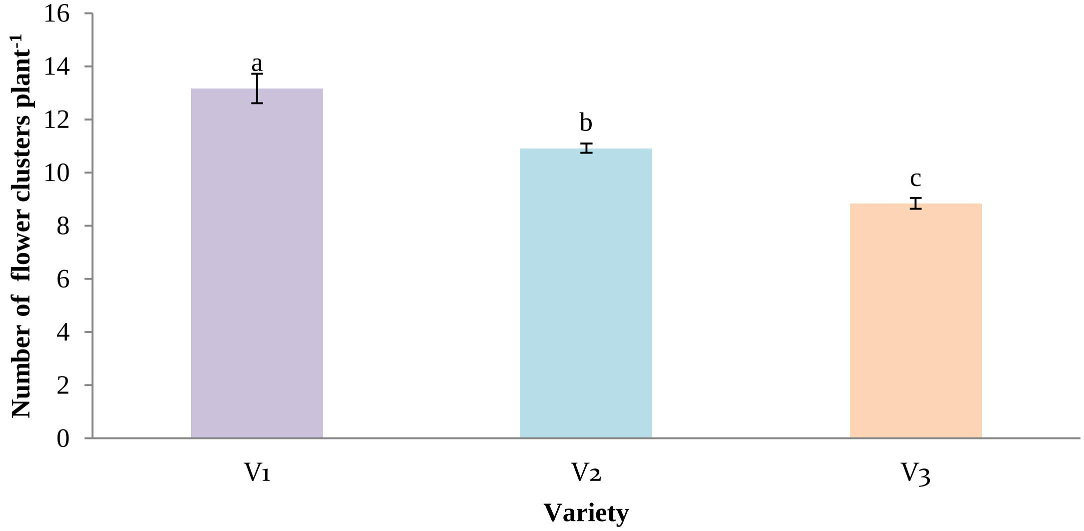
The days required for tomato flowering in a hydroponic system were significantly affected by variety and salt water concentrations (Table 4). According to the experimental results, the highest 38.67 days required for first flowering was discovered in the V_2S_0 treatment combination, which was statistically comparable to the V_3S_0 (37.99) treatment combination. While the V_1S_3 treatment combination had the lowest 32.34 days required for first flowering, and it was statistically comparable to the V_2S_3 (32.67) treatment combination.

4.5 Number of flower clusters plant^{-1}

Effect of variety

The number of flower clusters plant^{-1} at 60 DAT was significantly influenced by the tomato varieties grown in hydroponic culture system (Figure 9). Experimental result showed that the V_1 treatment had the highest number of flower clusters plant^{-1} (13.17) at

60 DAT. On the other hand the V_3 treatment, had the lowest flower clusters plant^{-1} (8.84) at 60 DAT. The varying genetic make-up of the tomato cultivars may be the cause of the variations in the number of flower clusters plant^{-1}. The findings of Naz *et al*. (2012), who indicated that there was significant variance in the number of flower clusters plant^{-1} among tomato varieties, were similar to the findings of the present study.

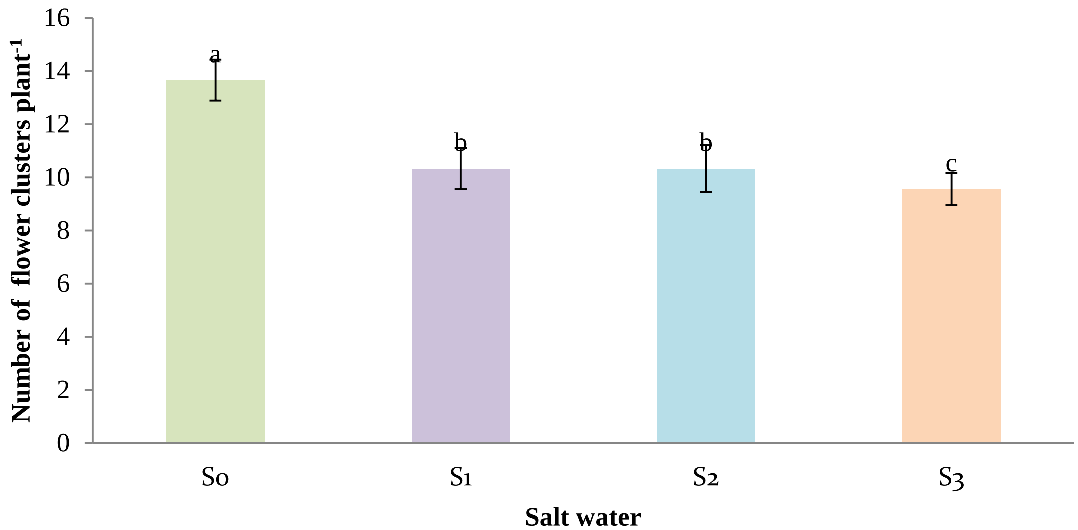


In the bar graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Vertical bars indicate standard error (SE). Here, Here, V_1 = BARI tomato-8, V_2 = BARI tomato-9, V_3 = BARI tomato-10

Figure 9. Effect of variety on number of flower clusters plant^{-1} at 60 DAT

Effect of salt water

The number of flower clusters plant^{-1} of tomato at 60 DAT was significantly affected by different salt water concentrations (Figure 10). At 60 DAT, the S_0 treatment had the highest number of flower clusters plant^{-1} (13.66). While the S_3 treatment had the lowest number of flower clusters plant^{-1} (9.56) at 60 DAT. The flower clusters plant^{-1} trait was affected negatively by saline conditions, this could be explained by the occurrence of ionic toxicity and nutritional imbalance due to the extreme accumulation of certain ions such as Na^+ and Cl^- in plant tissue. Zhang *et al*. (2016) reported that salt added to nutrient solution is an easy method that can improve tomato fruit quality, but plant growth and fruit and flower production were negatively affected. Salinity can decrease root water uptake through its osmotic effect, and subsequently induce water stress result in lower flower clusters plant^{-1}.



In the bar graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Vertical bars indicate standard error (SE). Here, S_0 = 0 NaCl ml L^{-1} + standard solution, S_1 = NaCl 0.5 ml L^{-1} + standard solution, S_2 = NaCl 0.75 ml L^{-1} + standard solution and S_3 = NaCl 1 ml L^{-1} + standard solution

Figure 10. Effect of salt water on number of flower clusters plant^{-1} at 60 DAT

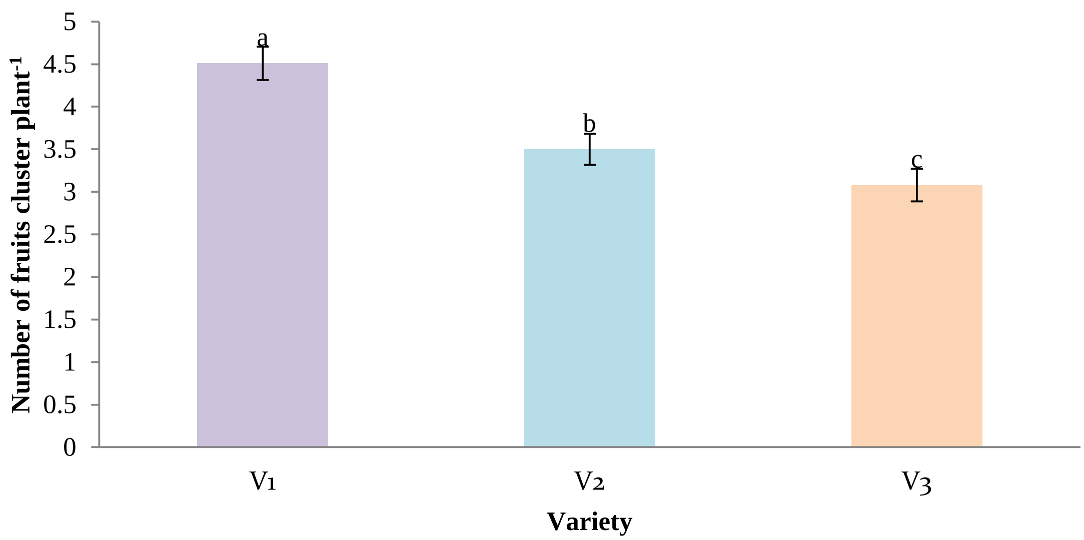
Combined effect of temperature and different salt water concentration

In hydroponic system tomato plant grown with different varieties along with various salt water concentrations had shown significant effect on the number of flower clusters plant^{-1} of tomato at 60 DAT (Table 4). The V_1S_0 treatment combination had the highest number of flower clusters plant^{-1} (16.33) at 60 DAT. However at 60 DAT, the V_3S_3 treatment combination had the lowest flower clusters plant^{-1} (7.67), which was statistically similar to the V_3S_2 (11.33) and V_3S_1 (11.33) treatment combination.

4.6 Number of fruits cluster plant^{-1}

Effect of variety

The number of fruits clusters plant^{-1} at 60 DAT was significantly influenced by the tomato varieties grown in the hydroponic culture system (Figure 11). According to experimental findings, V_1 treatment had the highest fruit clusters plant^{-1} (4.51) at 60 DAT. While the V_3 treatment had the lowest fruit clusters plant^{-1} (3.08) at 60 DAT. The diverse genetic make-up of the tomato varieties may be the cause of the variations in the number of fruit clusters on plant^{-1}. Kerketta *et al.* (2018) reported that the number of tomato fruit clusters per plant^{-1} varies depending on the genotype, and with genotype Kashi Aman having the highest fruit set per cluster (5.33) in comparison to other genotypes.



In the bar graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Vertical bars indicate standard error (SE). Here, Here, V_1 = BARI tomato-8, V_2 = BARI tomato-9, V_3 = BARI tomato-10

Figure 11. Effect of variety on number of fruits cluster plant^{-1} at 60 DAT

Effect of salt water

Different salt water concentrations significantly affected the number of fruits cluster plant^{-1} of tomato at 60 DAT (Figure 12). Experimental result revealed that, the S_0 treatment had the highest number of fruit clusters plant^{-1} at 60 DAT (4.45). At 60 DAT, the S_3 treatment had the lowest number of fruits clusters plant^{-1} (2.56). Ahmad *et al.* (2017) reported that fruit cluster plant^{-1} was reduced under various salinity stress condition comparable to control treatment.

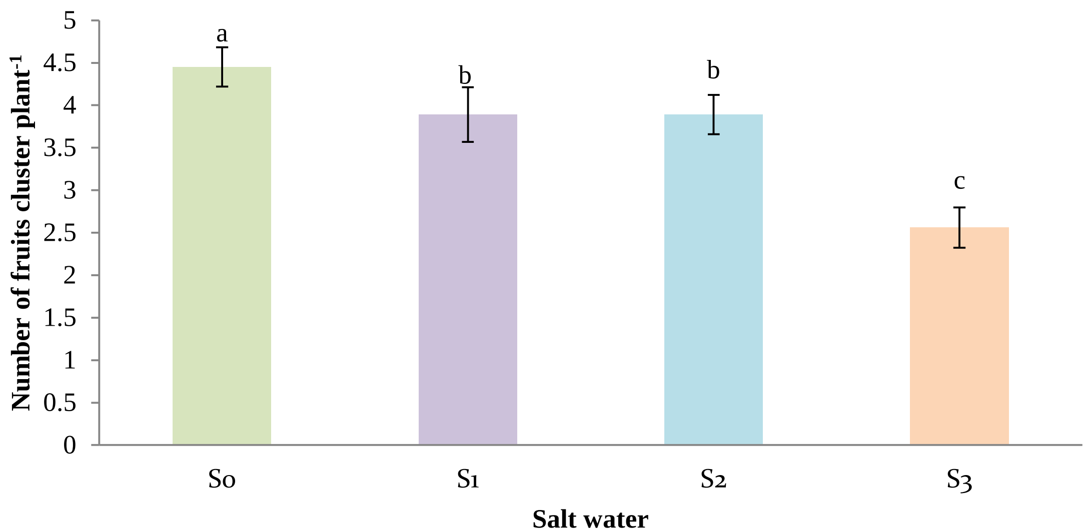


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Figure 12. Effect of salt water on number of flower clusters plant^{-1} at 60 DAT

Combined effect of temperature and different salt water concentration

In a hydroponic system, tomato plants grown at varying varieties and salt water concentrations had shown significant effect on the number of fruits clusters plant^{-1} at 60 DAT (Table 4). At 60 DAT, the V_1S_0 treatment combination had the highest number of fruits clusters plant^{-1} (5.00) which was statistically comparable to the V_1S_1 treatment combination (5.00). However, the V_3S_3 treatment combination had the lowest fruits clusters plant^{-1} (2.00) at 60 DAT.

Table 4. Combined effect of variety and different salt water concentration on days to first flowering, number of flower clusters plant^{-1} and number of fruit cluster plant^{-1} of tomato

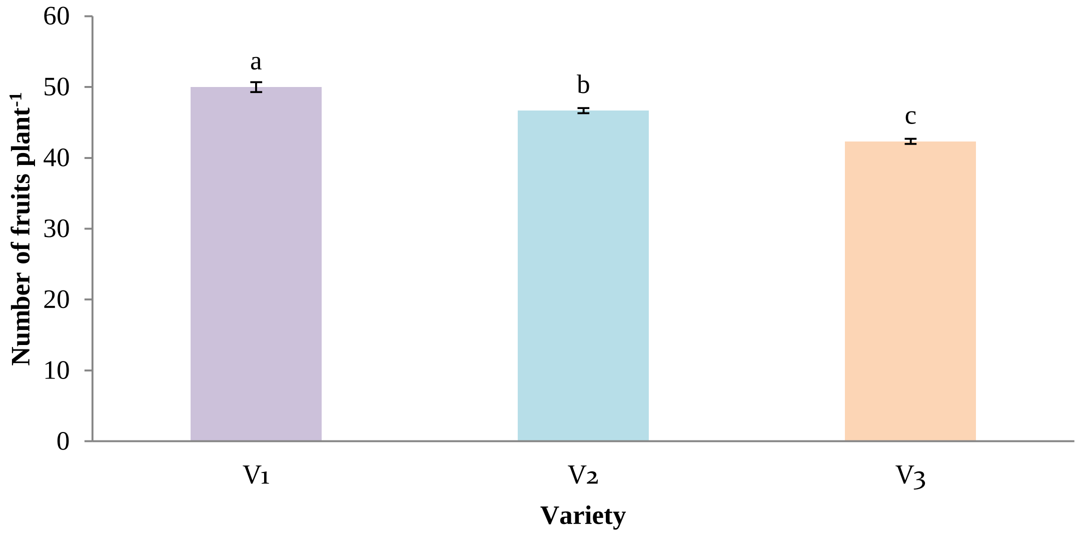
Treatment Combinations	Days to first flowering	No. flower clusters plant^{-1} (at 60 DAT)	No. fruits cluster plant^{-1} (at 60 DAT)
V_1S_0	36.33 b	16.33 a	5.00 a
V_1S_1	35.45 b-d	12.00 cd	5.00 a
V_1S_2	33.89 f	13.00 b	4.67 b
V_1S_3	32.34 g	11.33 d	3.36 d
V_2S_0	38.67 a	12.33 bc	4.67 b
V_2S_1	35.67 b-d	11.33 d	3.33 d
V_2S_2	35.00 c-e	10.33 e	3.67 c
V_2S_3	32.67 g	9.67 e	2.33 e
V_3S_0	37.99 a	12.33 bc	3.67 c
V_3S_1	36.00 bc	7.67 f	3.33 d
V_3S_2	34.33 ef	7.67 f	3.33 d
V_3S_3	34.67 d-f	7.67 f	2.00 f
$LSD_{(0.05)}$	1.07	0.70	0.17
CV(%)	1.80	3.80	2.69

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, V_1 = BARI tomato-8, V_2 = BARI tomato-9, V_3 = BARI tomato-10, S_0 = 0 NaCl ml L^{-1} + standard solution, S_1 = NaCl 0.5 ml L^{-1} + standard solution, S_2 = NaCl 0.75 ml L^{-1} + standard solution and S_3 = NaCl 1 ml L^{-1} + standard solution

4.7 Number of fruits plant^{-1}

Effect of variety

In hydroponic culture, tomato variety had shown significant effect on the number of fruits plant^{-1} (Figure 13). Experimental result revealed that the V_1 treatment contained the highest number of fruits plant^{-1} (50.00). In contrast, the V_3 treatment had the lowest number fruits plant^{-1} (42.33). The differences in number of fruits plant^{-1} might be due to the different genetic makeup of the tomato cultivars. Biswas *et al.* (2017) found similar results which supported the present finding and reported that the highest fruit yield plant^{-1} was recorded from the genotype HT-025 (2.02 kg plant^{-1}) and the lowest was recorded from the line FP-5 (1.17 kg plant^{-1}). The variation in different characters of tomato might be due to difference in cultivars used.



In the bar graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Vertical bars indicate standard error (SE). Here, Here, V_1 = BARI tomato-8, V_2 = BARI tomato-9, V_3 = BARI tomato-10

Figure 13. Effect of variety on number of fruits plant^{-1} of tomato

Effect of salt water

The number of fruits per plant^{-1} tomatoes was significantly influenced by different salt water concentrations (Figure 14). The experimental results demonstrated that the S_0 treatment had the highest number of fruits per plant^{-1} (49.22). While the S_3 treatment had the lowest number fruits per plant^{-1} (42.99). Salinity disturbs mineral supply, either an excess or deficiency; induced changes in concentrations of specific ions in the growth medium, may have a direct influence on growth and development result in lowest fruits per plant^{-1} of tomato. The result obtained from the present study was similar with the findings of Ahmad *et al*. (2019) who stated that number of fruits plant^{-1} decrease with increasing salinity level.

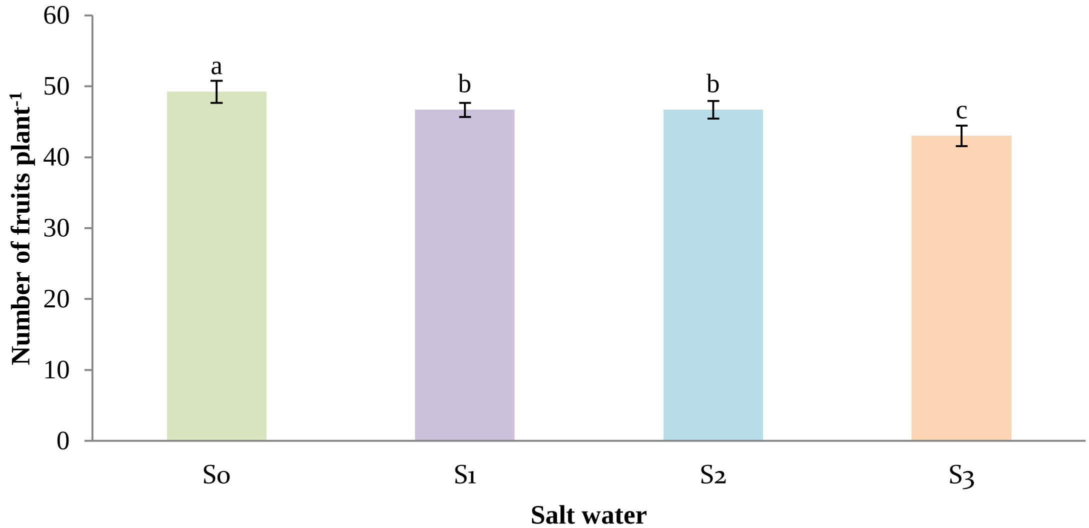


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Figure 14. Effect of salt water on number of fruits plant^{-1} of tomato

Combined effect of variety and different salt water concentration

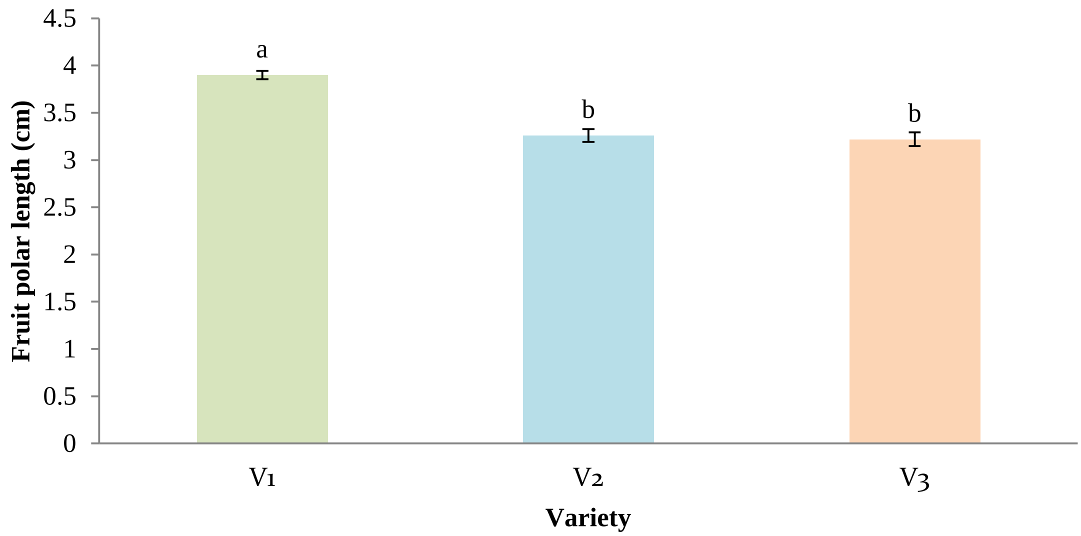
Tomato plants grown in a hydroponic system with different varieties and salt water concentrations had shown significant effect on the number of fruits plant^{-1} (Table 5). The V_1S_0 treatment combination had the highest number fruits plant^{-1} (53.67) which was statistically similar with V_1S_1 (50.67) treatment combination. While the V_3S_3 treatment combination, on the other hand, recorded the lowest number fruits plant^{-1} (38.67).

4.8 Fruit polar length (cm)

Effect of variety

Tomato fruit polar length (cm) was significantly influenced by different varieties grown in a hydroponic culture system (Figure 15). Experimental result revealed that the V_1 treatment, had the highest fruit polar length (3.90 cm). While the shortest fruit polar length (3.22 cm) was found in V_3 treatment which was statistically similar with V_2 (3.26 cm) treatment. Because of the genetic potential of the tomato varieties, there was a large differences in fruit polar length. Similar findings were obtained in Sanjida *et al*. (2020)

investigation, and they suggested that the summer tomato varieties' varied genetic make-up may be the cause of the noticeable variances in fruit length and fruit breadth.



In the bar graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Vertical bars indicate standard error (SE). Here, Here, V_1 = BARI tomato-8, V_2 = BARI tomato-9, V_3 = BARI tomato-10

Figure 15. Effect of variety on fruit polar length of tomato

Effect of salt water

Different levels of salt water concentrations significantly influenced on the fruit polar length (cm) of tomato (Figure 16). The highest fruit polar length (3.67 cm) was found in S_0 treatment. While the lowest fruit polar length (3.17 cm) was found in S_3 treatment. This could be because the presence of NaCl in the growing media in an improper mixture slows the vegetative growth of the plants. The higher amount of salinity resulted in a shorter plant with fewer leaves, which may have reduced photosynthetic activities and produced insufficient food for plant development and fruit enlargement. High amounts of Na + can induce an imbalance in the uptake and utilization of other cations, as well as disruption of chloroplasts, resulting in less photosynthesis and a shorter fruit polar length in tomatoes. Giannakoula and Ilias (2013) reported that the negative effect of salt stress on tomatoes is a result of retarded plant growth due to decline in photosynthetic rate which leads to a reduction in fruit size and total yield per plant, which are the most important factors for tomato producers.

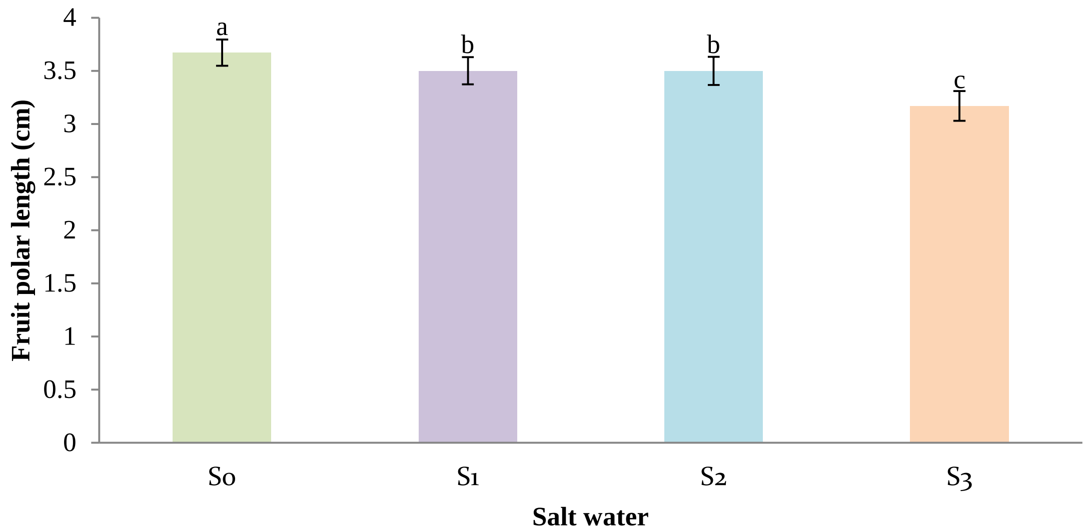


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Figure 16. Effect of salt water on fruit polar length of tomato

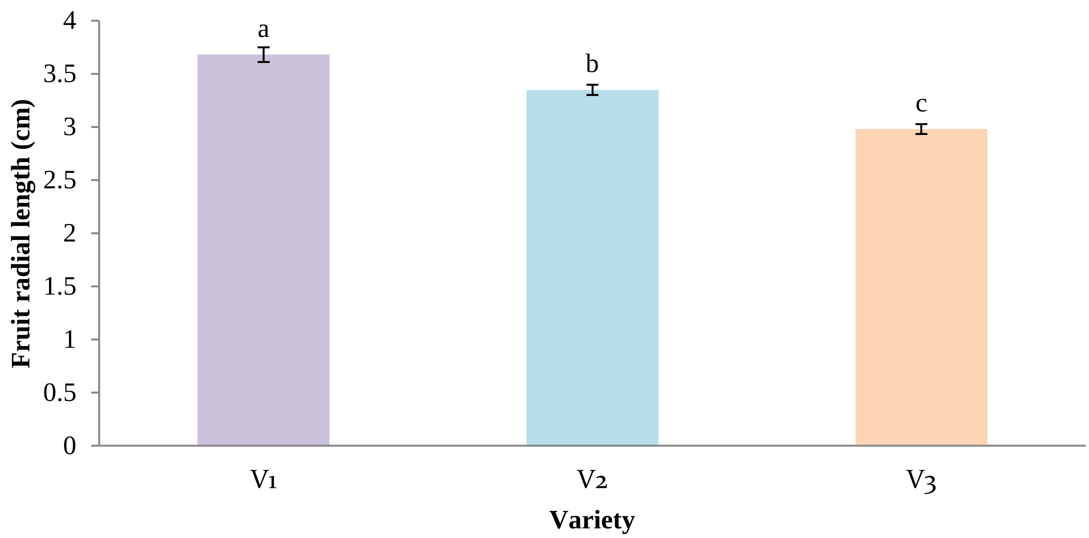
Combined effect of variety and different salt water concentration

Tomato plants grown in a hydroponic system with different varieties and salt water concentrations had shown significant effect on the polar length of the fruit (Table 5). V_1S_0 treatment combination had the longest fruit polar length (4.08 cm). In contrast, the V_3S_3 treatment combination had the shortest fruit polar length (2.89 cm).

4.9 Fruit radial length (cm)

Effect of variety

Tomato varieties growing in hydroponic culture significantly varying fruit radial length (cm) of tomato (Figure 17). The highest fruit radial length (3.68 cm) was found in V_1 treatment. While the lowest fruit radial length (2.98 cm) was found in V_3 treatment. The significant variation in relation to fruit radial length was probably due to the genetic potentiality of the tomato cultivars. Ali *et al.* (2012) found maximum fruit diameter (5.19 cm) and minimum fruit diameter (4.50 cm) in tomato hybrids T-7010 and PTM-1603 respectively during studying the performance of various tomato hybrids.



In the bar graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Vertical bars indicate standard error (SE). Here, Here, V_1 = BARI tomato-8, V_2 = BARI tomato-9, V_3 = BARI tomato-10

Figure 17. Effect of variety on fruit radial length of tomato

Effect of salt water

The fruit radial length (cm) of tomato was significantly influenced by different amounts of salt water concentration (Figure 18). Experimental result showed that, the S_0 treatment yielded the longest fruit radial length (3.60 cm). While the S_3 treatment had the shortest fruit polar length (3.07 cm). These results could be explained by that fact that high salt levels decrease water potential in plants which reduces water flow into fruit and limits the rate of fruit expansion. Moniruzzaman *et al*. (2013) reported that salinity affects plant growth and development by disturbing the water balance, causing an imbalance in plant nutrition and affecting plant physiological and biochemical processes result in poor fruit size and shape of tomato.

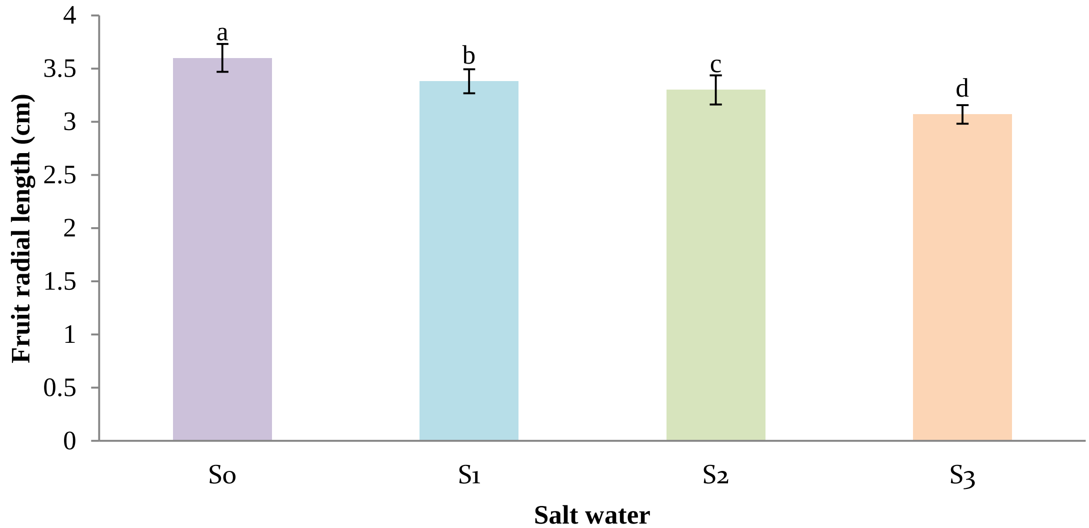


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Figure 18. Effect of salt water on fruit radial length of tomato

Combined effect of temperature and different salt water concentration

Tomato plants grown in a hydroponic system with different varieties and salt water concentrations had shown significant effect on the fruit radial length of tomato (Table 5). The V_1S_0 treatment combination had the longest fruit radial length (3.99 cm). While the V_3S_3 treatment combination, on the other hand, had the smallest fruit radial length (2.79 cm), which was statistically equivalent to the V_3S_2 treatment combination (2.86 cm).

Table 5. Combined effect of variety and different salt water concentration on number of fruits plant^{-1}, fruit polar and radial length of tomato

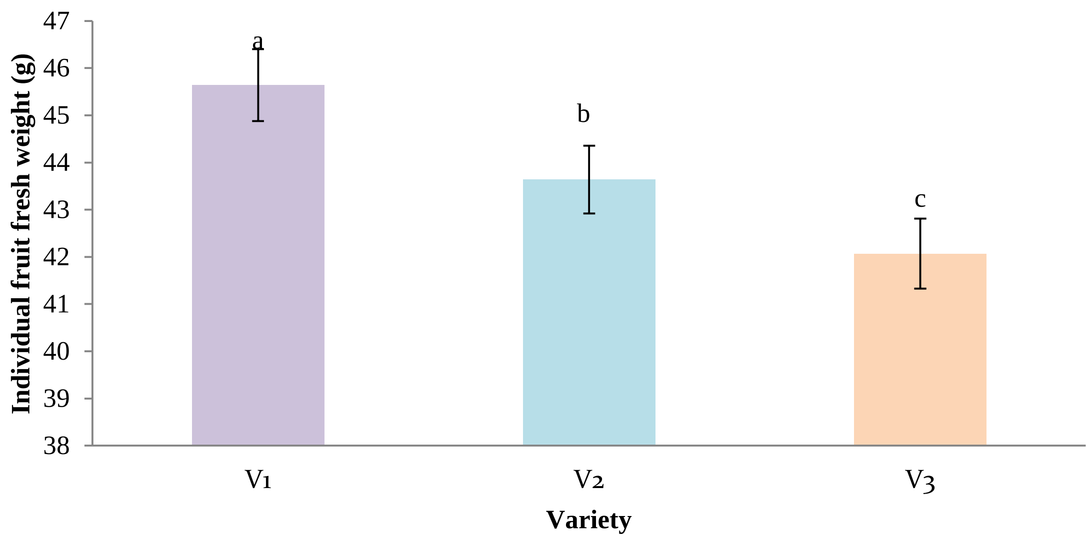
Treatment Combinations	No. of fruits plant^{-1}	Fruit polar length (cm)	Fruit radial length (cm)
V_1S_0	53.67 a	4.08 a	3.99 a
V_1S_1	50.67 ab	3.93 b	3.75 b
V_1S_2	48.33 b-d	3.93 b	3.67 bc
V_1S_3	47.33 c-e	3.65 c	3.31 de
V_2S_0	49.67 bc	3.36 de	3.61 c
V_2S_1	48.00 b-d	3.31 de	3.32 d
V_2S_2	46.00 d-f	3.38 d	3.37 d
V_2S_3	43.00 f	2.97 g	3.11 f
V_3S_0	44.33 ef	3.58 c	3.20 ef
V_3S_1	43.00 f	3.23 ef	3.08 f
V_3S_2	43.33 f	3.16 f	2.86 g
V_3S_3	38.67 g	2.89 g	2.79 g
$LSD_{(0.05)}$	3.01	0.13	0.12
CV(%)	3.84	2.29	2.04

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, V_1 = BARI tomato-8, V_2 = BARI tomato-9, V_3 = BARI tomato-10, S_0 = 0 NaCl ml L^{-1} + standard solution, S_1 = NaCl 0.5 ml L^{-1} + standard solution, S_2 = NaCl 0.75 ml L^{-1} + standard solution and S_3 = NaCl 1 ml L^{-1} + standard solution

4.10 Individual fruit fresh weight (g)

Effect of variety

Different tomato cultivars considerably altered the individual fruit weight (g) in a hydroponic growth system (Figure 19). Results of the experiment showed that the V_1 treatment, had the highest individual fresh fruit weight (45.64 g). While the V_3 treatment had the lowest individual fresh fruit weight (42.07 g). The findings of Shah *et al*. (2021), who showed that tomato cultivars varied in fresh weight, were consistent with the findings of the current investigation.

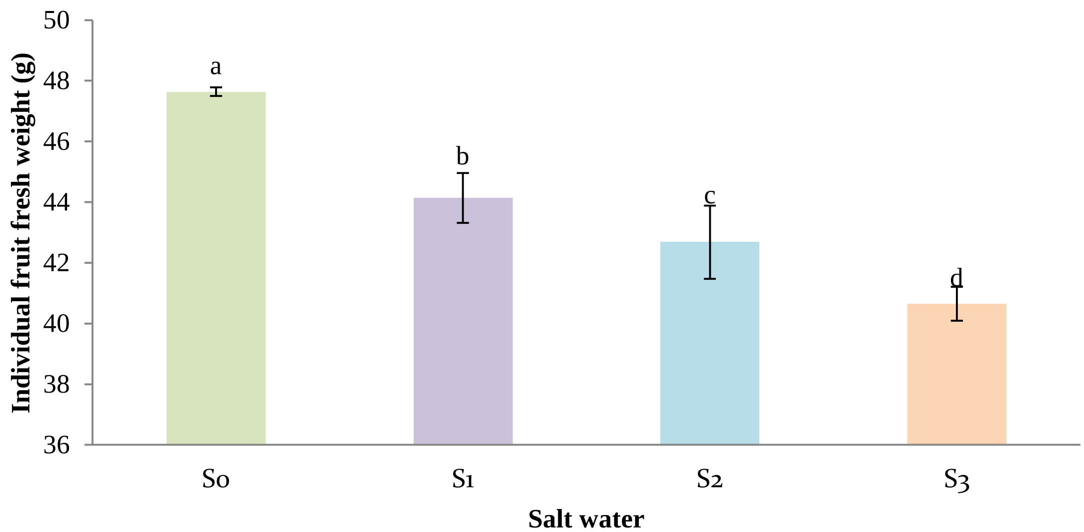


In the bar graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Vertical bars indicate standard error (SE). Here, Here, V_1 = BARI tomato-8, V_2 = BARI tomato-9, V_3 = BARI tomato-10

Figure 19. Effect of temperature on individual fruit fresh weight of tomato

Effect of salt water

Different salt water concentrations significantly influenced individual tomato fruit fresh weight (g) in a hydroponic growing system (Figure 20). According to the experimental results, S_0 treatment had the highest individual fruit fresh weight of tomato (47.64 g). While S_3 had the lowest individual fruit fresh weight of tomato (40.65 g). Increasing salt water concentrations gradually decreasing individual tomato fruit fresh weight due reason that salinity affects plants with nitrogen uptake, reducing growth and stopping plant reproduction. Some ions (particularly chloride) are toxic to plants and as the concentration of these ions increases, the plant is poisoned and dies. Ahmad *et al.* (2017) showed that fresh fruit weight of tomato was reduced under increased salinity stress condition.



In the bar graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Vertical bars indicate standard error (SE). Here, S_0 = 0 NaCl ml L^{-1} + standard solution, S_1 = NaCl 0.5 ml L^{-1} + standard solution, S_2 = NaCl 0.75 ml L^{-1} + standard solution and S_3 = NaCl 1 ml L^{-1} + standard solution

Figure 20. Effect of salt water on individual fruit fresh weight of tomato

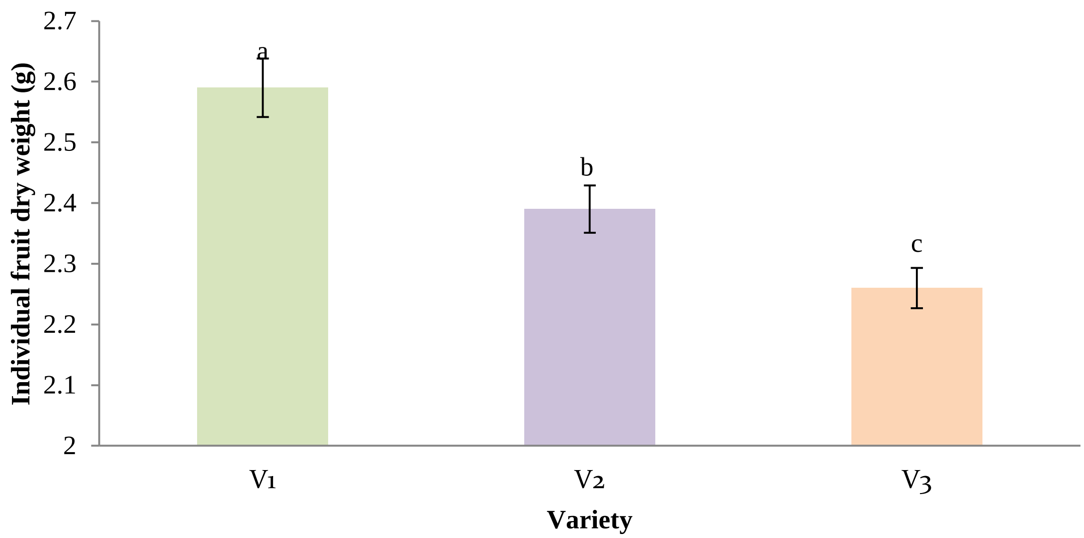
Combined effect of variety and different salt water concentration

Tomato plants grown in a hydroponic system with different varieties and salt water concentrations had shown significant effect on the fresh weight of individual fruits (Table 6). The V_1S_0 treatment combination had the highest individual fruit fresh weight (48.13 g), which was statistically comparable to the V_1S_1 (46.96 g) and V_3S_0 (47.42 g) treatment combination. While the lowest individual fruit fresh weight for the V_3S_3 treatment combination was (38.76 g), which was statistically equal to the V_3S_2 treatment combination (39.01 g).

4.11 Individual fruit dry weight (g)

Effect of variety

In a hydroponic growth system, various tomato varieties significantly influenced the individual fruit dry weight (g) of tomato (Figure 21). The experiment's findings revealed that the V_1 treatment had the highest weight of individual dry fruit (2.59 g). While the V_3 treatment had the lowest individual fruit dry weight of tomato (2.26 g).

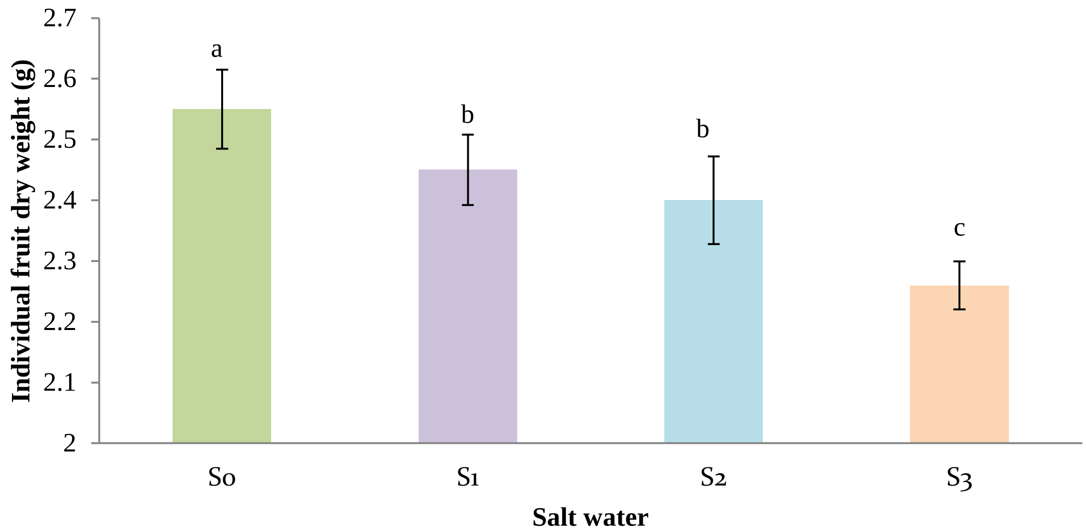


In the bar graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Vertical bars indicate standard error (SE). Here, Here, V_1 = BARI tomato-8, V_2 = BARI tomato-9, V_3 = BARI tomato-10

Figure 21. Effect of variety on individual fruit dry weight of tomato

Effect of salt water

Individual tomato fruit dry weight (g) was significantly influenced by different salt water concentrations in a hydroponic growing system (Figure 22). Experimental result revealed that, the S_0 treatment had the highest individual fruit dry weight of tomato, (2.55 g). While the S_3 treatment had the lowest individual fruit dry weight of tomato (2.26 g). Plants demonstrated toxicity symptoms such as inhibition of seed germination, decrease in plant height, lower fruit number, reduced fresh and dry weight, yield plant^{-1}, and sometimes leads to death when subjected to high salt conditions in soil or solution culture. The result obtained from the present study was similar with the findings of Al Daej (2018) who reported that different salinity treatments had a detrimental impact on average fruit fresh and dry weight as well as fruit number when compared to the control treatment.



In the bar graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Vertical bars indicate standard error (SE). Here, S_0 = 0 NaCl ml L^{-1} + standard solution, S_1 = NaCl 0.5 ml L^{-1} + standard solution, S_2 = NaCl 0.75 ml L^{-1} + standard solution and S_3 = NaCl 1 ml L^{-1} + standard solution

Figure 22. Effect of salt water on individual fruit dry weight of tomato

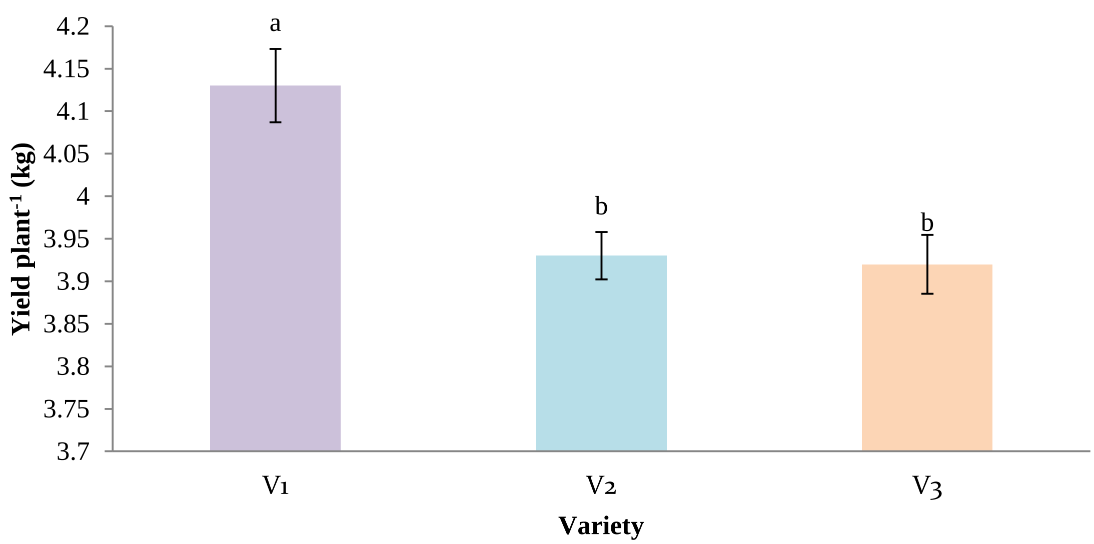
Combined effect of variety and different salt water concentration

Tomato plants grown in a hydroponic system with different varieties and salt water concentrations had shown significant effect on the dry weight of individual fruits (Table 6). Individual fruit dry weight was highest in the V_1S_0 treatment combination (2.77 g). While the V_3S_3 treatment combination had the lowest individual fruit dry weight (2.12 g), which was statistically equivalent to the V_3S_2 treatment combination (2.20 g).

4.12 Yield plant^{-1} (kg)

Effect of variety

The yield plant^{-1} of tomato varietals grown under hydroponic culture varied significantly (Figure 23). According to experimental findings, the V_1 treatment had the highest yield plant^{-1} (4.13 kg). While the V_3 treatment had the lowest yield plant^{-1} (3.92 kg) which was statistically similar with V_2 (3.93 kg) treatment. The genetic potential of the tomato varieties was likely the cause of the large difference in relation to yield plant^{-1}. The findings of Singh *et al*. (2013), who indicated that Avinash-23 recorded the highest yield per plant of 2.90 kg followed by Richa with a yield of 2.88 kg, were consistent with the results of the current study.

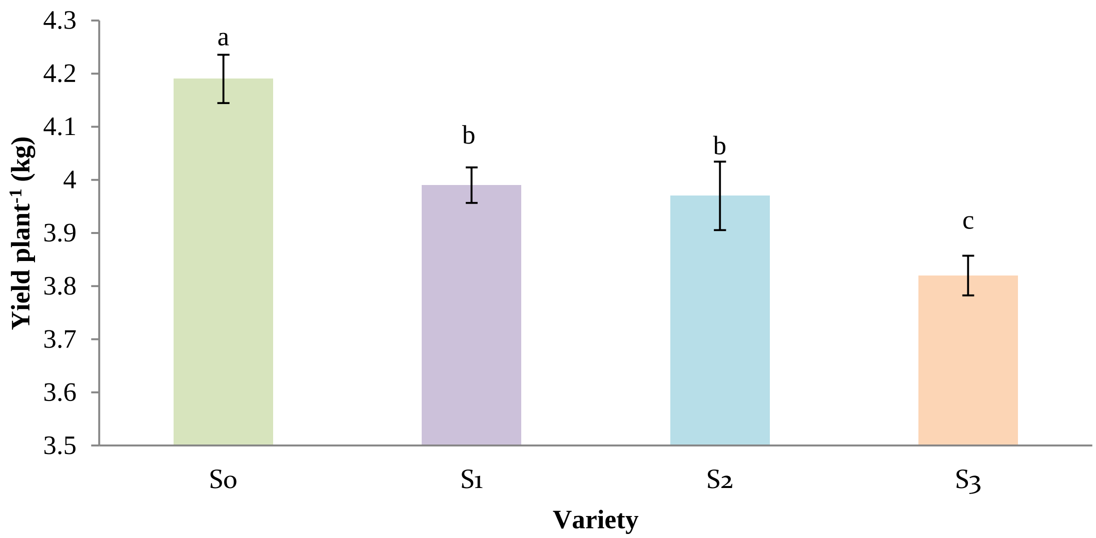


In the bar graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Vertical bars indicate standard error (SE). Here, Here, V_1 = BARI tomato-8, V_2 = BARI tomato-9, V_3 = BARI tomato-10

Figure 23. Effect of variety on yield plant^{-1} of tomato

Effect of salt water

Different salt water concentrations had shown significant effect on yield plant^{-1} of tomato (kg) in a hydroponic growing system (Figure 24). The results of the experiment showed that the S_0 treatment had the highest yield plant^{-1} (4.19 kg). Yield plant^{-1} of tomato was lowest (3.82 kg) in the S_3 treatment. The reason for reduction of yield plant^{-1} of tomato caused by salinity could be due to a lower supply of nutrients and water to the fruit during its development more than to a deficit in the supply of mineral ions, organic acids or starch. Zhang *et al.* (2017) showed that salinity reduces tomato root elongation rate and lateral root growth due to restriction of root cell growth and increased root lesion. Tomato leaf, shoot height and stem diameter reduced under salinity stress. Total yield of tomato is significantly reduced at salinity equal and above 5 dS m^{-1}, and a 7.2 % yield reduction per unit increase in salinity. Ahmed *et al.* (2017) reported that fresh water gave the highest fruit yield per plant tomato (1.52 kg) whereas the lowest fruit yield per plant (0.667 kg) was obtained from the higher level of saline water treatment of 10 dS m^{-1}.



In the bar graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Vertical bars indicate standard error (SE). Here, S_0 = 0 NaCl ml L^{-1} + standard solution, S_1 = NaCl 0.5 ml L^{-1} + standard solution, S_2 = NaCl 0.75 ml L^{-1} + standard solution and S_3 = NaCl 1 ml L^{-1} + standard solution

Figure 24. Effect of salt water on yield plant^{-1} of tomato

Combined effect of variety and different salt water concentration

Different varieties and salt water concentrations, tomato plants grown in a hydroponic system had shown significant effect on the yield plant^{-1} (Table 6). The V_1S_0 treatment combination had the highest yield plant^{-1} for tomatoes (4.33 kg). While plant^{-1}'s yield was lowest when the V_3S_3 treatment combination was used (3.70 kg).

Table 6. Combined effect of variety and different salt water concentration on fresh weight, dry weight and yield pot^{-1} of tomato

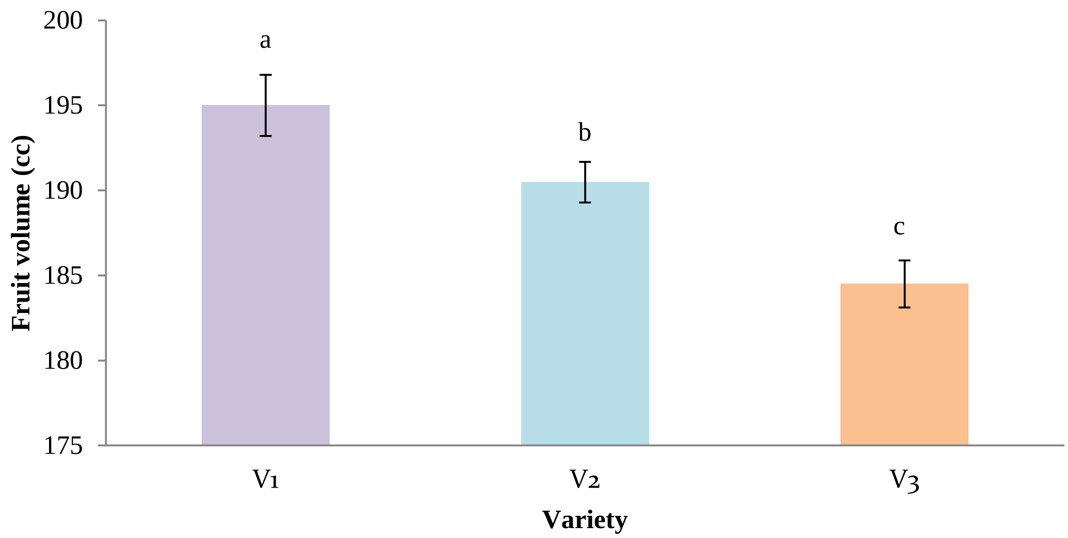
Treatment Combinations	Fresh weight (g)	Dry weight (g)	Yield pot^{-1} (kg)
V_1S_0	48.13 a	2.77 a	4.33 a
V_1S_1	46.96 ab	2.65 b	4.09 c
V_1S_2	46.26 b	2.63 b	4.19 b
V_1S_3	41.20 d	2.32 d	3.92 e
V_2S_0	47.37 ab	2.46 c	4.06 c
V_2S_1	42.40 cd	2.39 cd	3.89 e
V_2S_2	42.79 c	2.38 cd	3.91 e
V_2S_3	41.98 cd	2.33 d	3.84 f
V_3S_0	47.42 ab	2.41 cd	4.17 b
V_3S_1	43.07 c	2.32 d	3.99 d
V_3S_2	39.01 e	2.20 e	3.82 f
V_3S_3	38.76 e	2.12 e	3.70 g
$LSD_{(0.05)}$	1.35	0.11	0.04
CV(%)	1.82	2.80	3.70

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, V_1 = BARI tomato-8, V_2 = BARI tomato-9, V_3 = BARI tomato-10, S_0 = 0 NaCl ml L^{-1} + standard solution, S_1 = NaCl 0.5 ml L^{-1} + standard solution, S_2 = NaCl 0.75 ml L^{-1} + standard solution and S_3 = NaCl 1 ml L^{-1} + standard solution

4.13 Fruit volume (cc)

Effect of variety

Hydroponically grown tomato varietals had shown significant effect on tomato fruit volume (cc) (Figure 25). The maximal fruit volume (195.00 cc) was discovered in the V_1 treatment. While V_3 treatment, had the smallest fruit volume (184.50 cc). The genetic make-up of the crop and the environmental factors, which have a significant impact on how well the crop performs, were the causes of the variance in fruit volume.

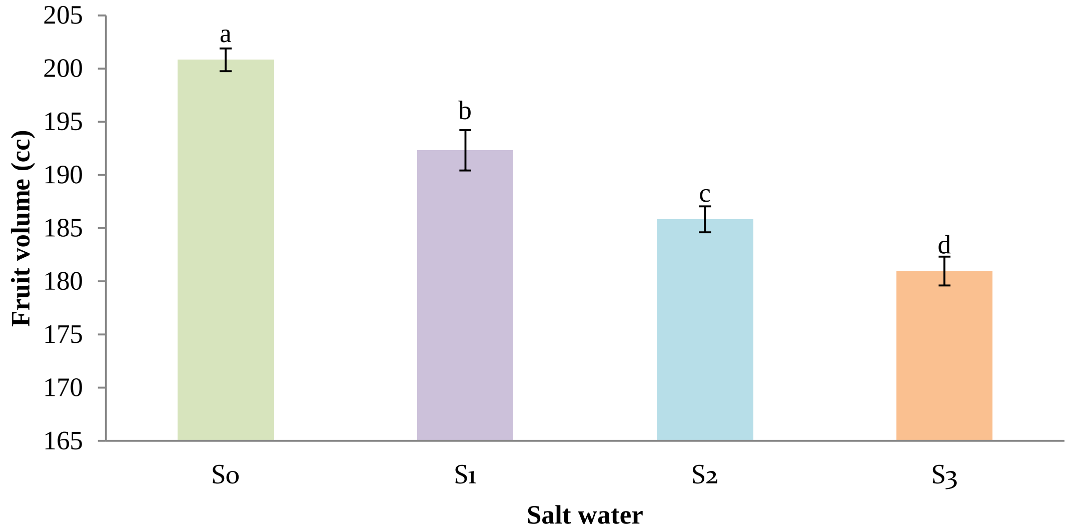


In the bar graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Vertical bars indicate standard error (SE). Here, Here, V_1 = BARI tomato-8, V_2 = BARI tomato-9, V_3 = BARI tomato-10

Figure 25. Effect of variety on fruit volume of tomato

Effect of salt water

The fruit volume (cc) of tomatoes produced by hydroponically grown tomatoes at various salt water concentrations was significantly differed (Figure 26). According to the experimental findings, the S_0 treatment had the highest fruit volume (200.83 cc). The S_3 treatment on the other hand had the lowest fruit volume (180.97 cc). Salinity-related reduction in tomato fruit volume may be the cause of changes in photosynthetic product translocation toward the roots, a reduction in plant height, particularly in the leaves, a partial or complete enclosing of stomata, and direct effects of salt on the photosynthesis system and ion balance.



In the bar graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Vertical bars indicate standard error (SE). Here, S_0 = 0 NaCl ml L^{-1} + standard solution, S_1 = NaCl 0.5 ml L^{-1} + standard solution, S_2 = NaCl 0.75 ml L^{-1} + standard solution and S_3 = NaCl 1 ml L^{-1} + standard solution

Figure 26. Effect of salt water on fruit volume of tomato

Combined effect of variety and different salt water concentration

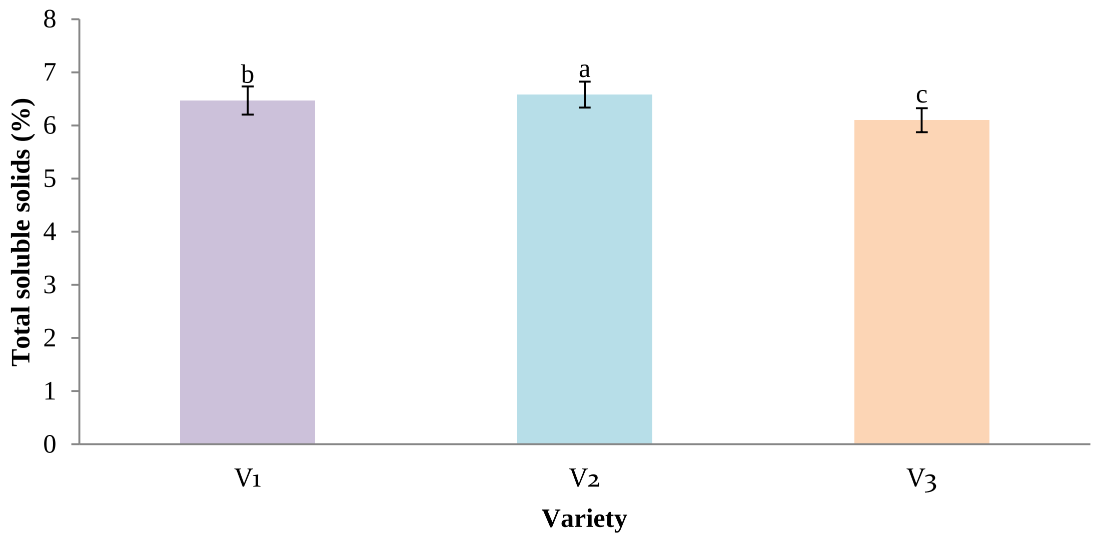
Different varieties and salt water concentrations, had shown significant effect on the fruit volume (cc) of tomato grown in a hydroponic system (Table 7). The V_1S_0 treatment combination had the highest fruit volume of tomato (204.50 cc) which was statistically similar with V_3S_0 (199.50 cc) treatment combination. While the lowest fruit volume was founded when the V_3S_3 treatment combination (169.50 cc).

4.14 Total soluble solids (%)

Effect of variety

The total soluble solids (%) of tomatoes was significantly influenced by tomato varieties when grown in hydroponic culture (Figure 27). Results of the experiment showed that the V_2 treatment had the highest amount of total soluble solids (6.58%). While the V_3 treatment had the lowest total soluble solids (6.10 %). The genetic make-up of the crop and the environmental factors, which have a significant impact on how well the crop performs, caused the variance in total soluble solids. Similar findings were made by

Sanjida *et al.* (2020), who showed that for summer tomato varieties, V_2 (BARI hybrid tomato 8) had the highest total soluble solids (TSS) (5.41%), while V_1 had the lowest total soluble solids (4.97%) (BARI hybrid tomato 4). variation was due to the varietal effect of different cultivars.

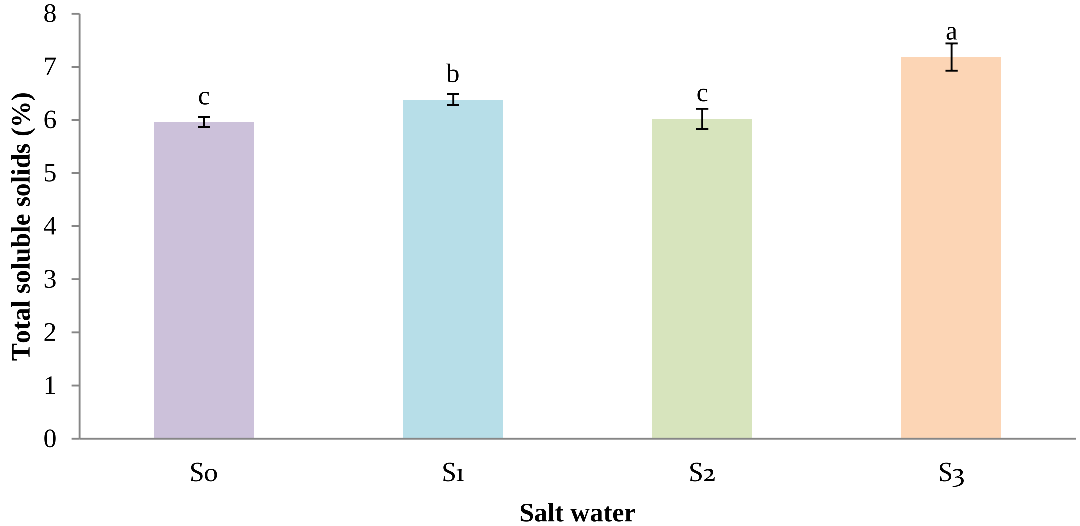


In the bar graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Vertical bars indicate standard error (SE). Here, Here, V_1 = BARI tomato-8, V_2 = BARI tomato-9, V_3 = BARI tomato-10

Figure 27. Effect of variety on total soluble solids of tomato

Effect of salt water

The variable salt water concentration at which tomatoes were grown in a hydroponic system had shown significant effect on their total soluble solids (Figure 28). The experimental findings showed that the S_3 treatment (7.18 %) had the highest total soluble solids. However, the S_0 treatment had the least amount of total soluble solids (5.96 %) which was statistically similar with S_2 (6.02 %) treatment. Islam *et al.* (2018) found that TSS of tomato was increased with increased in salinity. Huang *et al.* (2016) mentioned that increasing TSS plays a role in adaptation of plants to salinity.



In the bar graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Vertical bars indicate standard error (SE). Here, S_0 = 0 NaCl ml L^{-1} + standard solution, S_1 = NaCl 0.5 ml L^{-1} + standard solution, S_2 = NaCl 0.75 ml L^{-1} + standard solution and S_3 = NaCl 1 ml L^{-1} + standard solution.

Figure 28. Effect of salt water on total soluble solids of tomato

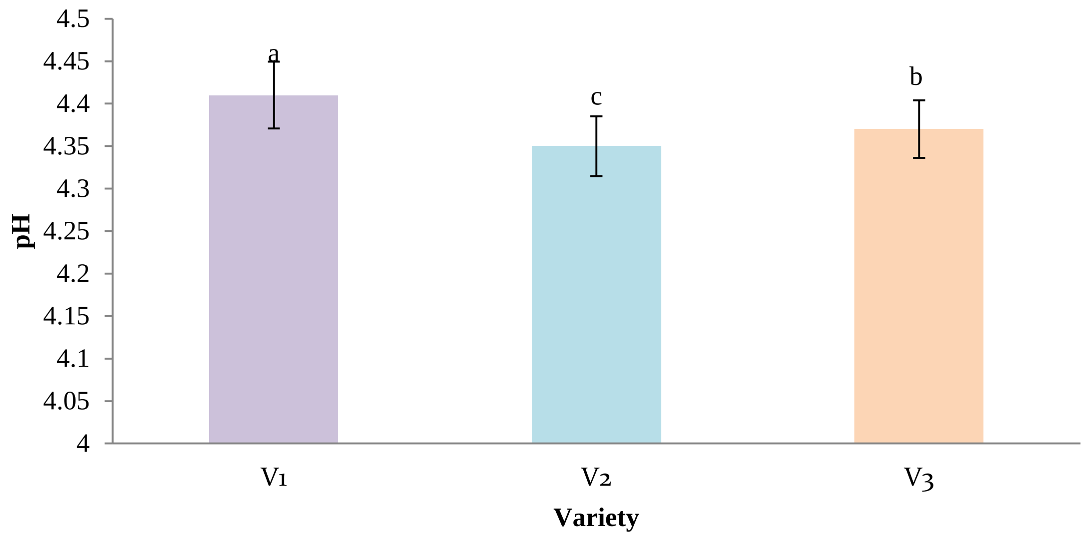
Combined effect of variety and different salt water concentration

In a hydroponic growth system, the combination of variety and salt water had shown significant effect on the tomato's total soluble solids (Table 7). According to experimental findings the V_1S_3 treatment combination exhibited the highest levels of total soluble solids (8.05%). While using the V_3S_2 treatment combination resulted in the lowest total soluble solids (5.43 %).

4.15 pH

Effect of cultivars

Different tomato cultivars growing in hydroponic culture system had shown significant effect on pH of tomato (Figure 29). Experimental results revealed that, the maximum pH (4.41) was found in V_1 treatment. While the lowest pH (4.35) was found in V_2 treatment. Spaldon and Hussain (2017) found similar result with the present study and reported that varietal character might influence the variations of pH in tomato genotypes. With respect to the quality traits, Arka Vikas variety reported highest fruit pH (4.49) and beta-carotene content (7.06mg/100g).

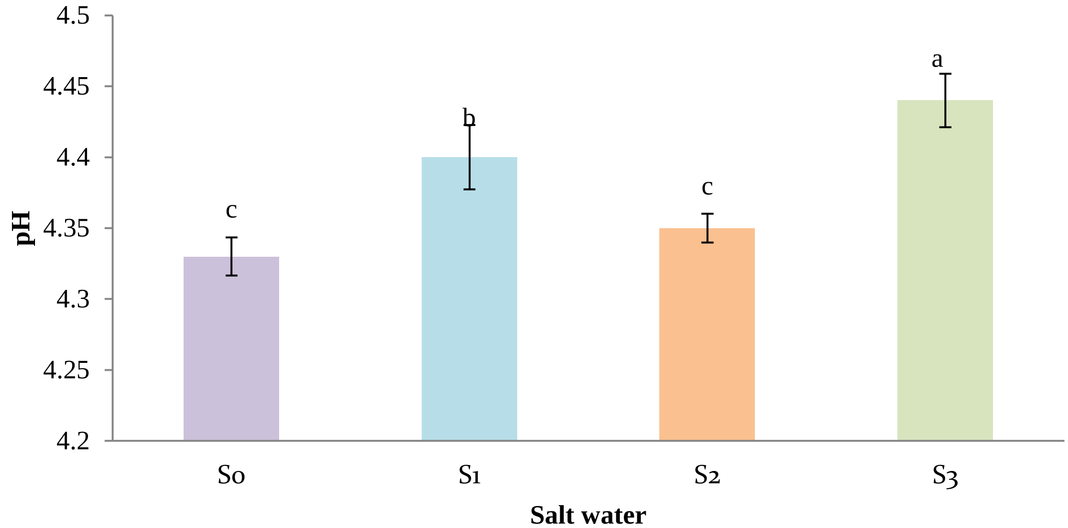


In the bar graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Vertical bars indicate standard error (SE). Here, Here, V_1 = BARI tomato-8, V_2 = BARI tomato-9, V_3 = BARI tomato-10

Figure 27. Effect of variety on pH of tomato

Effect of salt water

The salt water concentrations at which tomatoes were grown in a hydroponic system had had shown significant effect on their pH (Figure 30). The results of the experiment indicated that S_3 treatment had the highest pH (4.44). While the S_0 treatment had the lowest pH (4.33). Salt itself does not drastically change the pH or total alkalinity. However, the liquid form of chlorine generated by the salt cell will cause high pH swings.



In the bar graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Vertical bars indicate standard error (SE). Here, S_0 = 0 NaCl ml L^{-1} + standard solution, S_1 = NaCl 0.5 ml L^{-1} + standard solution, S_2 = NaCl 0.75 ml L^{-1} + standard solution and S_3 = NaCl 1 ml L^{-1} + standard solution

Figure 30. Effect of salt water on pH of tomato

Combined effect of variety and different salt water concentration

The combination of variety and different salt water concentration had shown significant effect on the pH of the tomato in a hydroponic growth system (Table 7). Experimental results showed that the V_1S_3 treatment combination had the highest pH (4.64). On the other hand the V_1S_0 treatment combination had the lowest pH, though (4.28).

Table 7. Combined effect of variety and different salt water concentration on volume, Brix^0 and pH content of tomato

Treatment Combinations	Volume (cc)	Brix^0	pH
V_1S_0	204.50 a	5.77 f	4.28 e
V_1S_1	196.50 b	6.01 e	4.35 cd
V_1S_2	190.50 c	6.06 e	4.38 c
V_1S_3	188.50 cd	8.05 a	4.64 a
V_2S_0	198.50 b	6.27 d	4.35 cd
V_2S_1	191.00 c	6.59 c	4.38 c
V_2S_2	187.50 cd	6.57 c	4.32 d
V_2S_3	184.90 de	6.87 b	4.35 cd
V_3S_0	199.50 ab	5.83 f	4.35 cd
V_3S_1	189.50 cd	6.53 c	4.48 b
V_3S_2	179.50 e	5.43 g	4.34 d
V_3S_3	169.50 f	6.61 c	4.32 d
$LSD_{(0.05)}$	5.44	0.18	0.03
CV(%)	1.69	1.66	0.48

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, V_1 = BARI tomato-8, V_2 = BARI tomato-9, V_3 = BARI tomato-10, S_0 = 0 NaCl ml L^{-1} + standard solution, S_1 = NaCl 0.5 ml L^{-1} + standard solution, S_2 = NaCl 0.75 ml L^{-1} + standard solution and S_3 = NaCl 1 ml L^{-1} + standard solution

CHAPTER V

SUMMARY AND CONCLUSION

Our experimental results revealed that different varieties and salt water concentration greatly influenced the growth, yield and quality parameters of tomato. In case of different variety the lowest yield plant^{-1} (3.92 kg) was obtained from V_3 treatment (BARI tomato-10). Whereas cultivation of BARI tomato-8 (V_1) in hydroponic system had the highest number of flower clusters plant^{-1} (13.17), fruits cluster plant^{-1} (4.51), fruits plant^{-1} (50.00), fruit polar length (3.90 cm), fruit radial length (3.68 cm), individual fruit fresh weight (45.64 g), fruit dry weight (2.59 g) yield plant^{-1} (4.13 kg), volume (195.0 cc) and pH value (4.41) while V_2 treatment contained the highest total soluble solids (6.58 %). In case of different concentration of salt water application the plant yield ranges between (3.82 -4.19 kg plant^{-1}). The highest yield plant^{-1} (4.19 kg) was recorded in S_0 (0 NaCl ml L^{-1} + standard solution) treatment which was due to enhanced yield attributes like flower clusters plant^{-1} (13.66), fruits cluster plant^{-1} (4.45), fruits plant^{-1} (49.22), fruit polar length (3.67 cm), fruit radial length (3.60 cm), individual fruit fresh weight (47.64 g), fruit dry weight (2.55 g). In case of combination, BARI tomato-8 (V_1) along with (S_0) no salt water application (0 NaCl ml L^{-1} + standard solution) affected plant growth, yield and quality parameters, leading to the maximum plant yield (4.33 kg) than compared to other treatment combination.

Conclusions

According to the findings of the present experiment, the following conclusions were drawn.

i. Higher fruit yield and other vegetative growth parameters and physiological traits of tomato were found in BARI toamto-8 variety.
ii. Higher fruit yield and other vegetative growth parameters and physiological traits of tomato were found in 0 NaCl ml L^{-1} + standard solution treated pot (S_0).

Therefore, it was concluded that the BARI toamto-8 variety in conjunction with non-salt water concentrations outperformed other treatment combinations for achieving higher yield and quality tomato production in a hydroponic cultivation system.

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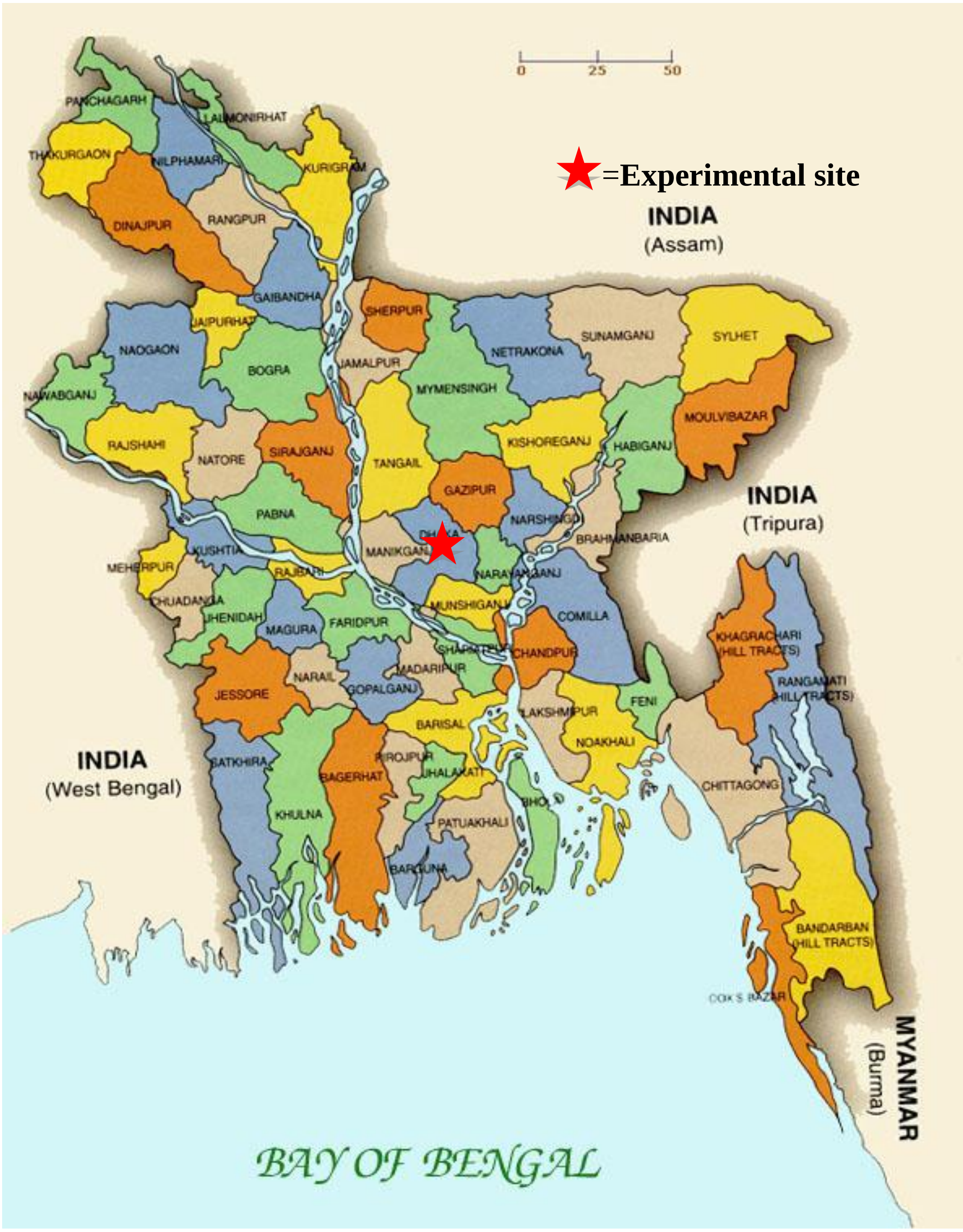
APPENDICES

Appendix I. Map showing the experimental site under study



Appendix II. Monthly meteorological information during the period from October, 2019 to March 2020.

Year	Month	Air temperature (^{0}C)		Relative humidity (%)	Total rainfall (mm)
		Maximum	Minimum		
2019	September	32.4	25.7	80	86
	October	31.2	23.9	76	52
	November	29.6	19.8	53	00
	December	28.8	19.1	47	00
2020	January	25.5	13.1	41	00
	February	25.9	14	34	7.7
	March	31.9	20.1	38	71

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

Appendix III. Analysis of variance of the data of plant height of tomato at different DAT

Source	DF	Mean square of plant height at			
		20 DAT	40 DAT	60 DAT	80 DAT
Replication (R)	2	44.320	48.303	275.053	304.351
Variety (V)	2	622.852*	13.480*	223.260*	281.535*
Salt water (S)	3	371.029*	135.230*	158.350*	196.825*
V×S	6	39.519*	5.600*	30.950*	20.225*
Error	22	2.545	2.129	4.755	6.442

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

Appendix IV. Analysis of variance of the data of number of leaves plant^{-1} of tomato at different DAT

Source	DF	Mean square of number of leaves plant^{-1} at			
		20 DAT	40 DAT	60 DAT	80 DAT
Replication (R)	2	76.681	84.520	321.120	298.570
Variety (V)	2	107.506*	69.173*	651.442*	666.392*
Salt water (S)	3	533.308*	150.722*	282.943*	312.176*
V×S	6	7.363*	4.910*	21.562*	16.446*
Error	22	0.270	0.636	6.880	1.930

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

Appendix V. Analysis of variance of the data of stem radius plant^{-1} of tomato at different DAT

Source	DF	Mean square of stem radius at		
		20 DAT	40 DAT	60 DAT
Replication (R)	2	2.004E-03	0.00370	0.01262
Variety (V)	2	1.756E-03*	0.00503*	0.01216*
Salt water (S)	3	5.015E-03*	0.01613*	0.03904*
V×S	6	1.186E-04*	0.00036*	0.00087*
Error	22	7.778E-05	0.00006	0.00007

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

Appendix VI. Analysis of variance of the data of days to first flowering, number of flower clusters plant^{-1} and number of fruits cluster plant^{-1} of tomato

Source	DF	Mean square of		
		Days to first flower	No. flower clusters plant^{-1}	No. fruits cluster plant^{-1}
Replication (R)	2	0.5833	46.0833	11.6044
Variety (V)	2	5.2201*	56.2756*	6.4481*
Salt water (S)	3	32.5134*	30.1867*	5.7537*
V×S	6	1.6876*	2.4678*	0.2510*
Error	22	0.4015	0.1742	0.0099

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

Appendix VII. Analysis of variance of the data of number of fruits plant^{-1}, fruit polar and radius perimeter of tomato

Source	DF	Mean square of		
		No. fruits plant^{-1}	Fruit polar length	Fruit radial length
Replication (R)	2	14.2468	0.63083	1.22934
Variety (V)	2	45.2131*	1.78703*	1.46147*
Salt water (S)	3	34.3565*	0.39549*	0.43365*
V×S	6	5.1723*	0.02789*	0.02071*
Error	22	0.6364	0.00629	0.00462

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

Appendix VIII. Analysis of variance of the data of individual fruit fresh weight, dry weight and yield plant^{-1} of tomato

Source	DF	Mean square of		
		Individual fruit fresh weight (g)	Individual fruit dry weight (g)	Yield plant^{-1} (kg)
Replication (R)	2	46.8208	0.40396	0.14247
Variety (V)	2	38.4753*	0.33031*	0.18098*
Salt water (S)	3	78.1343*	0.13109*	0.20344*
V×S	6	9.3884*	0.01802*	0.01917*
Error	22	0.6364	0.00456	0.00135

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

Appendix IX. Analysis of variance of the data of volume (cc), total soluble solids (%) and pH of tomato

Source	DF	Mean square of		
		Volume (cc)	Total soluble solids (%)	pH
Replication (R)	2	35.583	0.40583	0.02994
Variety (V)	2	332.852*	0.74977*	0.01237*
Salt water (S)	3	665.303*	2.83043*	0.02276*
V×S	6	47.153*	0.84138*	0.03416*
Error	22	10.311	0.01129	0.00045

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