GROWTH AND YIELD PERFORMANCE OF DIFFERENT TOMATO (*Solanum lycopersicum* L.) VARIETIES UNDER SALINITY

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CERTIFICATE

This is to certify that thesis entitled, ***"Growth and yield performance of different tomato (Solanum lycopersicum* L.*) varieties under salinity"*** *submitted to the faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE*** *in* ***AGROFORESTRY AND ENVIRRONMENTAL SCIENCE****, embodies the result of a piece of bona fide research work carried out by* ***SHAYLA SADIA****, Registration No.:* ***14-06084*** *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 been fully acknowledged by her.

Dated: June, 2021
Place: Dhaka, Bangladesh

(Dr. Jubayer-Al-Mahmud)
Associate Professor
Supervisor

DEDICATED

TO

MY BELOVED PARENTS

ABBREVIATIONS

Full word	Abbreviation	Full word	Abbreviation
Agro-Ecological Zone	AEZ	Milligram(s)	mg
Applied	App.	Milliliter	mL
Agriculture	Agric.	Millimeter	mm
Bangladesh Agricultural Research Institute	BARI	Mean sea level	MSL
Bangladesh Bureau of Statistics	BBS	Metric ton	MT
Biology	Biol.	North	N
Biotechnology	Biotechnol.	Nutrition	Nutr.
Botany	Bot.	Pakistan	Pak.
Centimeter	cm	Negative logarithm of hydrogen ion concentration (-log[H+])	p^H
Completely randomized design	CRD	Plant Genetic Resource Centre	PGRC
Cultivar	cv.	Regulation	Regul.
Degrees of freedom	DF	Research andResource	Res.
Degree Celsius	°C	Review	Rev.
Department	Dept.	Science	Sci.
Development	Dev.	Society	Soc.
Dry Flowables	DF	Soil plant analysis development	SPAD
East	E	Soil Resource Development Institute	SRDI
Editors	Eds.	Technology	Technol.
Emulsifiable concentrate	EC	Thailand	Thai.
Environment	Environ.	Tropical	Trop.
Entomology	Entomol.	Triple super phosphate	TSP
And others	*et al.*	United Kingdom	U.K.
Food and Agriculture Organization	FAO	University	Univ.
Gram	g	United States of America	USA
Horticulture	Hort.	Wettable powder	WP
International	Intl.	Serial	Sl.
Journal	J.	Percentage	%
Kilogram	Kg	Microgram	µg
Liter	L	Number	No.
Milliequivalents	Meqs	Sum of squares	SS
Mean sum of squares	MS	Coefficient of variation	CV

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- Author

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ABSTRACT

Salinity is a severe limiting factor for vegetable production. Therefore, a pot experiment was conducted at Sher-e-Bangla Agricultural University, from November 2019 to April 2020 to evaluate the performance of different tomato varieties e.g. BARI Tomato 2 (V1), BARI Tomato 15 (V2), and BARI Tomato 16 (V3) under different level of salinity e.g. 0 mM (S0), 75 mM NaCl (S1) and 150 mM NaCl (S2) in completely randomized design with three replications. The experiment revealed significant negative influence of salinity which decreased plant height, leaf number, branch number, chlorophyll content, growth rate, fresh and dry weight, fruit number etc. resulting yield loss. Damaged by S2 salinity is more severe than the S1. In normal condition V2 produced highest yield following V3 and V1. But severe salinity stress reduced yield by 32.66%, 43.9% and 42.8% in V1, V2 and V3 respectively. So, considering yield performance V1 variety is more tolerant to salinity than the other tested variety.

CHAPTER 1

INTRODUCTION

Tomatoes (*Solanum lycopersicum* L.) are one of the most widely produced vegetables worldwide, especially in Bangladesh. Tomatoes, sometimes known as "Love Apples," are a popular anti-oxidant-rich veggie. Botanically, it belongs to the Solanaceae family, with chromosome number 2n=24.Tomatoes can be eaten raw, cooked, or after being processed into juice, pulp, paste, or a variety of sauces (Cuartero and Fernandez, 1999). Because of its flavor, nutritional benefits, versatility, and commercial significance (Demirkaya, 2014). Tomatoes are one of the most significant, popular, and healthy vegetables crops in the world, with a worldwide following (FAOSTAT, 2014). Tomato is currently the second greatest vegetable crop in the world, after potato (FAO, 2016), and it leads the list of canned vegetables (Chowdhury, 1989). Tomatoes are high in photochemicals such lycopene, which has anti-carcinogenic properties, carotine, flavonoids, potassium, vitamin E and C, and folic acid. This ingredient, used together, has a positive impact on human health (Najla *et al*., 2009; Behrooj *et al*., 2012). Per 1pound edible piece, it has 97 calories, 2.7 mg iron, 4.5 g protein, 0.15 mg riboflavin, 50 mg calcium, 3.2 mg niacin, 123 mg phosphorus, and 102 mg ascorbic acid (Lester, 2006). In 2015, the world devoted 5.4 million hectares to tomato agriculture, with a total yield of 188.8 million tons. China, India, the United States, Turkey, Egypt, Iran, Italy, Spain, Brazil, and Mexico are the world's top 10 tomato producers (FAO, 2016). It is one of Bangladesh's most important and popular vegetables, growing across 76 thousand hectares and yielding 414,000 metric tons with productivity of 5471 kilograms per hectare (BBS, 2016).

Flooding, drought, salinity, high or low temperature, metal toxicity, and other abiotic environmental factors pose a severe threat to world agriculture. Among abiotic pressures, salt is one of the most important limiting factors for agricultural crop growth and production loss over the world, particularly in arid and semiarid area of the world (Kaashyap *et al*. 2018). Salinity affects between 20–33% of the world's farmed and irrigated land, with the negative effects anticipated to reach 50% by 2050. (Machado and Serralheiro, 2017). Tanji (2002) stated that crop growth and yield reduced more than 50% due to abiotic stress and among them salinity is one of the most brutal environmental factors which hamper the agricultural productivity including tomato. Salinity affects around 800 million hectares of land worldwide, resulting in billions of dollars in crop production losses (Shabala and Cuin, 2008). Munns *et al.*, (2006); Chaves *et al.*, (2009); Bayuelo-Jimenez *et al.*, (2012) found that salt stress causes a decrease in crop yield by affecting every area of physiology and biochemistry of metabolism and plant growth in distinct plant species. Many studies have found that in order to give tolerance to salinity, plant tissue metabolism is hindered, affecting growth performance and physiological processes (Mahajan and Tuteja, 2005). Tomato plants are vulnerable to moderate degrees of salt stress depending on cultivars or growth stage, and as a result, they play a significant role in agriculture. Salinity affects almost all physiological and biochemical aspects of plant development, lowering tomato yield and quality while also lowering nutritional value and food safety (Foolad, 2004; Sengupta and Majumder, 2009; Koushafar *et al.*, 2011). (Sancheg Blanco *et al*., 1991; Alarcon *et al*., 1993) studied the osmotic and elastic adjustment capacity of different tomato genotypes under salt stress conditions, as well as the water relationship, and found that the root can't extract saline water from the soil and can't transport it to the shoot, limiting the growth of salt-treated tomato plants. According to Reina-Sànchez *et al*., (2005) and Cuartero *et al.*, (2006), for 2.5, 3.5, and 7.6 dS m^{-1} salinity levels, tomato yield decreases by 0, 10%, and 50%, respectively. If cherry tomatoes are irrigated with saline water, their sugar and organic acid levels may increase.

Rafat and Rafiq (2009) found that as salinity levels increased up to 0.4 percent sea salt solution, overall chlorophyll content in tomato plants fell correspondingly. According to Amini and Ehsanpour (2006), salt stress causes a decrease in chlorophyll concentration in tomato cultivars. According to Khan *et al.* (2009), higher salinity reduced the quantity of fruit clusters, fruit size, fresh and dry weight of wheat. Tomato fruit output was lowered by 16 percent and 60 percent, respectively, while shoot biomass was reduced by 30 percent and >75 percent, when exposed to moderate and high salinities. According to Hossain (2002), tomato dry weight, shoot/root ratios, and yields increased with increasing moisture content and declined with increasing salt. Increased moisture regimes up to field capacity could lessen the negative effects of salinity on growth and yield. Higher salinity induced mineral nutrition disturbance by promoting Cl absorption in tomato plants, which was manifested in shoot and root dry matter. Javaid *et al*., (2002) tested plant height in four rice varieties with varied salinity effects (0, 20, 50, and 75 mM NaCl) and concluded that salt affects the morphological characteristics of the studied plants and that plant height decreases with greater salinity levels.

Currently, only a few projects have been completed to address the problem of salinity, resulting in more commercially viable technological solutions to aid crop production in saline environments. Because of the rising need for food, the solution to the salt stress problem in agriculture cannot be overlooked (Koushafar *et al*., 2011; Munns and Tester, 2008). The production technology of a crop in saline environments is exceedingly complex, and tomato yields have declined as salinity levels have increased. Irrigation, drainage, mulching, and other intercultural activities are all costly. As a result, impoverished farmers cannot afford this expense, and vegetable growers in our coastal area, in particular, have not benefited as projected from tomato planting. Nonetheless, developing cultivars with salt tolerance in the field is seen as a potential strategy. Many tomato cultivars have been created by BARI, however they have not been fully screened for salinity stress. Salinity not only decreases the agricultural production of most crops, but also, effects soil physicochemical properties, and ecological balance of the area. This study will help in identifying a potential solution to the problem by determining proper tomato variety which will contribute in nutritional food security in Bangladesh.

An inquiry was carried out with the following aims, taking into account the relevance and constraints of tomato cultivation in salty areas of Bangladesh:

- To assess the effect of salinity on growth and morpho-physiology of different tomato varieties
- To investigate the yield of tomato under different salinity stress condition
- To identify the most suitable salt tolerant variety (ies) among the tested variety

CHAPTER 2

REVIEW OF LITERATURE

Salinity is a major issue in Bangladesh's coastal region, where a large area has been left fallow for a long period. Tomatoes are an important crop plant in Bangladesh that provides Vitamin C and is consumed as a vegetable. It is an excellent source of Vitamin C for underprivileged coastal residents. Bangladeshi scientists are experimenting with several crops to see if they can grow in a saline environment, and tomato is one of them. Only a few studies have been done to adapt tomato crops to the saline environment of Bangladesh. In this chapter a brief review of various researches that were conducted about salinity stress on growth and development of tomato and morpho-physiological responses of tomato varieties under salinity. These reviews are the short summary of research works conducted in Bangladesh and other countries in the world.

2.1 Tomato

Tomatoes (*Solanum lycopersicum* L.) are the most popular home garden produce and the second most consumed vegetable in the world, behind potatoes (*Solanum tuberosum* L.). Tomatoes are in high demand because the world population consumes them daily. Tomatoes are a key source of antioxidants and are regularly consumed in everyday diets (Sgherri *et al.,* 2008). Rodriguez-Lafuente *et al*., (2010) found that they are a seasonal crop with limited availability during specific seasons.

Tomatoes can be used in a variety of ways, both fresh and cooked. Ketchup, sauces, pastes, and juice are examples of processed foods. It contains trace levels of vitamin B complex vitamins like thiamin, riboflavin, and niacin (Sainju and Dris, 2006). Tomatoes are also high in iron. Although yellow tomatoes contain more vitamin A than red tomatoes, red tomatoes also include lycopene, an anti-oxidant molecule that may help to prevent cancer (Naika *et al*., 2005). According to recent research, lycopene lowers the risk of prostate cancer (Miller *et al*., 2002). Tomatoes can help you avoid diseases including colon, rectal, and stomach cancer by lowering your risk of getting them. Finally, it is easily edible, and its vibrant hue piques one's interest (Sainju and Dris, 2006).

The rising importance of tomatoes in the global market has prompted many countries to raise their acreage and export share, particularly those located near key importing countries. During the previous half-century, the tomato has grown in popularity and been swiftly expanded into large-scale agriculture. It is now consumed more in the United States and Europe than the rest of the world. Tomato output has climbed by 164 percent worldwide in the last 40 years, but tomato consumption has increased by 314 percent (FAO, 2008). The global consumption quantity expanded at a rate of 3% per year on average (Xinhua, 2007).

Despite the fact that many developing nations, such as Bangladesh, benefited from the green revolution in cereal production in the past, they were unable to significantly alleviate poverty and malnutrition. Producing vegetables can assist farmers in generating cash, which can help to reduce poverty. In terms of area, production, yield, commercial use, and consumption, tomato is one of the most important vegetables. Tomatoes are grown on 6.10 percent of the land (BBS, 2005) in both the winter and summer. It is the most widely consumed vegetable crop, with potatoes and sweet potatoes at the top of the canned vegetable list.

2.2 Abiotic Stress

Stress refers to all biotic and abiotic elements that inhibit plant growth. The importance of abiotic stress factors has been increasing year by year as a result of global climate change. One of the most important abiotic stress factors, salinity, induces molecular, cellular, physiological, and morphological changes in plants. It decreases plant output and quality, particularly in numerous semi-arid and arid parts of the world.

World agriculture faces numerous problems, including providing 70% more food for an additional 2.3 billion people by 2050, while also combating poverty and hunger, more efficiently using finite natural resources, and adjusting to climate change (FAO 2009). Crop productivity, on the other hand, is not expanding in lockstep with food demand. Abiotic stressors are to blame for the reduced production in the majority of situations. To meet rising food demands, reducing crop losses caused by numerous environmental stresses is a critical problem (Shanker and Venkateswarlu, 2011).

Without a doubt, the growing population will put pressure on plant biologists to produce more crops and food resources, which appears to be a difficult challenge. Climate changes, as well as a variety of biotic and abiotic factors, are all posing challenges to agricultural crop development and output. Among abiotic pressures, salt is one of the most important limiting factors for agricultural crop growth and production loss over the world, particularly in arid and semiarid locations (Kaashyap *et al*., 2018).

Abiotic stressors continue to be the most significant constraint to agricultural production around the world. Abiotic stressors are estimated to be responsible for more than half of all yield reductions (Rodrguez *et al*., 2005). Drought, excessive salinity, cold, and heat negatively affect the survival, biomass production, and yield of staple food crops by up to 70% (Vorasoot *et al.,* 2003 ; Kaur et al., 2008 ; Ahmad *et al*., 2010a ; Thakur *et al.,* 2010 ; Ahmad *et al*., 2012).

Plants are frequently exposed to a plethora of unfavorable or even adverse environmental conditions, termed abiotic stresses (such as salinity, drought, heat, cold, flooding, heavy metals, ozone, UV radiation, etc.) and thus they pose serious threats to the sustainability of crop yield (Bhatnagar-Mathur *et al.,* 2008). The effect of these stresses is the production of ROS (Reactive Oxygen Species). The ROS included singlet oxygen, superoxide, hydrogen peroxide and hydroxyl radicals. At low concentration ROS works as a signaling molecules whereas at high concentration it makes damage to plant cell by lipid peroxidation, DNA and protein breakdown, and programmed cell death (PCD) (Hasanuzzaman *et al.*, 2012a).

2.3 Salinity

The term 'salinity' refers to the amount of soluble salt in a soil and is widely used. Electrical conductivity (EC) is a method for measuring salinity in soil solutions. It is based on the fact that the electrical current transmitted between two electrodes (i.e. with a standardised solution, temperature, and electrode areas that are usually equal to unity) increases with an increase in soluble ionic salts and vice versa (Ezlit *et al.*, 2010). Salinity is the most harmful of the abiotic stressors, limiting agricultural output significantly. Salinity, which is increasing day by day, affects a wide area of land around the planet. In irrigated cropland, salinity is a more serious issue. According to the FAO Land and Nutrition Management Service (2008), salt (salinity or sodicity) affects 6.5 percent of the world's total land area, or 831 million hectares.

The development of soil salinity can be caused by a variety of factors. Natural or primary salinity and secondary or human-induced salinity are the two main types. Primary salinity develops as a result of the natural accumulation of salts in the soil or surface water over time. This is a natural process that is mostly induced by the weathering of parent materials containing soluble salts as a result of the breakdown of rocks containing Cl^- of Na^+, Ca^{2+}, and Mg^{2+}, as well as $SO_4{}^{2-}$ and $CO_3{}^{2-}$. Furthermore, the deposition of sea salt delivered by wind and rain is a factor that changes depending on the kind of soil. Anthropogenic activities that alter the hydrologic balance of the soil between water applied (irrigation or rainfall) and water utilized by crops (transpiration) cause secondary salinity (Munns, 2005; Garg and Manchanda, 2008). Due to large volumes of applied water combined with insufficient drainage, the water table has risen in many irrigated areas.

The general osmotic effect and the particular ion effect both affect vegetation diversity in terms of plant development and yields. Soil salinity is thought to be primarily responsible for poor land usage and cropping intensity in the coastal area due to the influence of salt intrusion on tree and crop species. Crop productivity in coastal areas is mostly reduced due to the seasonally high level of salts found in the root zone of the soil. The land remains soggy as a result of drainage congestion, increasing salinity (Abedin, 2010).

According to Hasan *et al*. (2018), Bangladesh's coastal zone includes roughly 20% of the country's total land area and over 30% of cultivable land. Climate change-related water risks are anticipated to become a serious issue for Bangladesh, according to the National Adaptation Program of Action (NAPA). In Bangladesh's coastal zone, salinity in surface water, ground water, and soil has become a major threat. In terms of soil salinity, the results suggest that the western region is a very high saline zone, while the eastern region is a low saline zone. This study aims to identify the saline-affected area in Bangladesh's southern region from 1973 to 2009, as well as provide a salinity risk map. The parameter is the quantity of saline affected region, and the salinity risk maps are created by normalizing the amount of affected areas. During the last four decades, almost 0.223 million ha (26.7 percent) of new land has been damaged by varied degrees of salt. Galachipara Upazila in Patuakhali District has the most saline impacted territory, whereas Maladi Upazila in Barisal district has the least saline affected region. In the districts of Khulna, Bagerhat, Satkhira, and Patuakhali, the saline impacted 6areas have grown. Based on the risk map.

Although most salt strains in nature are caused by Na salts, primarily NaCl, salt stress can be divided into two categories: calcium salts and sodium salts. Osmotic, poisonous, and nutritional impacts of salinity can all be characterized. Salt stress that causes toxicity is referred to as primary salt damage, while salt stress that causes osmotic stress and nutritional stress (including mineral insufficiency) is referred to as secondary salt-induced stress (Manneh, 2004).

According to Habiba *et al*. (2014), salinity is a serious issue in Bangladesh's coastal region, accounting for 20% of the country's total land area. About 53% of the coastline area is affected by various levels of salt. Salinity intrusion at this site is mostly caused by climate change and anthropogenic influences, which make the region more vulnerable. As a result, salinity intrusion harms the region's water, soils, crops, fisheries, habitats, and livelihoods. This study shows how individuals and groups have tried a variety of adaptations to lessen salt impacts and assure food and drinking water availability. Furthermore, it highlights the actions of the government and other development groups in the face of salinity in order to mitigate its effects.

According to Mahmuduzzaman *et al*. (2014), water salinity in the coastal region is greatly influenced by Himalayan ice melting and the discharge of the rivers Ganga, Brahmaputra, and Meghna. These rivers have an average annual flow of 1.5 million cases, with seasonal variations. Salinity is responsible for the monsoon's peak flow (80 percent) and the winter/dry season's lean flow (20 percent). Reduced ice melting reduces river water discharge and hence increases salinity in the country's coastal region.

According to Abedin *et al*. (2012), the southwest coastline area is part of the dormant delta of the broad Himalayan river and is protected from tidal surges by the Sundarban mangrove forest. For all types of disasters, this region is the epicenter of cyclones, tidal waves, flooding, drought, saline incursions, recurring waterlogging, and land subsidence. Cyclonic tidal waves and flooding are the most prevalent calamities, and their effects are frequently seen at the local level. However, in this area, silent and invisible disasters such as rising salinity, arsenic contamination, and drought pose a threat to local livelihoods, people, and environments. Increased salinity, arsenic contamination, and drought sensitivity in the southwest is the result of a dynamic interaction between the country's biophysical, social, economic, and technical aspects. Furthermore, in the current and near future, the country is likely to be afflicted by the greatest, longest-lasting, worldwide yet quiet catastrophe: rising salinity, natural arsenic pollution, and drought. Natural disasters have made this region the most disaster-prone in Bangladesh, as well as the most sensitive to the consequences of climate change.

2.4 Plant responses to salinity

The genotype, developmental stage, as well as the degree and duration of the stress, all influence a plant's reaction to salt stress. In response to significant factors such as osmotic stress, ion-specificity, nutritional and hormonal imbalance, and oxidative damage, increased salinity has a variety of consequences on the physiology of plants cultivated in saline circumstances. These impacts may result in cellular membrane disruption, photosynthetic inhibition, toxic metabolite production, and nutrient absorption reduction, ultimately leading to plant death.

In general, a crop plant's response to salinity is a reduction in growth (Tavakkoli *et al*., 2011). Osmotic stress caused by salinity causes vegetative development, net assimilation capacity, leaf expansion rate, and leaf area index to slow down (Zheng et al. 2008; Hasanuzzaman *et al*., 2009). One of the most noticeable effects of salinity stress is a decline in photosynthesis (Leisner *et al*., 2010; Raziuddin *et al*., 2011). Plants have some morphological, anatomical, physiological, or biochemical adaptations to cope with salt stress, which assist them to survive and grow in saline circumstances.

2.4.1 Morphological Responses

2.4.1.1 Germination and Seedling Establishment

Seed germination is one of the most important and fundamental stages in the plant life cycle, since it determines plant establishment and crop output. The available literature revealed the effects of salinity on the seed germination of several crops such as Oryza sativa (Xu *et al*., 2011), Triticum aestivum (Akbarimoghaddam *et al*., 2011), Zea mays (Carpc *et al.,* 2009; Khodarahmpour *et al*., 2012). According to a (Khan and Weber, 2008) a higher amount of salt stress prevents seed germination, while a lesser level of salinity causes dormancy. Salinity has a variety of effects on the germination process: it affects seed imbibition of water due to the lower osmotic potential of germination media (Khan and Weber, 2008), alters protein metabolism (Dantas *et al*., 2007), disrupts hormonal balance (Khan and Rizvi 1994). It may also have a deleterious impact on cell, tissue, and organ ultrastructure (Koyro, 2002; Rasheed 2009). Seed germination under salty conditions is influenced by a number of internal (plant) and external (environmental) parameters, including seed coat, seed dormancy, seed age, seed polymorphism, seedling vigor, temperature, light, water, and gasses (Wahid *et al.,* 2011). Germination rates and percentages of germinated seeds vary greatly between species and cultivars at any given period.

Seed germination is a crucial and delicate stage in the life cycle of terrestrial angiosperms, as it controls seedling establishment and plant growth. Despite the importance of seed germination under salt stress, little is known about the mechanism(s) of salt tolerance in seeds. Salt stress reduces cell turgor and slows root and leaf elongation in vegetative plants, implying that ambient salinity predominantly affects water intake (Fricke *et al*., 2006). The influence of salinity stress on the quantitative and qualitative criteria yielded diverse results. Salinity treatment, according to Ashraf and Khanam (1997), reduced plant growth and development. Hossain and Nonami (2012) discovered that salt stress caused a decrease in development as well as a decrease in water potential in fruit tissue.

Seed germination is one of the most critical steps in the life cycle of higher plants. It is the sum of all physiological processes that take place inside the seed, beginning with water imbibition and ending with the formation of embryonic roots (Ouji *et al*., 2015).

Tobe *et al*. (2000) found that salt stress reduces seed germination by inducing plasmolysis and/or allowing harmful salt ions to permeate into the embryos. Depending on the plant species, salt stress influences germination % and seedling growth in different ways. According to several experts, the main cause of germination failure is the suppression of seed water intake due to high salt concentrations.

2.4.1.2 Effect of salinity on growth and development

Ali and Rab (2016) stated that salinity reduced root and shoot fresh weight, root and shoot dry weight, number of leaves per plant, shoot/root ratio, and tomato production. The application of additional potassium to tomato plants cultivated in a salty environment could reduce the salinity-induced reduction in growth and yield.

According to Muchate *et al*. (2016), salinity is a major abiotic environmental stressor that threatens agricultural output around the world. At the osmotic phase (early/short-term response) and ionic phase (late/long-term response), the negative impacts of salinity stress can be seen at the cellular, organ, and entire plant level. High salinity has a deleterious impact on important plant functions such as protein synthesis, photosynthesis, energy, and lipid metabolism by altering osmotic and ionic equilibrium. Plants have evolved physiological and biochemical systems to adapt to and survive salt stress, which are controlled by several biochemical pathways of ion homeostasis, osmolytes synthesis, ROS scavenging and hormonal balance. At the molecular level, such adaptation entails the activation of gene modulation cascades and the production of defensive metabolites. Several potential genes have been found and used to help in genetic engineering attempts to improve salt tolerance in crop plants in recent years. However, further work is needed to ensure the effective introduction of salt-tolerant cultivars in the field. The physiological, biochemical, and molecular characteristics of plant responses to salinity are presented in this article, as well as their application in genetic engineering to improve salt stress resistance.

Feleafel and Mirdad (2014) revealed that tomato plants displayed quick early development to avoid the harmful effect of water salinity by using four NPK starter solutions and three rates of humic acid, as well as their interactions. At 6, 8, and 10 weeks after transplanting (WAT), tomato plants receiving the greatest dose recorded maximum plant height, leaf number, and leaf P content. Tomato plants given medium amounts of fertilizer had the most root and shoot fresh weight, as well as the greatest mean values for number of flowers per cluster, leaf NK content, and fruit output per plant.

Shimul *et al.* (2014) investigated the impact of varying salt levels on plant growth and found that plant height of tomato genotypes increased significantly with lowering salinity levels. The largest plant height was obtained with a salinity level of 0 dSm^{-1}, and the shortest with a salinity level of 16 dSm^{-1}. Sengupta and Mazumder (2009) investigated the response of rice to various salt levels and discovered that the number of branches dropped as the salinity level increased.

Alaa El-Din Sayed Ewase (2013) reported that a pot experiment was conducted using the selection approach to investigate the effect of salinity stress on Coriander plant growth (*Coriandrum sativum* L.). For this objective, four treatments with varied amounts of NaCl were used: 0, 1000, 2000, 3000, and 4000 ppm. The length of the plant, the number of leaves, and the quantity and length of the roots were all measured. The results showed that when the concentration of NaCl increased, all of the growth metrics decreased. Coriander plants were found to be resistant to salt up to 3000 ppm NaCl concentration.

Alsadon *et al*. (2013) conducted a study in tomato to assess the genotypic responses to salinity tolerance and found that when water salinity levels increased, all plant growth parameters decreased dramatically. Plant height, stem diameter, leaf area, leaf fresh weight, and dry weight were all lower at the highest salinity level than at the control level, by about 13, 11, 17, 16 and 18 percent, respectively, for plant height, stem diameter, leaf area, and leaf fresh weight and dry weight.

according to Monireh and Hadi (2013) the antagonistic impact of Cl on nitrate causes nitrogen concentrations to decline. Tabatabaei (2006) found that increasing the quantity of NaCl in the nutrient solution lowered the amount of nitrogen and nitrate in the olive leaves. Nitrogen concentration increased as Ca2+ and K+ levels rose in salinity conditions. According to Levent Tuna *et al*., (2007), a high amount of Ca^{2+} in salinity conditions causes an increase in nitrogen content.

Lovelli *et al*. (2012) investigated the reactions of tomato plant leaf growth and development under salt stress conditions. Under salt stress, the length of the growth zone was reduced by 20%, and the maximal relative elemental growth rate was also lowered, notably in the leaf's youngest section. Salt stress caused a substantial drop in Ca in the growing sorghum leaf, according to Nahar and Hasanuzzaman (2009), which could be at least partly responsible for leaf development suppression. According to Nazar *et al*., (2011), salt inhibits symplastic xylem loading of Ca in the root, resulting in lower Ca levels in the developing region of leaves.

Shameem *et al.* (2012) observed 8 tomato genotypes with varying salinity levels at early development stages in an experiment of tomato plants to evaluate the yield and quality of fruit under salinity circumstances. Based on the amount of fruits, flowers, K^+ concentration, and K^+ /Na^+ ratio, it was discovered that the tomato genotype adapted to salt.

Fruit number was computed by Shabani *et al*., (2012) as the total number of fruit per plant. Fruit length was measured at maturity from clusters (4 fruit per plant) from stem end to blossom end, to two decimal places. The maximum diameter of fruits two decimal places at maturity from clusters was reported (in cm) (4 fruit for each plant). Al-Busaidi *et al*., (2010) discovered that when different genotypes were exposed to greater salinity, variants 38 and 46 had the maximum numbers of fruits, diameters, and weights of 33.17, 555.23g, and 344.34g, respectively.

Mirabdulbaghi and Pishbeen (2012) experimented with increasing salt levels in two barley cultivars, Afzal and EMB82-12. Chlorosis and necrosis of the leaves lowered the photo-synthetically active area, resulting in a decrease in the plant's shoot biomass production (Lester, 2006). The decline in freshness reduces the number of fruits and diameter, resulting in a yield reduction of 20-40%. Potato and cucumber yield and quality were unaffected by soil moisture stress created under salty circumstances and the reduction of growth under salinity stress during the early developmental stages.

Khalid *et al*. (2012) investigated the effect of salinity on brinjal plant growth using three different treatments of Na_2SO_4. The replicates with the highest salt concentration, 60 ppm Na_2SO_4, had the best development and demonstrated a beneficial reaction to stress on the plants. The researchers discovered that Na_2SO_4 salinity significantly inhibited Mo buildup.

Nasser (2012) conducted an experiment to determine how salinity affects plant development and seed germination, and found that the influence of four salt levels on seed germination, plant growth, K^+ and Na^+ content, and photosynthetic rate of four local cultivars and one commercial cultivar was evaluated. According to Chook hampaeng *et al*., (2007), as saline levels rise, tomato cultivars' fruit output, number of fruits, and fruit weight all drop.

According to Maggio *et al*. (2011), salinization at the root environment lowered plant development and, as a result, plant water use. As a result of salinization, both total and osmotic water potentials in tomato plants gradually decreased. Separately, longer roots and smaller leaves in triazole compound-treated plants are thought to promote salt tolerance by absorbing more water and losing less water, which improves salt tolerance in salt-stressed plants.

In a study conducted by Mohammad *et al*. (2011), it was discovered that salt reduced leaf pheophytin total and carotene levels, however potassium application increased these pigments in tomato leaves. Under salinity stress, K^+ had a beneficial effect.

According to Amirjani (2011) Carbons are required for adaptive and/or defensive reactions to stress, whereas sugars are a source of energy. Sugar accumulation was driven by high salinities, whereas proline accumulation was predominantly caused by elevated NO-3 in leaves (Bayoud, 2010). Sugars such as raffinose and sucrose have also been shown to play key roles in protecting cells from water stress (Ashraf and Foolad, 2007).

Saberi *et al*. (2011) observed that the impact of salinity and irrigation frequency in two forage sorghum varieties (Speedfeed and KFS4). Salinity levels of 0, 5, 10, and 15 dSm-1 were used to develop two cultivars. In non-saline soil with normal watering, the most leaves were generated. By reducing the number of leaves and tillers generated, high salinity and low soil water conditions reduced the number of leaves and tillers produced. Plants' leaf area shrank in response to salt and decreased soil water availability, and the suppressive impact was amplified when the two conditions were combined. The largest total leaf area was reached in the control treatment, however this metric decreased as salinity and watering frequency increased.

According to Dolatabadian *et al*. (2011) salinity stress reduced soybean shoot and root weight, total biomass, plant height, and leaf number. Salinity stress, on the other hand, had no effect on leaf area. Kaouther *et al.* (2012) investigated how salt stress (NaCl) affects the development, chlorophyll content, and fluorescence of Tunisian chili pepper cultivars.

Azarmi *et al*. (2010) investigated the impact of salt on the morphological and physiological changes in tomato yield, as well as the growth, yield, and quality of greenhouse tomatoes grown in hydroponics culture. The results of this experiment revealed that as salinity increased, growth parameters and yield decreased, but salinity improved qualitative properties.

Abdelhamid *et al*. (2010) conducted research to see if the effects of NaCl stress on tomato plant growth are reflected in reduced dry weights. Increased salinity may cause a drop in dry weights due to a combination of osmotic and specific ion effects of Cl and Na. The dry weights of the stems, leaves, and roots reduced in saline conditions due to salinity stress, according to the findings.

According to Hassine and Lutts (2010) plant height, number of flower clusters, fruit quantity, and yield were not adversely affected up to 8 dS m^{-1}, however ripening was delayed. With salt concentrations of 4 and 6 dS m^{-1}, there was an increase in yield above the control.

According to Perveen *et al.* (2010), under saline conditions, the salt-induced osmotic impact may cause a progressive drop in photosynthesis due to stomata closure. Salt stress was found to reduce the net CO2 absorption rate and stomatal conductance of undamaged leaves in various wheat genotypes when applied during the reproductive stage (Shahbaz and Ashraf, 2007).

Hasanuzzaman *et al*. (2009) conducted a field experiment to study how sodium and chlorine ions accumulate in transpiring leaves over time, causing high salt concentrations and leaf mortality in plants. The excessive salt load in the leaf, which exceeds the capacity of salt compartmentation in the vacuoles, causes salt to build up in the cytoplasm to toxic levels, causes leaf injury and death.

Tantawy *et al*. (2009) studied the influence of salinity on plant height. Due to the toxicity of Na^+ and Cl^-, a decrease in stem fresh weight in salt conditions may be linked to a lack of water and a reduction in plant height. In the case of lentils, the increase in saline levels resulted in a steady decrease in plant height, number of leaves, and leaf area (4 to 6 dS m^{-1}).

Zhang *et al.* (2009) obserbed that as a result of the salinity-induced osmotic action on plants, partial stomata closure occurs, lowering stomatal conductance and substomatal CO_2 concentration. In plants under saline stress, especially crops, photosynthetic capacity has a clear positive relationship with biomass production or seed yield.

Manikandan and Desingh (2009) investigated the effects of various sodium chloride concentrations on tomato growth and photosynthetic characteristics and discovered that the fresh weights of the shoots were dramatically reduced, with the 50 mM sodium chloride treatment having the least fresh weight. The photosynthetic rate was

53% lower than the control treatment, and the photosynthetic water consumption efficiency was 29% lower than the treatment.

Piao and Fried (2008) conducted a study on the effects of various salinity levels on plant development and discovered that carbon dioxide exchange characteristics have been recognized as an essential predictor of plant growth because of their direct link to net productivity. High Na^+ in soil solution induces intracellular K^+ deficit, which leads to K^+ /Na^+ disequilibrium, according to Kronzucker and Britto (2011); Pardo and Rubio (2011).

Karim (2007) found that all metrics, including panicle length, reduced as salinity increased in an experiment with varied degrees of salinity. The majority of the researchers agreed that soil salinity had a negative impact on rice plant panicle length (Islam *et al.,* 1998; Hossain, 2002; Islam, 2004).

Mortazainedzhad *et al.* (2006) found that when salinity increased, the quantity of rice tillers reduced at all growth stages. Rice plant growth is influenced by soil salinity. The degree of negative impact varies depending on the plant's growth stage. Rice is salt tolerant throughout the germination stage, but it becomes quite sensitive during the early seedling stage. Many rice researchers (LingHe *et al*., 2000; Burman et al., 2002; Weon young *et al*., 2003; Islam, 2004; Rashid, 2005; Karim, 2007) reported similar results. According to LingHe *et al*. (2000), the main reason of yield loss was a fall in tiller number.

Hajer *et al.* (2006) conducted two distinct tomato studies and found that when salinity increased, fruit output dropped in both saline and non-saline conditions.

Uddin *et al*. (2005) investigated the salt tolerance of *Brassica napus* and *Brassica campestris* cultivars in a saline environment, finding that increased salinity reduced the number of branches, siliqua number, and seed per siliqua.

Netondo *et al*. (2004) studied that sorghum plants were cultivated in sand culture in a greenhouse experiment. Control (0), 50, 100, 150, and 250 mM NaCl concentrations were used in the entire nutritional solution. With increased salinity levels, net assimilation, stomatal conductance, and transpiration rate were significantly reduced in both sorghum types, and the phenomena were identical for both kinds. In response to increased NaCl content, leaf development, gas exchange, and chlorophyll fluorescence of two sorghum types (Serena and Seredo) were studied. Salinity influenced photosynthesis per unit area indirectly through stomatal closure, according to the findings. Furthermore, salt limits leaf area expansion, lowering overall plant photosynthesis. This effect begins with low sodium chloride levels. At increasing salinity concentrations, on the other hand, net photosynthesis per unit area decreases. It has been reported that as salt levels rise in a saline stress situation, plants' chlorophyll content decreases.

2.4.1.3 Effect on Yield

The effects of salt stress on plants stated above eventually lead to a drop in crop output, which is the greatest measurable effect of salt stress in agriculture. With the exception of halophytes, most crops' yields were severely reduced due to salt stress.
Yokoi *et al*., (2002) stated that salt stress can be imposed continuously or sporadically, or progressively become more severe and at any stage of development, making tolerance and yield stability multigenic traits that are difficult to create in crops. Mass (1986) found that based on their relative yields, crop species have shown significant variances in salt tolerance. The percent reduction in relative yield per unit of electrical conductivity in dSm^{-1} above the threshold has been defined in terms of two parameters: the threshold electrical conductivity and the percent decrease in relative yield per unit of electrical conductivity in dSm^{-1}. It was discovered that relative yield changed significantly depending on salt levels and tolerance levels.

Hajer *et al*. (2006) conducted two distinct tomato studies and found that when salinity increased, fruit output dropped in both saline and non-saline conditions.

According to Nahar and Hasanuzzaman (2009), salt stress has a significant impact on different yield components of V. radiata. Salinity levels were adversely linked with the number of pods per plant, seeds per pod, and seed weight. Salinity had an effect on the reproductive growth of V. radiata, as the number of pods per plant reduced significantly as salinity levels increased.

2.4.2 Physiological responses under salinity

2.4.2.1 Photosynthesis

Many physiological elements of plant growth are affected by salt stress. The osmotic effect of the salt in the growth medium and the poisonous effect of the salt within the plant both affect plant growth. Plants change their osmotic balance in reaction to high salt concentrations by lowering cell expansion, cell division, stomatal closure, and gradually reducing leaf area, reducing photosynthesis and growth.

Sudhir and Murthy (2004) stated that the decrease in photosynthetic rates in salt-stressed plants is mostly due to a decrease in water potential. When excessive quantities of Na^+ and/or Cl^- accumulate in chloroplasts, photosynthesis is also impeded. Because photosynthetic electron transport is essentially unaffected by salts, salt stress may impair either carbon metabolism or photophosphorylation. Different crops have shown a favorable association between salt stress-induced photosynthetic rate and yield (Pettigrew and Meredith 1994; Sudhir and Murthy 2004).

In fact, the effect of salinity on photosynthetic rate is influenced by salt content, plant species, and genotypes. There is evidence that salinity can increase photosynthesis at low salt concentrations. Parida *et al.*, (2004) found that rate of photosynthesis increased at low salinity and reduced at high salinity in *Bruguiera parviflora*, but stomatal conductance remained unchanged at low salinity and decreased at high salinity.

2.4.2.2 Water Relation

According to Romero-Aranda *et al*., (2001), an increase in salt in the root media might result in a reduction in leaf water potential, which can affect a variety of plant processes. The decrease of the soil water potential due to an increase in solute concentration in the root zone has osmotic effects on plants. This condition makes it difficult for plants to take water from the soil and sustain turgor at very low soil water potentials.

Ghoulam *et al.* (2002) observed that plants adjust osmotically (accumulate solutes) and maintain a potential gradient for water in flux at low or moderate salt concentrations (higher soil water potential). In sugar beet cultivars, salt treatment resulted in a considerable reduction in relative water content (RWC).

Vysotskaya *et al.* (2010) found that because of the reduced transpiration in a salt-stressed state, this scenario alters. In these circumstances, more water follows the cell-to-cell channel, flowing across living cell membranes.

2.4.2.3 Nutrient Imbalance

It is widely known that salinity-induced nutritional problems can have a negative impact on crop performance. However, the relationship between salinity and crop mineral nutrition is complicated.

The influence of salinity on nutrient availability, competitive absorption, transport, or distribution within the plant could cause nutritional problems. Salinity lowers nutrient uptake and accumulation in plants, according to several studies (Rogers *et al.* 2003; Hu and Schmidhalter, 2005).

According to (Hu and Schmidhalter, 1997, 2005; Asch *et al*., 2000) a high level of external Na^+ induced a drop in both K^+ and Ca^{2+} concentrations in plant problems of many plant species, according to several plant studies.

The solubility of micronutrients, the pH of the soil solution, the redox potential of the soil solution, and the type of binding sites on the organic and inorganic particle surfaces all influence their availability in saline soils. Furthermore, depending on the crop species and salt levels, salinity can impact micronutrient concentrations in plants in different ways (Oertli, 1991).

Zhu *et al*. (2004) stated that because of the elevated pH, micronutrient deficiencies are especially common under salt stress.

2.4.2.4 Salinity Induced Oxidative Stress

Salt stress can cause stomatal closure, which reduces CO_2 availability in the leaves and inhibits carbon fixation. This exposes chloroplasts to excessive excitation energy, which increases the generation of reactive oxygen species (ROS) like superoxide ($O_2^{\bullet-}$), hydrogen peroxide (H_2O_2), hydroxyl radical (OH•), and singlet oxygen ($^1O_2$) (Ahmad and Sharma 2008; Ahmad *et al*. 2010a, 2011) (Parida and Das, 2005; Ahmad and Sharma, 2008; Ahmad *et al*., 2010a, 2011).

ROS are extremely reactive molecules that can harm cells by oxidizing lipids, proteins, and nucleic acids (Pastori and Foyer, 2002; Apel and Hirt, 2004; Ahmad *et al.*, 2010a, b).

Hasanuzzaman *et al*. (2011a) and Hasanuzzaman *et al.* (2011b) observed that increased lipid peroxidation and levels of H_2O_2 were detected in *B. napus* and *T. aestivum* with increased salinity in a recent study.

2.5 Effect of salinity on tomato growth

2.5.1 Effects on tomato root development

Root growth is reduced under salt stress due to root cell growth restriction, root-zone water stress, and a rise in root disease. Due to direct contact with salt solution during soilless culture, the root plays a significant role in plant growth. Salinity stress affects root growth, as well as the plant's physiology and morphology.

According to Satti and Lopez (1994), the decrease in root dry matter could be due to salinity-induced water stress, which impeded photosynthesis and resulted in the failure of assimilates or photosynthates translocation.

According to Schwarz and Grosch (2003), increasing the EC of nutrient solution (EC range: 1.5-10 dS m^{-1}) lowered the fresh and dry mass of tomato (*Solanum lycopersicum* [Mill] L. cv. Counter) root, total root length, number of adventitious root, tap root, and lateral root.

Albacete *et al.* (2008) reported that in saline circumstances, tomato (*Solanum lycopersicum* L.) root fresh weight decreased by 30% after three weeks (100 mM NaCl).

Lovelli *et al*. (2011) reported that under salinity (10 dS m^{-1}), root dry matter decreased along with an increase in the root-shoot ratio.

2.5.2 Effects on tomato shoot development

Under salinity stress, shoot reduction is induced by a decrease in photosynthesis, which results to a decrease in tissue expansion and a disruption in mineral delivery.

Zhu (2002) found that reduction in shoot growth under saline conditions is possible due to three reasons: (1) Salinity inhibits photosynthesis, limiting the availability of glucose required for growth; (2) Salinity inhibited shoot and root growth by lowering the water potential in the root growth medium, which reduced turgor in expanding tissues ; and (3) Salinity disrupts mineral delivery, either too much or too little; caused variations in specific ion concentrations in the growth media may have a direct impact on growth.

Saberi *et al*. (2011) also observed that stem diameter was one of the growth characteristics that reduced with increasing salt, similar to how stem diameter decreased with increasing salinity in forage sorghums (*Sorghum bicolor* L.).

Oztekin and Tuzel (2011) stated that average tomato (21 commercially known cultivars) plant height showed 29.03% reduction under 200 mM NaCl treatment when compared with no salt treatment.

Kamrani *et al.* (2013) found that salinity must reach 20 mM to have an effect on tomato shoot growth; they also found that higher salt reduces shoot height considerably.

According to Bustomi *et al.*, (2014) under 4dS m^{-1} and 3dS m^{-1}, respectively, tomato plant height decreased dramatically from 8 weeks to 10 weeks after transplant.

2.5.3 Effects on tomato leaf development

In their review, Parida and Das (2005) state that salt accumulation in leaves can impede photosynthesis by increasing stomatal and mesophyll conductance to CO_2 diffusion, as well as impairing Ribulose biphosphate (RuBp) carboxylase.

Azarmi *et al*., (2010) also discovered that as salinity increased (EC range: 2.5-6 dS m^{-1}), the total leaf area of tomato (Lycopersicon esculentum Mill.) reduced.

Azarmi *et al.* (2010) observed that salinity reduced leaf chlorophyll content. Taffouo et al., (2010) also found that salt stress reduces total chlorophyll concentration in tomato leaves in all cultivars except Lindo at 50 and 100 mM NaCl and Ninja at 50 mM NaCl.

Shimul *et al*. (2014) recently demonstrated that increasing salinity reduces total tomato (var. BARI Tomato 14) leaf chlorophyll content, stomatal resistance, and photosynthetic activities.

2.5.4 Effects of salinity stress on tomato yield

The fact that tomato yield is lowered when salt levels exceed threshold levels is undeniable.

According to Qaryouti *et al*. (2007) the overall yield of tomato (*Lycopersicon esculentum M*. cv. Durinta F1) is dramatically reduced at salinity equivalent to and above 5 dS m^{-1}, with a 7.2 percent yield reduction per unit increase in salinity.

Magan *et al.* (2008) also found that as salinity increased, tomato (*Lycopersicon esculentum* Mill) total and marketable fresh fruit output declined dramatically.

Hajiboland *et al*. (2010) stated that tomato (*Solanum lycopersicum* L.) growth and yield reduction affected by salinity could be the reasons for variation in photosynthetic products translocation toward root, reduction of plant top especially leaves, partial or total enclosed of stomata, direct effect of salt on photosynthesis system and ion balance.

According to Bustomi *et al.* (2014), tomato (*Solanum lycopersicum*) production increased as the EC of the nutrient solution climbed from 0 to 3 dS m^{-1} due to an increase in nutrients, but declined as the EC of the nutrient solution increased from 3 to 5 dS m^{-1} due to an increase in salinity stress.

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

2.5.5 Effects of salinity stress on tomato fruit quality

Qaryouti *et al*. (2007) also found that raising salinity up to 5 dSm^{-1} improved tomato (*Lycopersicon esculentum M.* cv. Durinta F1) fruit quality parameters (fruit dry matter percent, total soluble solids, and titratable acidity) compared to the control, while decreasing fruit hardness.

According to Magan *et al.* (2008) total soluble solids (Brix index) and titratable acidity increased by 5.4 and 9.2 percent per dS m^{-1}, respectively, in tomato cultivated in soil-less greenhouses in a Mediterranean environment.

Azarmi *et al.* (2010) observed that total soluble solid and titratable acidity were significantly enhanced at EC of above 3 dS m^{-1}, and EC increased from 2.5 to 6 dS m^{-1}, total soluble solid and titratable acidity were increased to 13.4% and 28.9%, respectively.

Zhang *et al*. (2016) also found that increased salinity increased tomato (*Lycopersicum esculentum*, Pepe) total fruit sugar and total acid content; additionally, increased nutrient solution salinity from 0.78 dS m^{-1} to 1.58 dS m^{-1} raised sugar and acid content to 14.3% and 28%, respectively.

From the preceding analysis of research, it is clear that salinity has a significant impact on plant growth and development, as well as yield of crops.

CHAPTER 3

MATERIALS AND METHODS

The experiment was conducted during the period from November 2019 to April 2020. The materials and methods those were used and followed for conducting the experiment have been presented under the following headings.

3.1 Location of the experiment

This study was conducted at the Agroforestry and Environmental Science Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. The location of the experimental site is 23°74′ N latitude and 90°35′ E longitude at an altitude of 8.6 meter above the sea level. The experimental site is shown in the map of AEZ of Bangladesh in Appendix I.

3.2 Climatic condition of the experimental site

The experimental site is situated in the subtropical monsoon climatic zone, which is characterized by heavy rainfall during the months from April to September (Kharif season) and scanty of rainfall during rest of the year (Rabi season). Plenty of sunshine and moderately low temperature prevail during October to March (Rabi season), which are suitable for growing of tomato in Bangladesh. The weather information regarding temperature, rainfall, relative humidity and sunshine hours prevailed at the experimental site during the cropping season October 2019 to March 2020 have been presented in Appendix II.

3.3 Characteristics of soil

The soil of the experimental area belongs to the Modhupur Tract under AEZ No. 28. The characteristics of the soil under the experiment were analyzed at the SRDI, Dhaka in Appendix III.

3.4. Experimental material

Seeds of BARI Tomato -2, BARI Tomato -15 and BARI Tomato -16 were used. The seeds of the varieties were collected from Olericulture Division, Horticulture Research Centre (HRC) of Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur-1701. The seeds were healthy, vigorous, well matured and free from other crop seeds and inert materials.

3.5. Preparation of soil

A total of 27 plastic pots were prepared with 14 kg air dried soil. The size of the pot was 30 cm top diameter with a height of 25 cm. Thus the surface area of an individual pot was 706.5 sq cm. Plant parts, inert materials, visible insects and pests were removed from soil by sieving. Collected soil was dried under the sun. The dry soil was thoroughly mixed with well rotten cow dung and fertilizers before filling the pots. The pots were placed in the shad.

3.6 Pot preparation

A ratio of 1:3 well rotten cow dung and soil were mixed and pots were filled 15 days before transplanting. Silt Loam soils were used for pot preparation. All 27 pots were filled on October 2019. Weeds and stubbles were completely removed from the soil.

3.7 Experimental treatments and design

Three levels (0, 75 and 150mM) of saline water irrigation were imposed to three cultivars of tomato (BARI Tomato-2, BARI Tomato-15 and BARI Tomato-16), which composed of 3 treatments altogether. The experiment was set up in a two factor completely randomized design with three replications. Thus 27 experimental pots were placed in ambient air at the Agroforestry farm premises of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh.

Factor A: Tomato cultivars

1. BARI Tomato 2- (V1)

2. BARI Tomato 15- (V2)

3. BARI Tomato 16- (V3)

Factor B: Salinity levels (mM**)**

1. Control- 0 mM NaCl (S0)

2. Mild stress- 75 mM NaCl (S1)

3. Severe stress- 150 mM NaCl (S2)

3.8 Application of manures and fertilizer in the pot

The required amount of fertilizers (N, P, K, and S kg ha^{-1}) and manure (cow dung @ 10 t ha^{-1}) was estimated on the basis of initial soil test result following Fertilizer Recommendation Guide (BARC, 2012). As per recommendation urea 7.0g, triple super phosphate (TSP) 7.0g, muriate of potash (MoP) 3.0g, gypsum 2.0g, and 100.0g cow dung pot^{-1} was applied. One third of urea and entire amount of cow dung, TSP and MoP, were mixed with the soil in each pot before sowing. Rest of the urea was applied as side dressing at 25 and 45 days after transplanting.

3.9 Imposition of salinity treatments

Salinity was imposed as per treatments at the pre-flowering stage three times at 20, 30, and 40 DAT. The developed irrigation water salinity and pot soil were measured by using an electrical conductivity meter (HANNA HI 993310, Direct Salinity Meter) which was expressed in dSm^{-1}.

3.10 Sowing of seeds

The seeds of three tomato cultivars were sown on the 1st week of November 2019 by hand in separate pot to raise the seedling due to lack of seedbed in the experimental site. Proper care was taken following recommended measures for the development of healthy seedlings.

3.11 Seedling raising

A common procedure was followed in raising of seedlings in the pot. Tomato seedlings were raised in four pot at Agroforestry Farm of Sher-e-Bangla Agricultural University, Dhaka. The size of the pot was 30 cm in top area and 25 cm in bottom area. The soil was well prepared with spade and made into loose friable and dried mass to obtain fine tilth. All weeds and stubbles were removed and 5 kg well rotten cow dung was applied during pot preparation. The seeds were sown in the pot at 4 November, 2019 to get 30 days old seedlings. Germination was visible 5 days after sowing of seeds. After sowing, seeds were covered with light soil to a depth of about 0.6 cm. Heptachlor was applied @ 4 kg ha^{-1} around each seedbed as precautionary measure against ants and worm. The emergence of the seedlings took place within 6 to 7 days after sowing. Weeding, mulching and irrigation were done from time to time as and when required and no chemical fertilizer was used in this pot.

3.12 Transplanting of seedling

Healthy 30 days old tomato seedlings were uprooted separately from the pots. The seedlings were watered before uprooting so as to minimize damage of roots. Two seedlings were transplanted to the each experimental pot in the afternoon during the last week of November 2019. Light irrigation was given immediately after transplanting by using water can. One seedling was uprooted leaving one seedling in each pot after seedling establishment.

Plate 1. Steps of seed sowing to transplanting. A) Soil preparation, B) Pot preparation C) Emergence of seedlings, D) Established seedling

3.13 Intercultural operations

Proper intercultural operations were done for better growth and development of tomato plants in pots. Weeding and mulching were accomplished as and when necessary to keep the crop free from weeds, better soil aeration and to break the soil crust.

3.13.1 Staking

At pre-flowering stage, the juvenile plants were staked with bamboo sticks to keep them erect and to protect from damage caused by storm and strong wind. The plants were tied by plastic ropes to the stems with bamboo slices which are hung above them.

3.13.2 Irrigation

Immediately after transplanting, light irrigation to the individual pot was provided to overcome water deficit. After establishment of seedlings, each pot was watered in alternate days to keep the soil moist for normal growth and development of the plants. During pre-flowering stage, irrigation was done with saline water as per treatments upto 50 DAT. Thereafter, no irrigation was given. However, water was sprayed over the foliage at regular intervals.

3.13.3 Plant protection measures

3.13.4 Insect pests and Diseases

As a preventive measure against the insect pest Ripcord was applied @ 2.0 ml L^{-1}. To prevent plants from insect infection, Volume flexi was applied @ 0.5 ml L^{-1} at the early stage of tomato. Virtako was also applied for controlling virus.

3.14 Harvesting of fruits

Fruits were harvested during early ripening stage when they attained red color. Harvesting was started on 9 March, 2020 and completed by 20 April.

Plate 2. Different intercultural operations. A) Hand weeding, B) Protection of plant from heavy rain, C) Labeling and tagging plants, D) Staking the plants

3.15 Parameters Studied:

Data on the following parameters were recorded:

3.15.1 Measurement of growth and morpho-physiological characters

1) Plant height (cm)

2) Number of primary branch Plant^{-1}

3) Number of leaves Plant^{-1}

4) Plant fresh weight

5) Plant dry weight

6) Leaf chlorophyll content

3.15.2 Measurement of yield and yield contributing characters

1) Number of Fruits Cluster Plant^{-1}

2) Number of Fruits Plant^{-1}

3) Individual Fruit Weight (g)

4) Fruit length (cm)

5) Fruit diameter (cm)

6) Average fruit weight (g)

7) Total fruit yield Plant^{-1} (g)

3.16 Detailed Procedures of Recording Data

A brief description of data collection and recording procedure which was followed during the study is given below:

A. Measurement of morphological characters

1. Plant height (cm)

Plant heights were measured in centimeter (cm) from the ground level to the tip of the longest stem from 20 DAT to 70 DAT interval at 10 days interval.

2. Number of primary branch plant^{-1}

The branch number of individual plant was counted at 20 days interval from 30 DAT, 50 DAT and 70 DAT and the average number of branch plant^{-1} was calculated.

3. Number of leaves plant^{-1}

The leaf number of individual plant was counted at 10 days interval from 20 DAT to 60 DAT and the average number of leaves plant^{-1} was calculated.

4. Plant fresh weight

Plant fresh weight excluding fruits was counted after uprooting plant using electrical balance machine and mean was calculated.

5. Plant dry weight

Plant dry weight excluding fruits was counted after drying the uprooted plant sample using electrical balance machine and mean was calculated. Dry weight measuring procedure of tomato plant is shown in Plate 3.

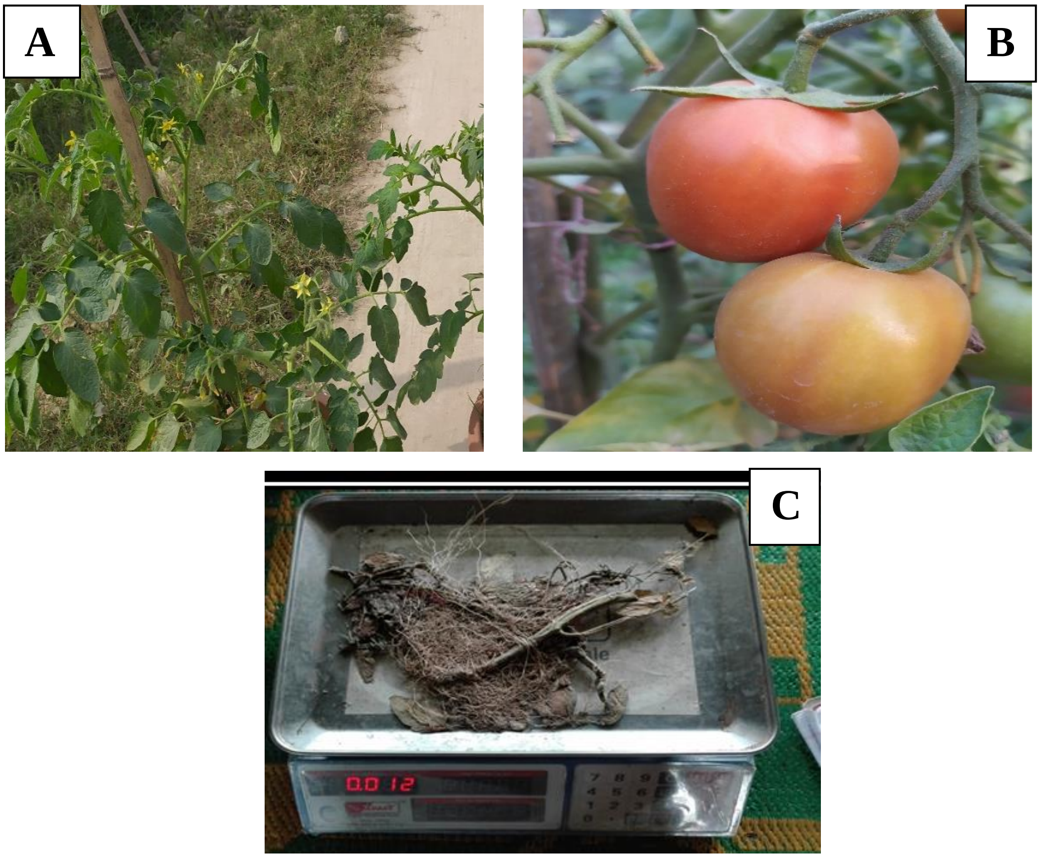

Plate 3. Data recording procedure and tomato growth stages A. Flowering stage, B. Fruit maturity stage, C. Plant dry weight measurement

B. Measurement of yield and yield contributing characters

1. Number of fruits cluster plant^{-1}

The number of fruit cluster of individual plant was recorded and the average number of cluster was recorded.

2. Number of fruits plant^{-1}

The number of fruits of individual plant was recorded and the average number of fruit was recorded.

3. Individual fruits weight (g)

The fresh weight of individual fruits from individual plant was recorded by an electric balance and the mean value was calculated

4. Fruit length (cm)

The length of fruit was measured with a slide calipers from the neck of the fruit to the bottom of 10 fruits from each plant and their average was taken and expressed in cm.

5. Fruit diameter (cm)

Diameter of fruit was measured at middle portion of 10 fruits from each plant with a slide calipers. Their average was taken and expressed in cm.

6. Wt. of individual fruit (g)

Among the total number of fruits during the period from first to final harvest, fruit was considered for determining the individual fruit weight by the following formula: Weight of individual fruit (g) = Total weight of fruits/ Total number of fruits.

7. Fruit wt. plant^{-1} (g)

Fruit weight of tomato plant^{-1} was calculated from the whole fruit plant-1 and was expressed in gram (g).

8. Average fruit wt. plant^{-1} (g)

The average fruits weight of in individual plant was recorded by an electric balance and then the fruit yield was calculated.

9. Chlorophyll contents (SPAD value)

Leaf chlorophyll content as SPAD values were measured from the youngest fully-expanded leaf in the third position from the tip by a portable chlorophyll meter (SPAD-502, Konica Minolta Sensing, Inc., Japan). The SPAD-502 chlorophyll meter can estimate total chlorophyll amounts in the leaves of a variety of species with a high degree of accuracy and is a nondestructive method.

3.17 Analysis of data

The data in respect of growth, yield contributing characters and yield were statistically analyzed to find out the statistical significance of the experimental results. The means for all the treatments were calculated and the analyses of variance for all the characters were performed by LSD test. The analyses were done following the software STATISTIX 10. The significance of the difference among the means was evaluated by the Least Significant Difference Test (LSD) at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Growth (vegetative) parameters

4.1.1 Salinity Effect on plant height

4.1.1.1 Plant height at 30 DAT

In the study maximum plant height observed in V2 (40 cm) and minimum plant height observed in V3 (38.33 cm) in normal condition. Salinity stress significantly decreased the plant height of all the tested tomato varieties with the increase of salinity level. In case of mild stress plant at 30 DAT plant height decreased by 18.38%, 20.82%, 10.43% and in case of severe stress plant height decreased by 24.35%, 27.07%, 18.67% in variety V1, V2, V3, respectively. Plant height decreased most in V2 variety (27.07%) and least reduction occurred in V3 variety (18%) compared to control under severe stress (Figure 1).

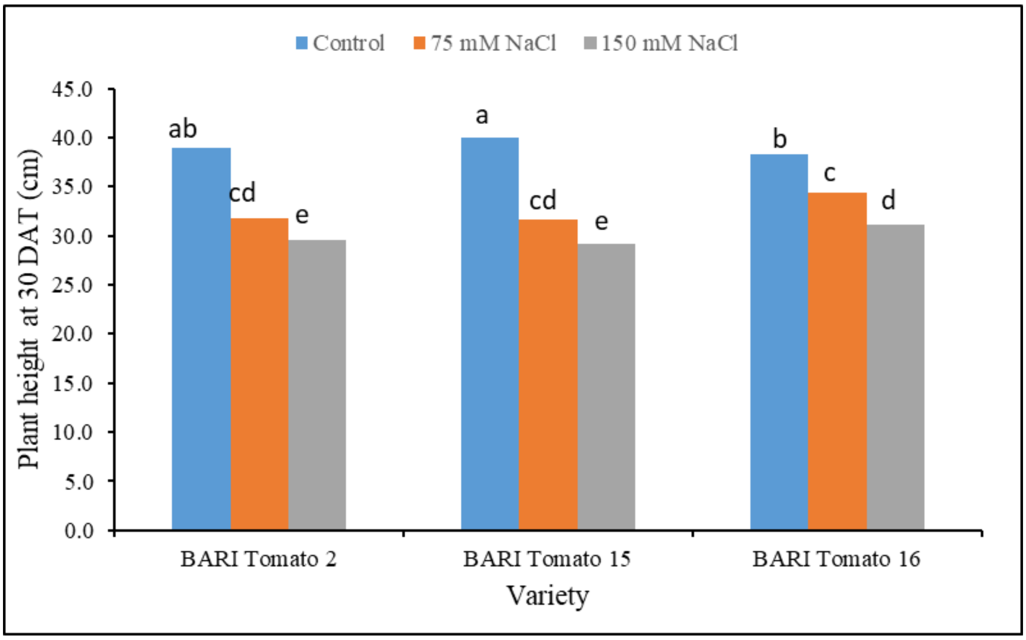

Figure 1. Effect of salinity on plant height at 30 DAT (days after transplanting). Means (±SD) were calculated from three replications for each treatment. Different letters are significantly different at P≤0.05 applying Fisher's LSD test

4.1.1.2 Plant height at 70 DAT

At 70 DAT, maximum plant height observed in V2 (93.67 cm) and minimum plant height observed in V1 (81.33 cm) in control. In case of mild stress plant height decreased by 5.32%, 16.19%, 3.37% and in case of severe stress plant height decreased by 9.11%, 22.78%, 12.09% in variety V1, V2, V3 respectively. Mild stress (S1) decreased most in V2 variety (16.19%) and least reduction occurred in V3 variety (3.37%) compared to control. Again in severe stress (S2), plant height decreased most in V2 variety (22.78%) and least reduction occurred in V1 (9%) variety compared to control (Figure 2).

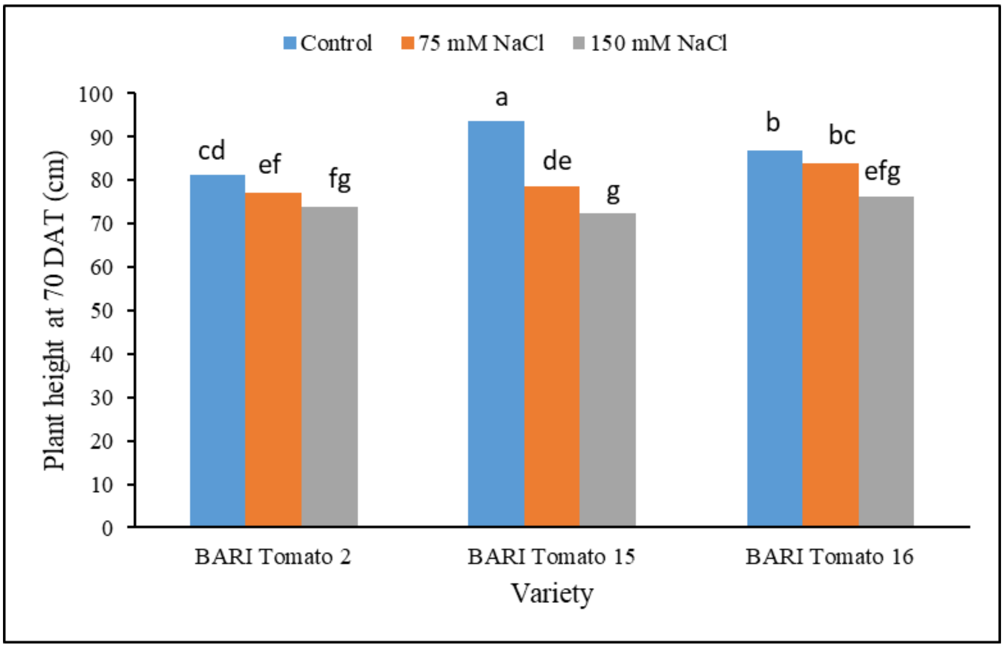

Figure 2. Effect of salinity on plant height at 70 DAT (days after transplanting). Means (±SD) were calculated from three replications for each treatment. Different letters are significantly different at P≤0.05 applying Fisher's LSD test

The results are in conformity with the results of Javed *et al.*, (2002) who observed decreased plant height in tomato under salinity stress. Salt stress inhibits cell division, cell elongation as well as plant growth (Munns and Tester, 2008). These results also supported by Islam *et al.*, (2011) and Al-Busaidi *et al.*, (2010) who reported that salt stress inhibit plant height as well as plant growth.

4.1.2 Effect on number of leaves plant^{-1}

4.1.2.1 Leaf number at 30 DAT

In the experiment maximum leaf number was observed in V3 (13) and minimum leaf number observed in V2 (11.67) in normal condition. Salinity stress gradually decreased the number of leaves per plant of all tested tomato varieties with the increase of salinity level and there is a significant variation in the decreased number of leaves per plant. In case of mild stress plant at 30 DAT leaf number decreased by 15.78%, 20.05%, 33.30% and in case of severe stress plant height decreased by 21.07%, 20.05%, 38.46% in variety V1, V2, V3 respectively. In mild stress (S1), leaf number per plant decreased most in V3 variety (33.30%) and least reduction occurred in V1 variety (15.78%) compared to respective control. In severe stress (S2), plant leaf number plant^{-1} decreased most in V3 variety (38.46%) and least reduction occurred in V2 variety (20%) compared to control (Figure 3).

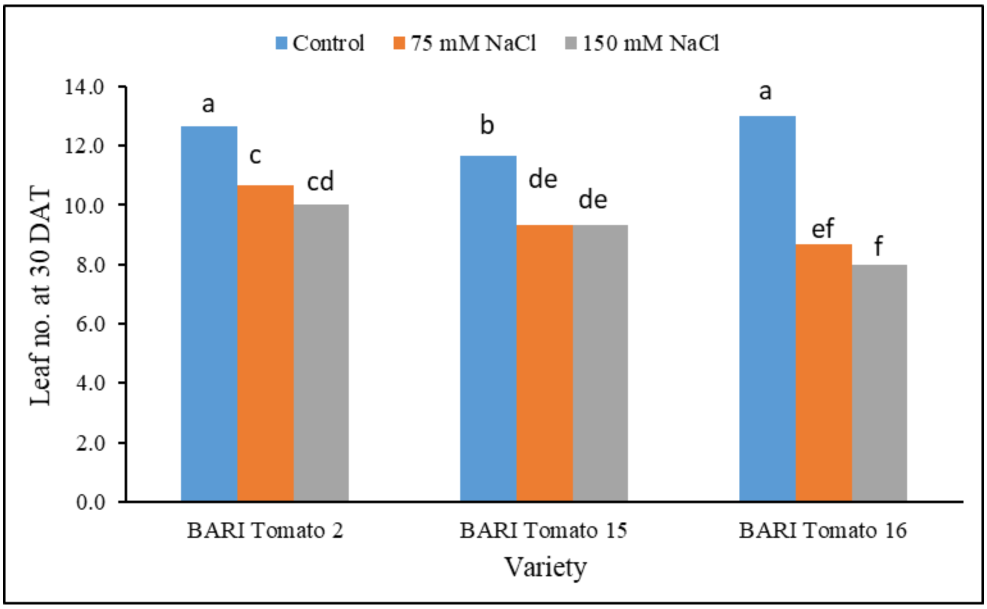

Figure 3. Effect of salinity on number of leaves at 30 DAT (days after transplanting). Means (±SD) were calculated from three replications for each treatment. Different letters are significantly different at P≤0.05 applying Fisher's LSD test

4.1.2.2 Leaf number at 50 DAT

At 50 DAT, maximum leaf number observed in V3 (25.33) and minimum leaf number observed in V1 (19.50) under control. In case of mild stress plant leaf number decreased by 16.25%, 17.15%, 11.64% and in case of severe stress leaf number decreased by 17.94%, 20.30%, 18.39% in variety V1, V2, V3 respectively. In a mild stress (S1), leaf number plant^{-1} decreased most and least respectively at V2 (17.15%) and V3 (12%). Whereas in severe stress (S2), leaf number per plant decreased most in V2 variety compared to control and least decreased in V1 variety (Figure 4).

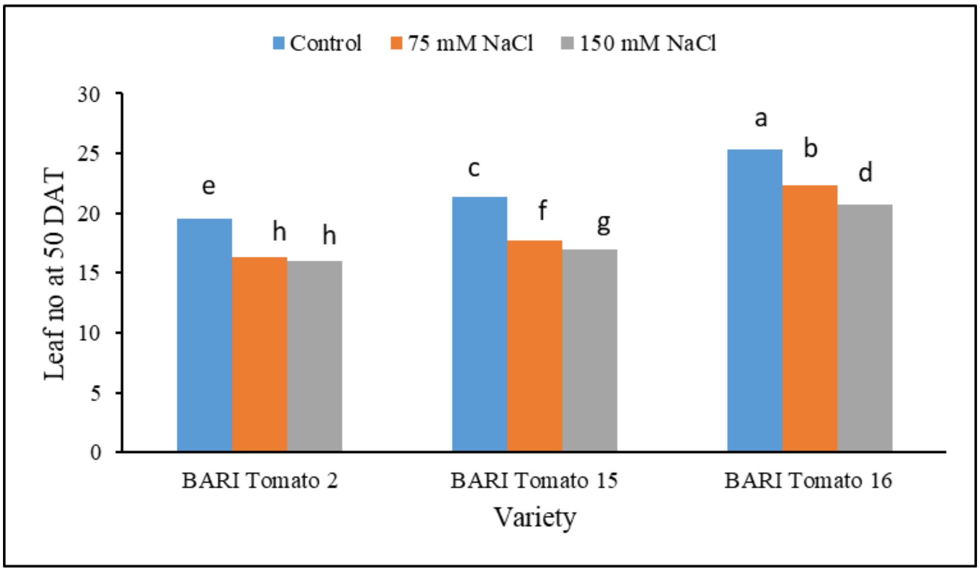

Figure 4. Effect of salinity on number of leaves at 50 DAT (days after transplanting). Means (±SD) were calculated from three replications for each treatment. Different letters are significantly different at P≤0.05 applying Fisher's LSD test

4.1.2.3 Leaf number at 70 DAT

At 70 DAT, maximum leaf number observed in V3 (29.67) and minimum leaf number observed in V2 (22.67) under control. In case of mild stress plant leaf number decreased by 5.7%, 2.9%, 14.62% and in case of severe stress leaf number decreased by 17%, 13.23%, 23.59% in variety V1, V2, V3 respectively. In case of mild stress (S1), leaf number per plant decreased most in variety V3 (14.62%) and least number of leaf plant^{-1} was observed in V2 (2.9%) variety. On the other hand, in severe stress (S2), leaf number plant^{-1} decreased most in variety V3 (23.59%) and least in variety V2 (13.23%) compared to control (Figure 5).

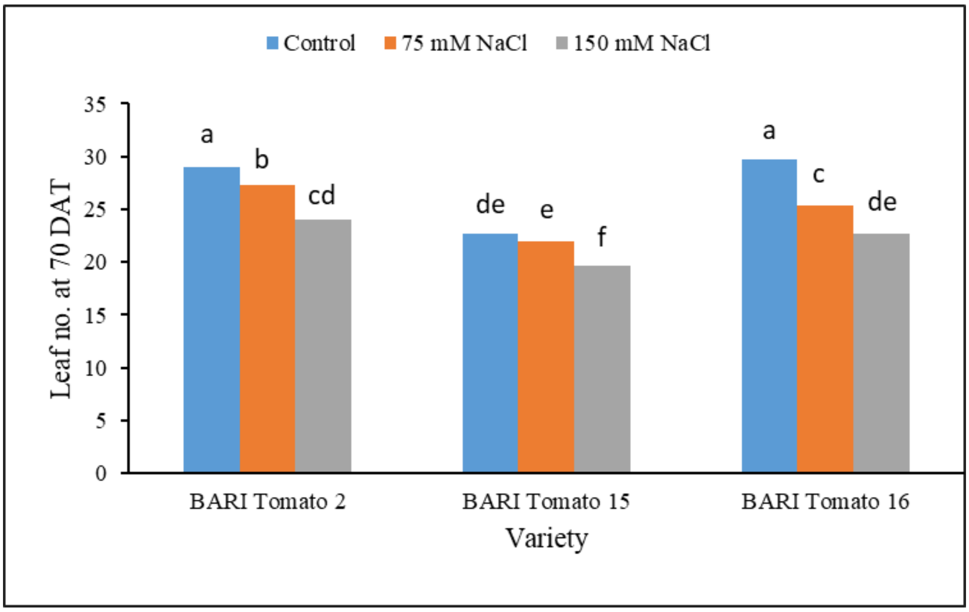

Figure 5. Effect of salinity on number of leaves at 70 DAT (days after transplanting). Means (±SD) were calculated from three replications for each treatment. Different letters are significantly different at P≤0.05 applying Fisher's LSD test

Ali and Rab (2016) confirmed that plant growth decreased due to reduction of leaf number as well as declining of total leaf area. Reduction of leaf number under different level of salinity stress also observed by Islam *et al*. (2011) and Alsadon *et al*. (2013).

4.1.3 Effect on number of branch plant^{-1}

4.1.3.1 Branch number at 50 DAT

In the experiment maximum brunch number observed in V3 (4.67) and minimum brunch number observed in V2 (3.33) in normal condition at 50 DAT. Salinity stress reduced the number of branches per plant of all tomato varieties studied as the salinity degree increased, and the decreased number of branches per plant. In case of mild stress plant leaf number decreased by 0%, 9.26%, 7.2% and in case of severe stress leaf number decreased by 9.26%, 27.24%, 28.69% in variety V1, V2, V3 respectively. When exposed to mild salinity (S1), the number of branches per plant reduced most in the V2 variety (9.26%), while no decline occurred in the V1 variety. In severe salinity (S2), the number of branches per plant decreases the most in V3 variety (28.69%) and the least in V1 variety (9.26%) compared to control (Figure 6).

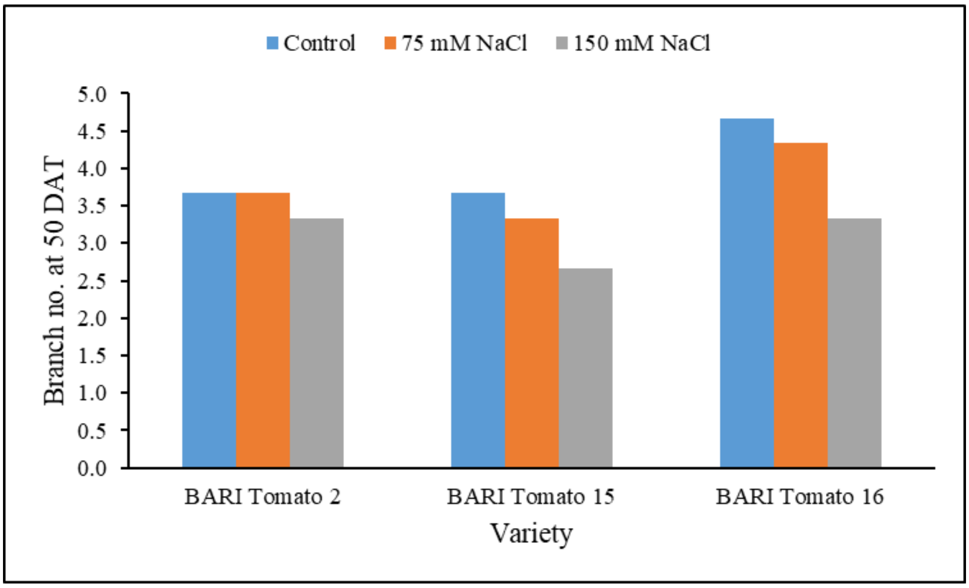

Figure 6. Effect of salinity on number of branches at 50 DAT (days after transplanting). Means (±SD) were calculated from three replications for each treatment.

4.1.3.2 Branch number at 70 DAT

At 70 DAT, maximum branch number observed in V3 (5.67) and minimum branch number observed in V1 (4.67) under control. In case of mild stress plant branch number decreased by 7.2%, 13.4%, 17.63% and in case of severe stress branch number decreased by 14.3%, 26.6%, 35.27% in variety V1, V2, V3 respectively. In mild stress (S1), maximum number of branch plant^{-1} decreased most in the variety V3 (17.63%) and least decreased in variety V1 (7.2%). In severe salinity (S2), the number of branches per plant fell the most in V3 variety (35.27%) and the least in V1 variety (14.3%) compared to control (Figure 7).

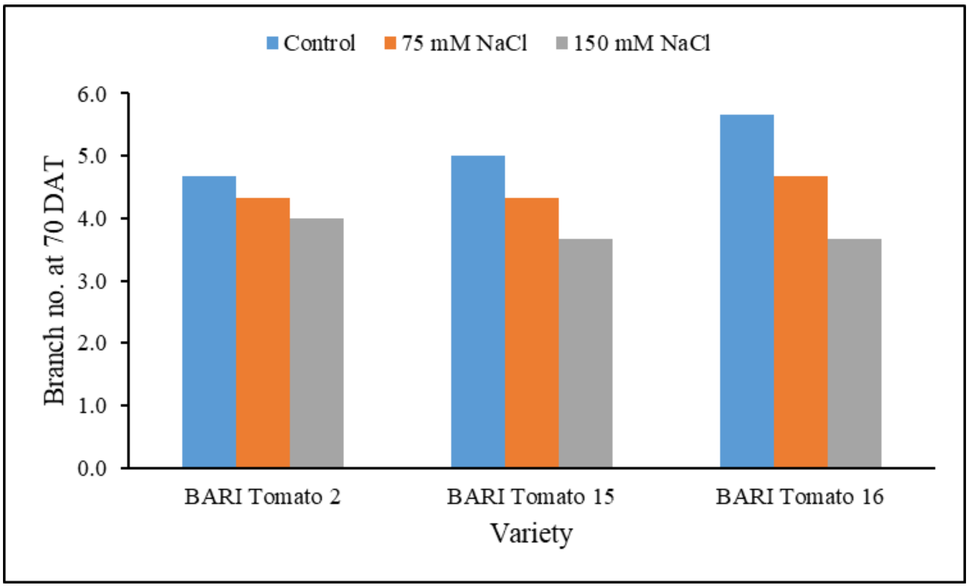

Figure 7. Effect of salinity on number of branches at 70 DAT (days after transplanting). Means (±SD) were calculated from three replications for each treatment.

Salinity stress restricted the generation of branch number and reduced the yield (Shimul *et al*. 2014; Islam *et al*., 2011). Alsadon *et al*. 2013 and Parvin, 2013 conducted experiment and confirmed salinity stress decreased branching of plant. The results of their study is parallel with this study.

4.1.4 Plant fresh weight

In the study maximum plant fresh weight observed in V3 (162.83 g) and minimum plant fresh weight observed in V1 (123.57 g) in normal condition. Salinity stress lowered the plant fresh weight of all tomato cultivars examined as the salinity level increased. In case of mild stress plant fresh weight decreased by 4.6%, 0.08%, 1% and in case of severe stress plant fresh weight decreased by 30.9%, 30.26%, 28.7% in variety V1, V2, V3 respectively. Plant fresh weight reduced non-significantly in the V2 (0.08%) and V3 (1%) variety during mild salinity (S1). In severe salinity (S2), plant fresh weight reduced in the most in V2 variety (30.26%) and the least in V1 variety (28.7%) compared to control (Figure 8). Salinity decreased the growth such as root and shoots fresh weight; root and shoot dry weight, number of leaves per plant, shoot/ root ratio and yield of tomato (Javed *et al.*, 2002; Khalid *et al.*, 2012). This result was also supported by Ali and Rab (2016).

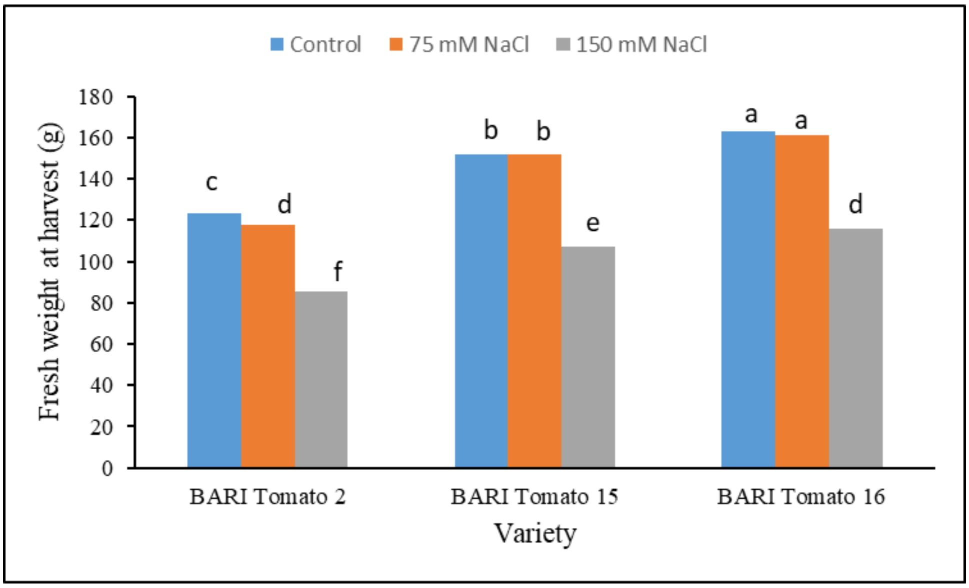

Figure 8. Effect of salinity on plant fresh weight at harvest. Means (±SD) were calculated from three replications for each treatment. Different letters are significantly different at P≤0.05 applying Fisher's LSD test

4.1.5 Plant dry weight

In the study maximum plant dry weight observed in V3 (34.65g) and minimum plant dry weight observed in V1 (20.14g) in normal condition. With increasing salinity levels, the dry weight of all tomato cultivars examined declined significantly. In case of mild stress plant dry weight decreased by 0.89%, 8.3%, 7.6% and in case of severe stress plant dry weight decreased by 5.2%, 41.1%, 47.9% in variety V1, V2, V3 respectively. Plant dry weight dropped non-significantly in the V1 variety (0.89%) during mild salinity (S1). In severe salinity (S2), plant dry weight declined the highest in V3 variety (47.9%) and the least in V1 variety (5.2%) compared to control (figure9). Salinity stress condition reduces number of branches per plant (Shimul *et al.*, 2014) and for this reason produces lower dry matter content in plant, which results in lower plant dry weight after drying. Similar results were also reported by Javed *et al*. (2002) and Ali and Rab (2016).

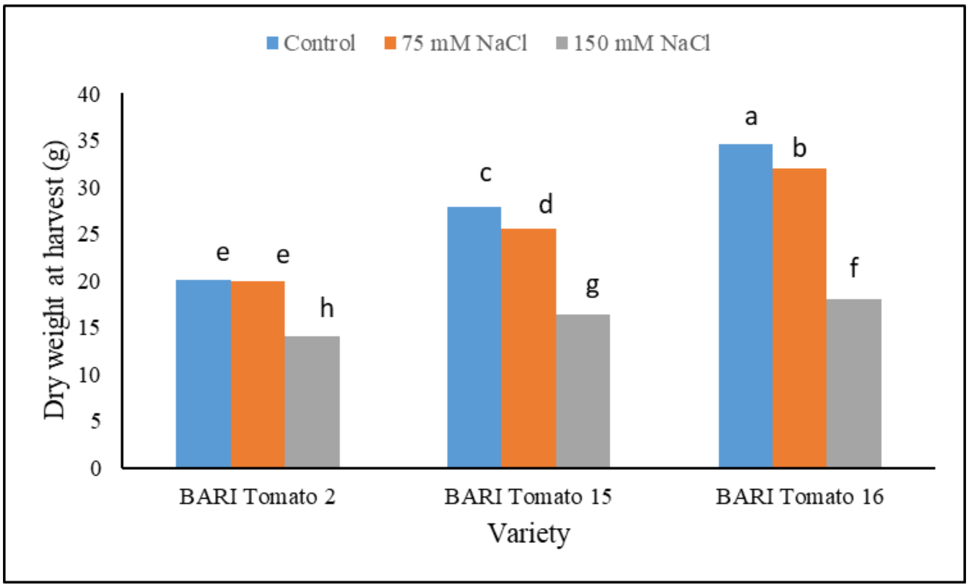

Figure 9. Effect of salinity on plant dry weight at harvest. Means (±SD) were calculated from three replications for each treatment. Different letters are significantly different at P≤0.05 applying Fisher's LSD test

4.1.6 SPAD value of leaf

Maximum SPAD value of leaf observed in V1 (61) and minimum SPAD value of leaf observed in V2 (56.7) in normal condition in our study. Salinity stress reduced the SPAD value of the leaf of all tomato cultivars examined as the salinity level increased. In case of mild stress SPAD value of leaf decreased by 14.45%, 11.8%, 12.39% and in case of severe stress SPAD value of leaf decreased by 19.18%, 17.10%, 17.09% in variety V1, V2, V3 respectively. When exposed to mild salinity (S1), the SPAD value of the leaf reduced most considerably (14.75%) in the V1 variety and least significantly (11%) in the V2 variety. When compared to control, the SPAD value of leaf fell most strongly in V1 (19.18%) and V3 (19.09%) varieties during severe salinity (S2) (Figure 10). Hassanuzzaman et al. (2009) confirmed that salinity stress decreased the plant chlorophyll content and decreased the photosynthetic performance. It was found that reduction of SPAD value (chlorophyll content) due to increase of salinity. These results also supported by (Parvin, 2013) who reported that chlorophyll content decreased with increasing the level of salinity.

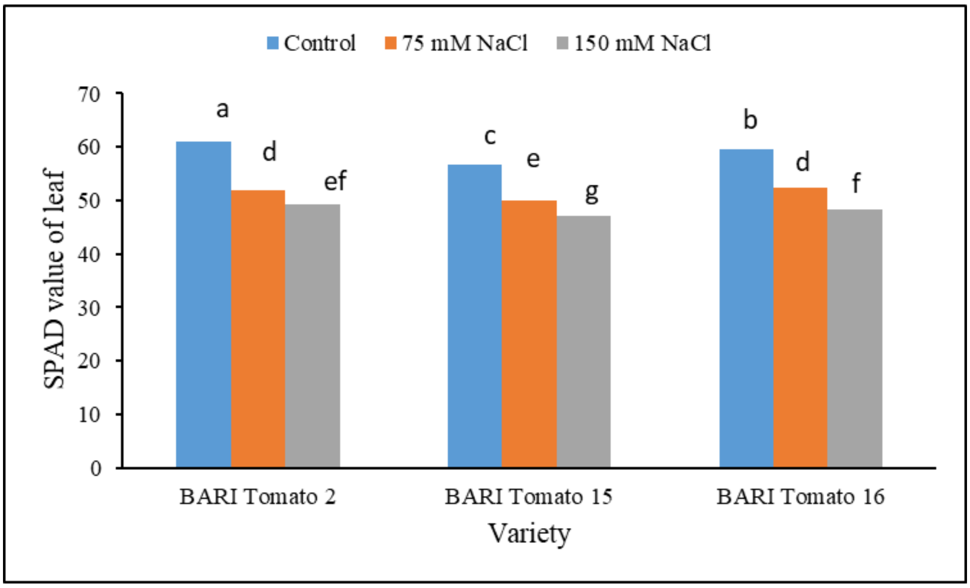

Figure 10. Effect of salinity on chlorophyll content (SPAD value) of tomato. Means (±SD) were calculated from three replications for each treatment. Different letters are significantly different at P≤0.05 applying Fisher's LSD test

4.2 Yield (reproductive) parameters

4.2.1 Number of fruits per cluster

In this study maximum number of fruits per cluster observed in all the three varieties (5.3) in normal condition compared with salinity. Number of fruits per cluster decreased with increasing the level of salinity. . In case of mild stress number of fruits per cluster decreased by 11.32%, 11.32%, 18.86% and in case of severe stress number of fruits per cluster decreased by 24.52%, 18.86%, 24.52% in variety V1, V2, V3 respectively. When subjected to a mild salinity (S1), the number of fruits reduced in the V1 and V2 varieties (11.32%) and most reduced in V3 variety (18.86%). When compared to control, the number of fruits reduced most considerably in V1 and V3 varieties (24.52%) during severe salinity (S2) (Figure 11). These results in agree with previous studies (Islam *et al*., 2011; Biswas *et al*., 2015) who reported that number of fruit per cluster varied with the variation of genotypes.

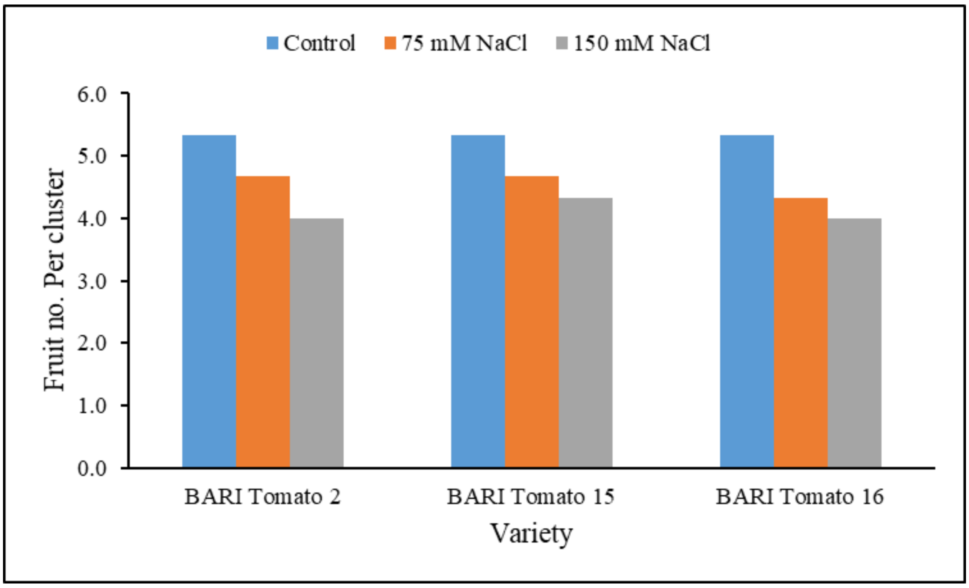

Figure 11. Effect of salinity on number of fruit per cluster of tomato. Means (±SD) were calculated from three replications for each treatment.

4.2.2 Number of fruits per plant

In this study maximum number of fruits per plant observed in V1 (19) and minimum number of fruits per plant observed in V3 (17.6) in normal condition. Salinity stress reduced the amount of fruits per plant of all tomato cultivars examined as the salinity degree increased. In mild salinity (S1), the quantity of fruits per plant reduced by7.36%, 11.22%, and 21.59% in the V1, V2, and V3 varieties, respectively, compared to control. In severe salinity (S2), the quantity of fruits per plant reduced by 16.31%, 19.78% and 35.79% in the V1, V2, and V3 varieties, respectively, compared to the control. In mild salinity, the V3 variety clearly outperforms others in terms of yield, but in extreme salinity its yield is significantly reduced. Despite having the largest significant production drop in mild salinity, the V1 variety showed least reduction in fruit number per plant when moving from mild to severe salinity (Figure 12). Number of fruit plant^{-1} decreased with increasing the level of salinity as flower dropping increased with increasing the level of salt stress. Salt stress decreased the reproductive growth and yield (Sun and Hauster, 2004; Shabani *et al.*, 2012). The results also suggested similar results as salinity decreased number of fruit plant^{-1}.

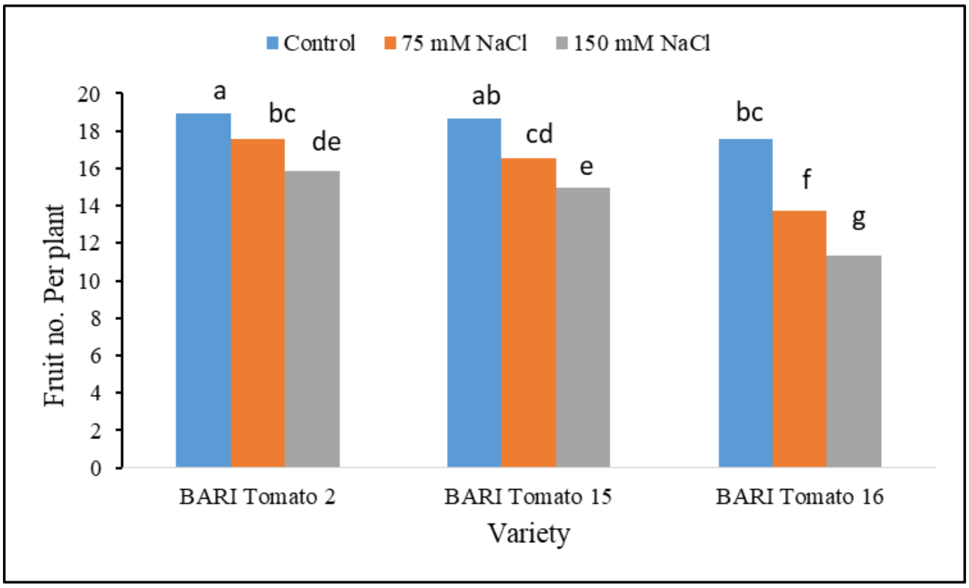

Figure 12. Effect of salinity on number of fruit per plant of tomato. Means (±SD) were calculated from three replications for each treatment. Different letters are significantly different at P≤0.05 applying Fisher's LSD test

4.2.3 Fruit length

In normal condition, maximum fruit length observed in V3 (5.1 cm) and minimum fruit length observed in V1 (4.7 cm) in our study. Salinity stress reduced the fruit duration of all tomato cultivars studied as the severity of salinity increased. In mild salinity (S1), fruit length reduced by 4.2%, 8%, and 7.8% in the V1, V2, and V3 varieties, respectively, compared to control. In severe salinity (S2), fruit length reduced by 6.38%, 14% and 11.76% in the V1, V2, and V3 varieties, respectively, compared to the control. Fruit length fell most in the V2 (8%) during a mild salinity (S1) compared to control. In severe salinity (S2), fruit length fell the most in V2 variety (14%) and the least in V1 variety (6.38%), compared to control (Figure 13). Based on the statistics, it is obvious that the V1 variety perform best in terms of fruit length in salinity and is the most salinity tolerant of the varieties. These results are in agreement with Hossain (2002) who reported that length of fruit decreased with increasing salinity. Similar results also observed by Kibria *et al*., (2013) who noted that fruit length varied with varietal variation.

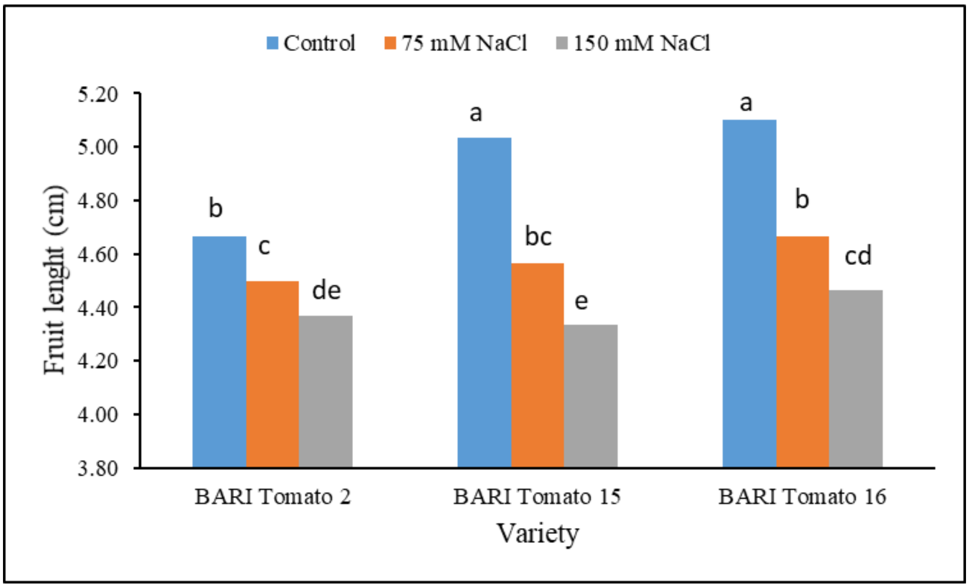

Figure 13. Effect of salinity on fruit length of tomato. Means (±SD) were calculated from three replications for each treatment. Different letters are significantly different at P≤0.05 applying Fisher's LSD test

4.2.4 Fruit diameter

In normal condition, maximum fruit diameter observed in V1 (5 cm) in our study. Salinity stress reduced the fruit diameter of all tomato cultivars studied as the level of salinity increased. In mild salinity (S1), fruit diameter reduced by 6%, 4.2%, and 6.38% in the V1, V2, and V3 varieties, respectively, compared to control. In severe salinity (S2), fruit diameter reduced by 12%, 8.5% and 10.6% in the V1, V2, and V3 varieties, respectively, compared to the control. Fruit diameter most reduced in the V3 variety (6.38%) and was least reduced in the V2 (4.2%) variety during a mild salinity (S1) compared to control. In severe salinity (S2), fruit diameter reduced the most in the V1 variety (12%), and the least in the V2 variety (8.5%), compared to control (Figure 14). Based on the collected data, it is obvious that the V2 variety performs best in terms of fruit diameter in salinity and is the most salinity tolerant of the varieties. These results supported by Islam *et al.* (2011) who noted that reproductive growth (e.g. fruit diameter, fruit length) of tomato decreased under salt stress and the level of deterioration increased with increasing the level of salinity.

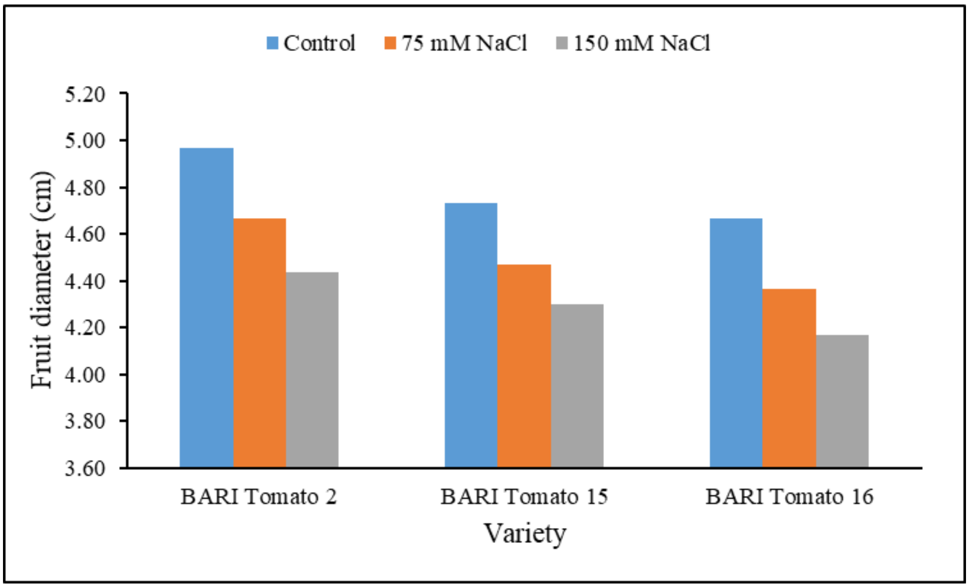

Figure 14. Effect of salinity on fruit diameter of tomato. Means (±SD) were calculated from three replications for each treatment.

4.2.5 Individual fruit weight per plant

In our study maximum individual fruit weight per plant observed in V3 (102.8 g) variety and minimum individual fruit weight per plant observed in V1 (89.9) in normal condition. Salinity stress reduced the individual fruit weight per plant of all tomato cultivars studied as the salinity level increased. In mild salinity (S1), individual fruit weight per plant decreased by 3.4%, 5.47%, and 7.29% in V1, V2 and V3 respectively compared to control. Again in severe salinity (S2), individual fruit weight per plant decreased by 19.6%, and 30.16% and 11.28% in V1, V2 and V3 varieties respectively compared to control. In mild salinity (S1), individual plant weight most decreased in V3 (7.29%) variety and lest reduced in V1 (3.4%) variety but in extreme salinity, its yield most reduced in V2 (30.16%). Again V3 variety showed better performance in severe salinity as yield reduction is lowest than others in spite of having highest yield reduction in mild salinity (Figure 15). Our finding supported by Islam *et al*. (2011) who noticed that individual fruit weight decreased under salt stress condition and fruit weight decreased with increasing the level of salt stress. Hossain (2002) also confirmed the similar results which strengthen our results.

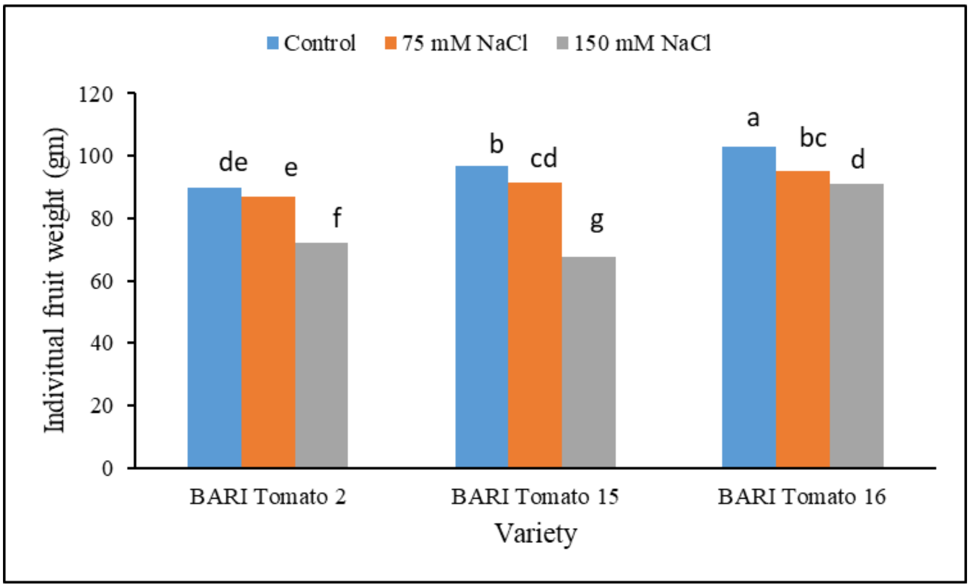

Figure 15. Effect of salinity on individual fruit weight of tomato. Means (±SD) were calculated from three replications for each treatment. Different letters are significantly different at P≤0.05 applying Fisher's LSD test

4.2.6 Fruit weight per plant

In this study maximum fruit weight per plant observed in V2 (1.809 kg) variety and minimum individual fruit weight per plant observed in V1 (1.707 kg) in normal condition. Salinity stress slightly decreased the fruit weight of all tested tomato varieties in mild salinity condition, but highly decreased showed in the three varieties in severe salinity. In mild salinity (S1), fruit weight per plant decreased most significantly in V3 variety (27%) and least reduction occurred in V1 variety (10%) compared to control. In severe condition (S2), fruit weight per plant most decreased in V2 (43.8%) variety and least reduced in V1 (10.58%) compared to control (Figure 16). Similar results were also reported by (Biswas *et al*., 2015; Kibria *et al*., 2013).

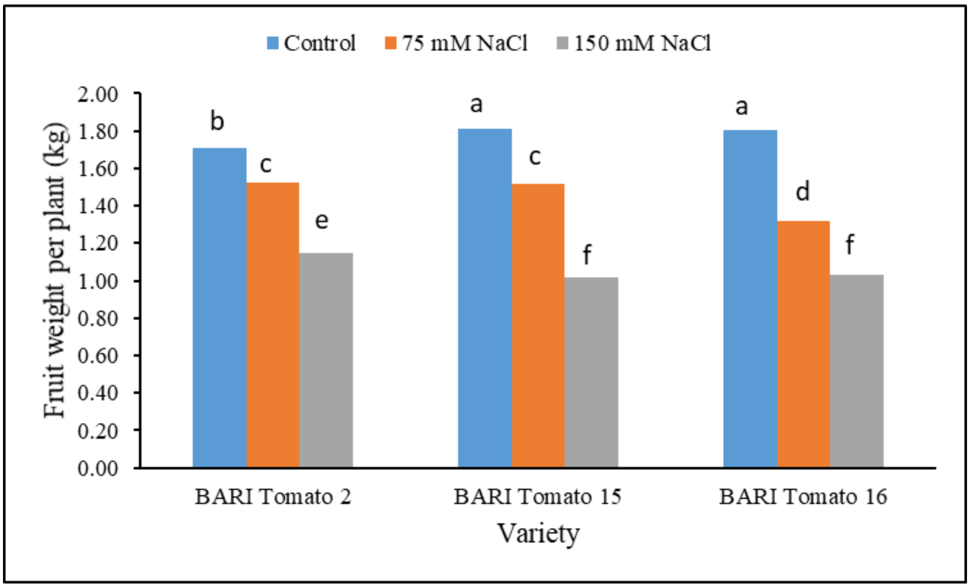

Figure 16. Effect of salinity on fruit weight of tomato. Means (±SD) were calculated from three replications for each treatment. Different letters are significantly different at P≤0.05 applying Fisher's LSD test

4.2.7 Yield per ha

In this study maximum yield observed in V2 (43.06 ton/ha) variety and minimum yield observed in V1 (40.6 3ton/ha) in normal condition. Salinity stress significantly decreased the yield per plant of all tested tomato varieties with the increase of salinity level. In mild salinity (S1), yield per plant decreased in V1, V2, and V3 variety respectively 10.75%, 16.16%, and 27.1% compared to control. Again in severe salinity (S2), yield per plant significantly decreased in V1, V2 and V3 variety respectively 32.66%, 43.9%, and 42.8% compared to control (Figure 17). This result is showing that in mild salinity stress V1 variety showed best performance compared to others. Again V1 variety showed better performance in severe salinity as yield reduction is lowest compared the others. This observation ensured that V1 variety is the most adaptable variety for mild salinity and V1 variety is the most suitable variety for severe salinity condition (Figure 17). Salt stress decreased total flower plant^{-1}, number of fruit plant^{-1}, individual fruit weight as well as fruit yield (Javed *et al.*, 2002; Khalid *et al.*, 2012). These results are in agreement with previous findings (Islam *et al.*, 2011 and Kibria *et al.*, 2013).

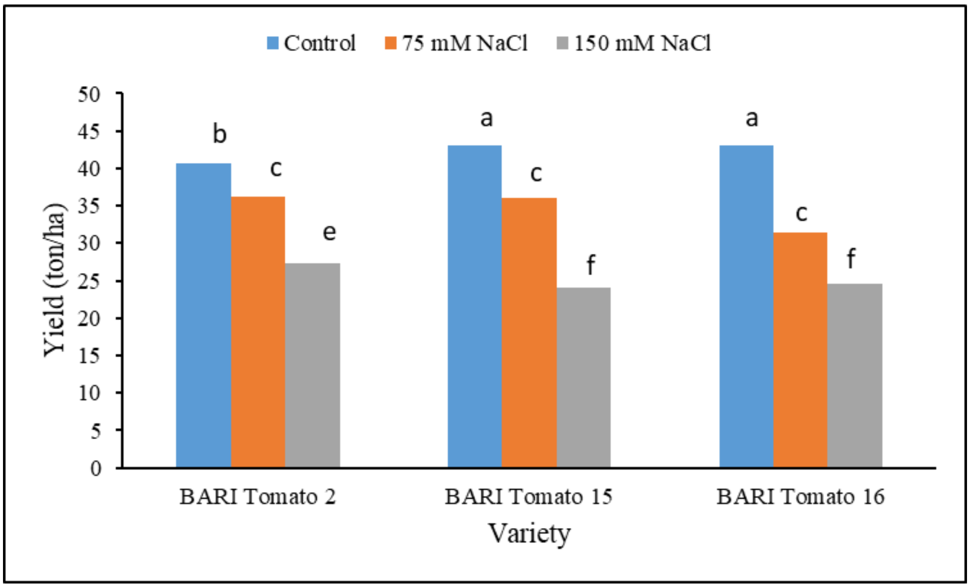

Figure 17. Effect of salinity on fruit yield per plant of tomato. Means (±SD) were calculated from three replications for each treatment. Different letters are significantly different at P≤0.05 applying Fisher's LSD test

CHAPTER V

SUMMARY AND CONCLUSION

5.1 SUMMARY

A pot experiment was conducted to observe the effects of salinity on morphological, yield and yield attributes of tomato cultivar. The experiment was carried out at the Agroforestry and Environmental Science Farm, Sher-e-Bangla Agricultural University (SAU) Dhaka, during the period from November, 2019 to April, 2020. Two factorial experiment including three tomato varieties viz. V1 (BARI Tomato 2), V2 (BARI Tomato 15), V3 (BARI Tomato 16) and three salinity treatments, S0 (control), S1 (mild salinity stress) and S2 (severe salinity stress) were outlined in completely randomized design (CRD) with 3 replications.

The results revealed that, growth, development, yield and yield attributes of tomato varied with the variation of genotypes. Among interactions of tomato varieties and salinity treatments, in case of plant height at 30 DAT, in mild salinity (S1), plant height most decreased in V2 variety (20.82%) and least reduction occurred in V3 variety (10.43%) and in case of 70 DAT, in mild salinity (S1), plant height most decreased in V2 variety (16.19%) and least reduction occurred in V3 variety (3.37%) compared to control. Again in severe salinity (S2) at 30 DAT, plant height decreased most in V2 variety (27.07%) and least reduction occurred in V3 variety (18.67%) compared to control and at 70 DAT, plant height decreased most in V2 (22.78%) variety and least reduction occurred in V1 (9.1%) variety compared to control . In case of number of leaves per plant, in mild salinity (S1) at 30 DAT, number of leaves per plant decreased most in V3 variety (33.30%) and least reduction occurred in V1 variety (15.78%) and at 50 DAT, number of leaves per plant decreased most in V2 variety (17.15%) and least reduction occurred in V3 variety (11.84%) and also at 70 DAT, number of leaves per plant decreased most in V3 variety (14.62%) and least reduction occurred in V2 variety (2.9%) compared to control. Again in severe salinity (S2) at 30 DAT, number of leaves per plant decreased most in V3 (38.46%) variety and least reduction occurred in V2 (20.05%) variety, at 50 DAT, number of leaves per plant decreased most in V3 variety (18.39%) and least reduction occurred in V1 variety (17.94%) and at 70 DAT, number of leaves per plant decreased most in V3 variety (23.59%) and least reduction occurred in V2 variety (13.23%) compared to control. In case of number of branches per plant at 50 DAT, in mild salinity (S1), number of branches per plant decreased most in V2 (9.26%) variety and least reduction occurred in V1 (0%) variety and at 70 DAT, in mild salinity (S1), number of branches per plant decreased most in V3 (17.63%) variety compared to control and least reduction occurred in V1 (7.2%) variety compared to control. Again in severe salinity (S2) at 50 DAT, number of branches per plant decreased most in V3 (28.69%) variety and least reduction occurred in V2 (9.26%) variety and at 70 DAT, number of branches per plant decreased most in V3 (35.27%) variety and least reduction occurred in V1 (14.3%) variety compared to control. In case of plant fresh weight, in mild salinity (S1), plant fresh weight decreased most in V1 variety (4.6%) and no reduction occurred in V2 variety compared to control. Again in severe salinity (S2), plant fresh weight decreased most in V2 (30.26%) variety and least reduction occurred in V3 variety (28.7%) compared to control. In case of plant dry weight, in mild salinity (S1), plant dry weight decreased most in V2 variety (8.3%) non-significant and reduction occurred in V1 (0.89%) variety compared to control. Again in severe drought (S2), plant dry weight mot decreased most in V3 variety (47.9%) and least significant reduction occurred in V1 variety (5.2%) compared to control. In case of SPAD value of leaf, in mild salinity (S1), SPAD value of leaf decreased most in V1 variety (14.75%) and least reduction occurred in V2 variety (11.8%) compared to control. Again in severe salinity (S2), SPAD value of leaf decreased most in V1 variety (19.18%) and least reduction occurred in V2 variety (17.10%) compared to control. In case of number of fruits per cluster, in mild salinity (S1), number of fruits decreased most in V3 variety (18.86%) and least reduction occurred in V1 and V2 variety(11.32%) compared to control. Again in severe salinity (S2), number of fruits decreased most in V1 and V3 variety (24.52%) and least reduction occurred in V2 variety (18.86%). In case of number of fruits per plant, in mild salinity (S1), number of fruits per plant decreased most in V3 variety (21.59%) and least decreased in V1 variety (7.36%) compared to control. Again in severe salinity (S2), number of fruits per plant decreased in V1, V2 and V3 variety respectively 16.31%, 1.789%, and 35.79% compared to control but most decreased in V3. In case of fruit length, in mild salinity (S1), fruit length decreased most in V2 variety (8%) and least reduction occurred in V1 variety (4.2%) compared to control. Again in severe salinity (S2), fruit length decreased most in V2 variety (14%) and least reduction occurred in V1 variety (6.38%). In case of fruit diameter, in mild salinity (S1), fruit diameter decreased most in V3 variety (6.38%) and least reduction occurred in V2 variety (4.2%) compared to control. Again in severe salinity (S2), fruit diameter decreased most in V1 variety (12%) and least reduction occurred in V2 variety (8.5%) compared to control. In case of individual fruit weight per plant, in mild salinity (S1), individual fruit weight per plant decreased in V1, V2 and V3 variety respectively 3.4%, 5.47% and 7.29% compared to control. Again in severe salinity (S2), individual fruit weight per plant decreased in V1, V2 and V3 variety respectively 19.6%, 30.16% and 11.28% compared to control. In case of fruit weight per plant, in mild salinity (S1), fruit weight per plant decreased most in V3 variety (27.22%) and least reduction occurred in V1 variety (10.58%) compared to control. Again in severe salinity (S2), fruit weight per plant decreased most in V2 variety (43.8%) and least reduction occurred in V1 variety (32.3%) compared to control. In case of yield per plant, in mild salinity (S1), yield per plant decreased most in V3 variety (27.1%) and least reduction occurred in V1 variety (10.75%) compared to control. Again in severe salinity (S2), yield per plant decreased most in V2 variety (43.9%) and least reduction occurred in V1 variety (32.66%) compared to control. Considering the present results, we can concluded that growth and yield of tomato varied with and without salt stress. Exposure of salt stress in tomato cultivar (BARI Tomato 2, BARI Tomato 15 and BARI 16) decreased growth and yield with increasing the level of salinity.

5.2 CONCLUION

Salinity is one of the world's most serious environmental hazards, reducing crop growth and output. Tomato (*Solanum lycopersicum L.*), a member of the Solanaceae family, is one of Bangladesh's most significant vegetable crops and is highly susceptible to salinity. So salinity tolerant tomato varieties must be chosen to combat the salinity problem. Salinity disturbs the plant physiological activities which have negative effects on growth and yield performances of tomato. In normal condition BARI Tomato-15 produced highest yield following BARI Tomato-16 and BARI Tomato-2. But severe salinity stress reduced yield by 32.66%, 43.9% and 42.8% in BARI Tomato-2, BARI Tomato-15 and BARI Tomato-16 respectively. Results of the experiment showed that BARI Tomato-2 was comparatively more salt tolerant than the other cultivar used in this experiment.

RECOMMENDATIONS

- In the future, further growth and yield-based field study on this topic should be conducted in saline prone area to obtain more precise results.
- There should be more exploration in the physiological and molecular level of salinity tolerance.
- More poplar varieties of tomato should be explored to get good result.

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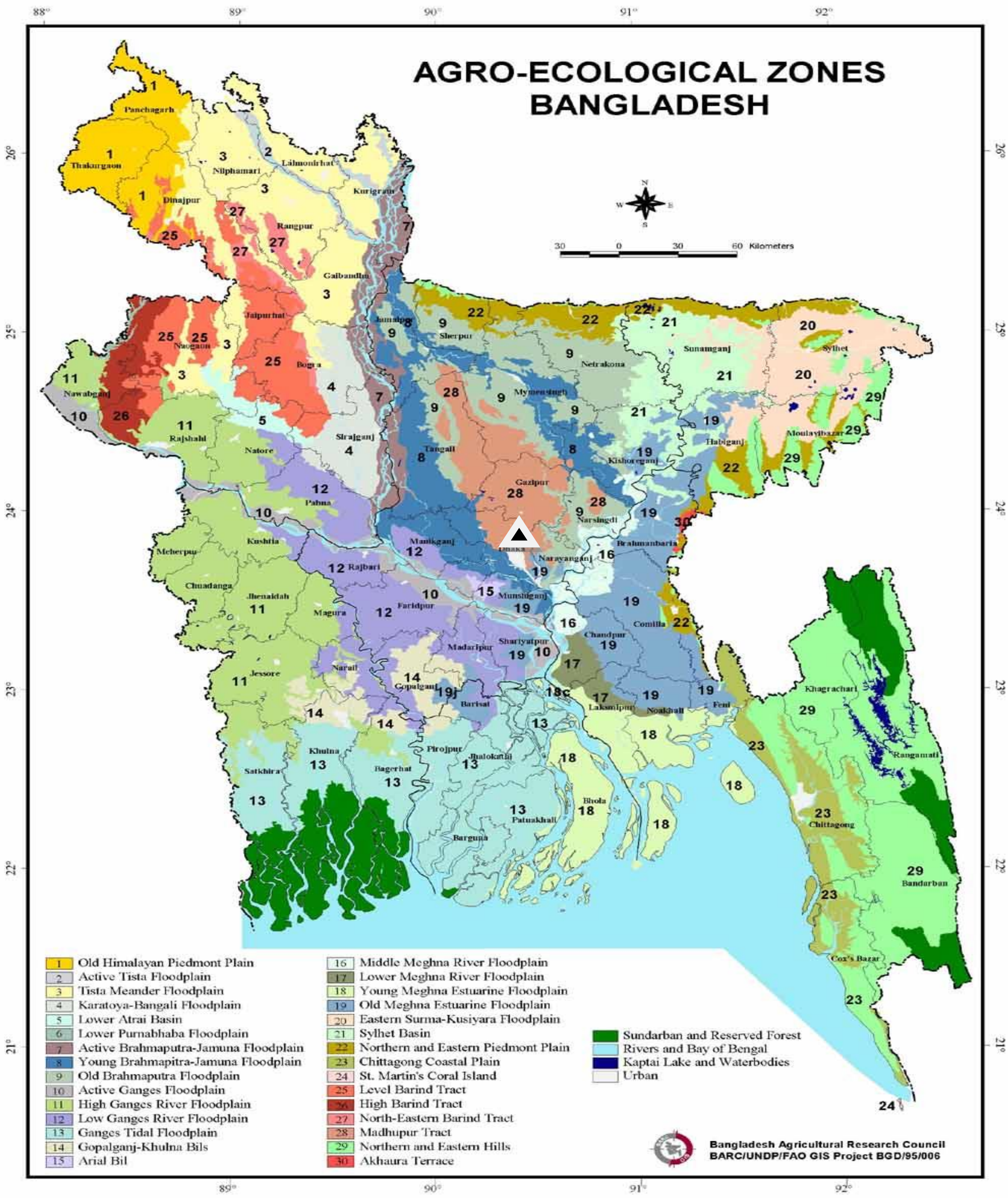
APPENDICES

Appendix 1. Map showing the experimental site under the study



▲ The experimental site under study

Appendix 2. Monthly records of air temperature, relative humidity, rainfall and sunshine hours during the period from October 2019 to March 2020.

Month	Year	Monthly average air temperature (°C)			Average relative humidity (%)	Total rainfall (mm)	Total sunshine (hours)
		Maximum	Minimum	Mean			
Oct.	2019	36	21	28	69	Trace	219
Nov.	2019	31	18	24	63	Trace	216
Dec.	2019	28	16	22	61	Trace	212
Jan.	2020	27	13	20	57	Trace	198
Feb.	2020	29	18	23	70	3	225
Mar.	2020	32	22	25	73	4	231

Source: Bangladesh Meteorological Department (Climate division), Agargaon Dhaka-1212.

Appendix 3. The mechanical and chemical characteristics of soil of the experimental site as observed prior to experimentation (0 -15 cm depth).

Mechanical composition:

Particle size	**Constitution**
Texture	Loamy
Sand	40%
Silt	40%
Clay	20%

Chemical composition:

Soil characters	Value
Organic matter	1.44 %
Potassium	0.15 meq/100 g soil
Calcium	1.00 meq/100 g soil
Magnesium	1.00 meq/100 g soil
Total nitrogen	0.072
Phosphorus	22.08 µg/g soil
Sulphur	25.98 µg/g soil
Boron	0.48 µg/g soi
Copper	3.54 µg/g soil
Iron	262.6 µg/g soil
Manganese	164 µg/g soil
Zinc	3.32 µg/g soil

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

Appendix 4. Mean values of different growth and yield contributing traits of three tomato varieties under control and salinity stress treatment

	Plant height at 30 DAT (cm)	Plant height at 70 DAT (cm)	Leaf no. at 30 DAT	Leaf no. at 50 DAT	Leaf no. at 70 DAT	Number of branches at 50 DAT	Number of branches at 70 DAT
V1S0	39.00	81.33	12.67	19.50	29.00	3.67	4.67
V1S1	31.83	77.00	10.67	16.33	27.33	3.67	4.33
V1S2	29.50	73.92	10.00	16.00	24.00	3.33	4.00
V2S0	40.00	93.67	11.67	21.33	22.67	3.67	5.00
V2S1	31.67	78.50	9.33	17.67	22.00	3.33	4.33
V2S2	29.17	72.33	9.33	17.00	19.67	2.67	3.67
V3S0	38.33	86.83	13.00	25.33	29.67	4.67	5.67
V3S1	34.33	83.90	8.67	22.33	25.33	4.33	4.67
V3S2	31.17	76.33	8.00	20.67	22.67	3.33	3.67

S0: control; S1: Mild Salinity; S2: Severe Salinity

Appendix 4. (cont.)

	SPAD value of leaf	Plant fresh weight (g)	Plant dry weight (g)	Number of fruits per cluster	Number of fruits per plant
V1S0	61.0	123.57	20.14	5.3	19.0
V1S1	52.0	117.80	19.96	4.7	17.6
V1S2	49.3	85.33	14.09	4.0	15.9
V2S0	56.6	152.10	27.92	5.3	18.7
V2S1	50.0	151.97	25.59	4.7	16.6
V2S2	47.0	106.93	16.44	4.3	15.0
V3S0	59.7	162.83	34.65	5.3	17.6
V3S1	52.3	161.17	32.00	4.3	13.8
V3S2	48.3	116.07	18.05	4.0	11.3

S0: control; S1: Mild Salinity; S2: Severe Salinity

Appendix 4. (cont.)

	Individual fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Fruit Weight Per plant(g)	Yield per plant (ton/ha)
V1S0	89.9	4.7	5.0	1.707	40.633
V1S1	86.8	4.5	4.7	1.523	36.260
V1S2	72.2	4.4	4.4	1.150	27.360
V2S0	96.8	5.0	4.7	1.809	43.067
V2S1	91.5	4.6	4.5	1.517	36.100
V2S2	67.6	4.3	4.3	1.015	24.150
V3S0	102.8	5.1	4.7	1.808	43.023
V3S1	95.3	4.7	4.4	1.318	31.360
V3S2	91.2	4.5	4.2	1.033	24.577

S0: control; S1: Mild Salinity; S2: Severe Salinity

Appendix 5. Factorial ANOVA Table for all the growth and yield parameters of three tomato varieties under control and salinity stress treatment

Factorial ANOVA Table for Plant height (cm)

Factorial AOV Table for Plant Height at 30 DAT

Source	**DF**	**SS**	**MS**	**F**	**P**
Replication	2	3.389	1.694		
Variety	2	2.389	1.194	1.65	0.2239
Treatment	2	422.389	211.194	291.02	0.0000
Variety* Treatment	4	13.889	3.472	4.78	0.0099
Error	16	11.611	0.726		
Total	26	453.667			

Grand Mean 33.778
CV 2.52

Factorial AOV Table for Plant Height at 70 DAT

Source	**DF**	**SS**	**MS**	**F**	**P**
Replication	2	14.86	7.428		
Variety	2	125.39	62.697	11.34	0.0009
Treatment	2	775.54	387.770	70.12	0.0000
Variety*Treatment	4	207.03	51.757	9.36	0.0004
Error	16	88.48	5.530		
Total	26	1211.30			

Grand Mean 80.424
CV 2.92

Factorial ANOVA Table for Number of leaves per plant

Factorial AOV Table for Leaf Numbers at 30 DAT

Source	**DF**	**SS**	**MS**	**F**	**P**
Replication	2	0.1296	0.0648		
Variety	2	7.6296	3.8148	15.77	0.0002
Treatment	2	58.9630	29.4815	121.88	0.0000
Variety*Treatment	4	7.7037	1.9259	7.96	0.0010
Error	16	3.8704	0.2419		
Total	26	78.2963			

Grand Mean 10.370
CV 4.74

Factorial AOV Table for Leaf Numbers at 50 DAT

Source	DF	SS	MS	F	P
Replication	2	0.296	0.1481		
Variety	2	147.241	73.6204	534.52	0.0000
Treatment	2	86.685	43.3426	314.69	0.0000
Variety*Treatment	4	1.926	0.4815	3.50	0.0311
Error	16	2.204	0.1377		
Total	26	238.352			

Grand Mean 19.574
CV 1.90

Factorial AOV Table for Leaf Numbers at 70 DAT

Source	DF	SS	MS	F	P
Replication	2	0.296	0.1481		
Variety	2	146.963	73.4815	100.46	0.0000
Treatment	2	112.963	56.4815	77.22	0.0000
Variety*Treatment	4	15.704	3.9259	5.37	0.0062
Error	16	11.704	0.7315		
Total	26	287.630			

Grand Mean 24.704
CV 3.46

Factorial ANOVA Table for Number of branches per plant

Factorial AOV Table for Brunch Numbers at 50 DAT

Source	DF	SS	MS	F	P
Replication	2	0.07407	0.03704		
Variety	2	3.62963	1.81481	20.36	0.0000
Treatment	2	3.85185	1.92593	21.61	0.0000
Variety*Treatment	4	0.81481	0.20370	2.29	0.1051
Error	16	1.42593	0.08912		
Total	26	9.79630			

Grand Mean 3.6296
CV 8.22

Factorial AOV Table for Brunch Numbers at 70 DAT

Source	DF	SS	MS	F	P
Replication	2	0.0185	0.00926		
Variety	2	0.5185	0.25926	2.80	0.0906
Treatment	2	9.4074	4.70370	50.80	0.0000
Variety*Treatment	4	0.8148	0.20370	2.20	0.1152
Error	16	1.4815	0.09259		
Total	26	12.2407			

Grand Mean 4.4815
CV 6.79

Factorial ANOVA Table for SPAD value of leaf

Source	DF	SS	MS	F	P
Replication	2	1.407	0.704		
Variety	2	41.185	20.593	41.57	0.0000
Treatment	2	563.185	281.593	568.45	0.0000
Variety*Treatment	4	6.148	1.537	3.10	0.0455
Error	16	7.926	0.495		
Total	26	619.852			

Grand Mean 52.926
CV 1.33

Factorial ANOVA Table for Plant fresh weight (g)

Source	DF	SS	MS	F	P
Replication	2	60.3	30.17		
Variety	2	6934.5	3467.23	324.25	0.0000
Treatment	2	10677.1	5338.56	499.26	0.0000
Variety*Treatment	4	164.0	40.99	3.83	0.0227
Error	16	171.1	10.69		
Total	26	18007.0			

Grand Mean 130.86
CV 2.50

Factorial ANOVA Table for Plant dry weight (g)

Source	DF	SS	MS	F	P
Replication	2	0.63	0.316		
Variety	2	465.23	232.615	448.77	0.0000
Treatment	2	676.86	338.432	652.92	0.0000
Variety*Treatment	4	92.25	23.063	44.49	0.0000
Error	16	8.29	0.518		
Total	26	1243.27			

Grand Mean 23.204
CV 3.10

Factorial ANOVA Table for Number of fruits per cluster

Source	DF	SS	MS	F	P
Replication	2	0.2222	0.11111		
Treatment	2	6.8889	3.44444	8.55	0.0030
Variety	2	0.2222	0.11111	0.28	0.7625
Treatment*Variety	4	0.2222	0.05556	0.14	0.9658
Error	16	6.4444	0.40278		
Total	26	14.0000			

Grand Mean 4.66667
CV 13.60

Factorial ANOVA Table for Number of fruits per plant

Source	DF	SS	MS	F	P
Replication	2	0.181	0.0904		
Treatment	2	85.379	42.6893	101.25	0.0000
Variety	2	51.845	25.9226	61.48	0.0000
Treatment*Variety	4	9.277	2.3193	5.50	0.0056
Error	16	6.746	0.4216		
Total	26	153.427			

Grand Mean 16.148
CV 4.02

Factorial ANOVA Table for Individual fruit weight (g)

Source	DF	SS	MS	F	P
Replication	2	16.19	8.094		
Treatment	2	1829.51	914.754	170.87	0.0000
Variety	2	933.01	466.507	87.12	0.0000
Treatment*Variety	4	365.83	91.459	17.08	0.0000
Error	16	85.67	5.355		
Total	26	3230.21			

Grand Mean 88.221
CV 2.62

Factorial ANOVA Table for Fruit diameter (cm)

Source	DF	SS	MS	F	P
Replication	2	0.02741	0.01370		
Treatment	2	1.08741	0.54370	189.48	0.0000
Variety	2	0.38741	0.19370	67.48	0.0015
Treatment*Variety	4	0.00815	0.00204	0.71	0.5971
Error	16	0.04593	0.00287		
Total	26	1.55630			

Grand Mean 4.5296
CV 1.18

Factorial ANOVA Table for Fruit length (cm)

Source	DF	SS	MS	F	P
Replication	2	0.02889	0.01444		
Treatment	2	1.37556	0.68778	190.46	0.0000
Variety	2	0.24667	0.12333	34.15	0.0000
Treatment*Variety	4	0.15111	0.03778	10.46	0.0002
Error	16	0.05778	0.00361		
Total	26	1.86000			

Grand Mean 4.6333
CV 1.30

Factorial AOV Table for Fruit weight per plant (g)

Source	DF	SS	MS	F	P
Replication	2	0.00313	0.00156		
Treatment	2	2.29468	1.14734	927.02	0.0013
Variety	2	0.02585	0.01292	10.44	0.0000
Treatment*Variety	4	0.10327	0.02582	20.86	0.0000
Error	16	0.01980	0.00124		
Total	26	2.44673			

Grand Mean 1.4295
CV 2.46

Factorial ANOVA Table for Yield per plant (kg)

Source	DF	SS	MS	F	P
Replication	2	1.77	0.886		
Treatment	2	1299.80	649.901	927.02	0.0000
Variety	2	14.64	7.320	10.44	0.0000
Treatment*Variety	4	58.50	14.624	20.86	0.0000
Error	16	11.22	0.701		
Total	26	1385.93			

Grand Mean 34.021
CV 2.46