GENOTYPE × STRESS INTERACTION UNDER SALINITY AND DROUGHT CONDITION IN TOMATO *(Solanum lycopersicum* L.*)*

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BY

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CERTIFICATE

This is to certify that thesis entitled, "GENOTYPE × STRESS INTERACTION UNDER SALINITY AND DROUGHT CONDITION IN TOMATO (Solanum lycopersicum L.)" 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 GENETICS AND PLANT BREEDING****, embodies the result of a piece of bona fide research work carried out by ABU BAKAR SIDDIQUE, Registration No. 13-05333 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 duly been acknowledged.

Dated: June, 2019
Place: Dhaka, Bangladesh

(Prof. Dr. Naheed Zeba)
Supervisor

DEDICATED

TO

MY BELOVED PARENTS

Some commonly used abbreviations

Full Word	Abbreviation	Full Word	Abbreviation
Ammonium Nitrate	NH_4NO_3	Horticulture	*Hort.*
Amonium Ion	NH_4	International	*Intl.*
Agriculture	*Agric.*	Journal	*J.*
Applied	*App.*	Killo gram	Kg
Analysis of Variance	ANOVA	Least Significant Difference	LSD
Botany	*Bot.*		
Biology	*Biol.*	Leaf Area	LA
Bangladesh Bureau of Statistics	BBS	Membrane Stability Index	MSI
Bangladesh Agricultural Research Institute	BARI	Micro molar	umol
		Meter	m
Calcium Ion	Ca^{2+}	Milli gram	mg
Carbon Dioxide	CO_2	Mili molar	mmol
Chloride ion	Cl^-	Millimeter	mm
Completely Randomized Design	CRD	Nitric Acid	HNO_3
		Parts per Million	ppm
Centimeter	cm	Perchloric Acid	$HClO_4$
Days after transplanting	DAT	Plant Genetic Resource Centre	PGRC
Decisimens per meter	dS/m		
Experimental	*Expt.*	Physiology	*Physiol.*
Environment	*Envriron.*	Potassium Ion	K^+
Electrical Conductivity	EC	Relative Water Content	RWC
Farmyard Manure	FYM	Sher-e-Bangla Agricultural University	SAU
Food and Agriculture Organization	FAO		
		Sodium Hydroxide	NaOH
Gram	g	Ultra Violet Ray	UV

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The Author

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GENOTYPE × STRESS INTERACTION UNDER SALINITY AND DROUGHT CONDITION IN TOMATO *(Solanum lycopersicum* L.*)*

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ABSTRACT

This study was conducted to investigate the genotype and stress interaction under salinity and drought condition. The experiments were conducted in net house of Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University from November 2018 to March 2019. Two independent experiments were conducted with eight tomato genotypes collected from Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University. The genotypes were SL 021 (G_1), SL 022 (G_2), SL 023 (G_3), SL 024 (G_4), SL 025 (G_5), SL 026 (G_6), SL 027 (G_7) and BARI tomato 11 (G_8). Four salinity treatments viz. T_1 (control), T_2 (4 dS/m, mild salinity), T_3 (8 dS/m, moderate salinity), T_4 (12 dS/m, severe salinity) and four drought treatments viz. T_1 (control), T_2 (10 days withhold of water, mild drought), T_3 (20 days withhold of water, moderate drought), T_4 (30 days withhold of water, severe drought) were applied to the genotypes. Completely Randomized Design (CRD) with three replications was followed in both experiments. Genotypes, salinity and drought influenced singly and in interaction on agromorphogenic, physiological and nutritional traits of tomato. Salinity treatment affected almost all traits of tomato negatively except days to first fruit setting, days to maturity, dry matter content, Na+ uptake, Brix content, titrable acidity and vitamin C content. Drought treatment interacted negatively with all traits except days to first flowering, days to fruit setting, days to maturity, proline content, etc. Early flowering (22.67 DAT) and early maturity (65 DAT) was found in G_8 at moderate and severe salinity respectively. G_8 showed higher number of cluster per plant, number of flower per cluster, number of fruit per cluster and number of fruit per plant in both mild to moderate salinity and drought treatment. G_4 showed higher average fruit weight and higher yield per plant in both mild to moderate salinity and drought treatments. G_5 showed lower Na^+ uptake and higher K^+ uptake in severe saline treatment and higher Membrane stability index at moderate drought treatments. G_5 also showed higher increase of proline and vitamin C content with the increase of drought treatment. From the research findings, G_8 could be suggested for early flowering, early fruit setting, early maturity, higher dry matter content and highest lycopene content at mild to moderate saline prone area. G_8 could be suggested for higher number of clusters per plant, fruits per cluster and higher number of fruits per plant for moderate saline and drought prone area. G_4 could be suggested for higher fruit weight, higher yield per plant for mild to moderate drought and saline area. G_5 could be considered for the cultivation at mild to moderate saline condition for its lower Na^+ uptake, higher K^+ uptake and higher vitamin C content. These genotypes viz. G_4, G_5 and G_8 could also be utilized as parental material for future hybridization program for these specific traits at specific stress prone area of Bangladesh.

CHAPTER I

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is a model plant for genetics and genomic studies which belongs to the Solanaceae family and this family includes 3000 species with origins in both the old (eggplant in China and India) and new world (pepper/potato/tomato in Central and South America) (Knapp, 2002). Among all related species, *Solanum lycopersicum* is the only domesticated species (Bilkish, 2016). Tomato plant is a short-lived perennial which grown annually. Fruit of tomato is edible, usually red color called berry. Fruit is 1-2 cm diameter in wild plants, commonly much larger in cultivated forms. It is nutritionally categorized as a vegetable. Tomato has much more influence on its nutritional traits but the environment where it is grown plays major role on its growth (Purseglove *et al.*, 1981).

In Bangladesh tomato is cultivated with a larger area due to its adaptability and it is the most popular vegetable in Bangladesh (Brown *et al*., 2013; Ahamed, 1995). Tomato rich in higher contents of vitamins A, B and C including calcium and carotene. In Bangladesh more than 7 % of vitamin C comes from tomato. Tomato contains 94 g water, 0.5 g minerals, 0.8 g fiber, 0.9 g protein, 0.2 g fat and 3.6 g carbohydrate. 48 mg calcium, 0.4 mg iron, 356 mg carotene, 0.12 mg vitamin B1, 0.06 mg vitamin B2 and 27 mg vitamin C is present in each 100 g edible ripen tomato (BARI, 2010). Tomato is cultivated on 4.5 million hectares in 144 countries and total production is 141 million tons (FAOSTAT, 2013). Consumption of tomatoes has been increased ~ 4.5% each year after 1990 to 2004 (Aherne *et al*., 2009). The average tomato production in Bangladesh is 50-90 tons/ha (BARI, 2010). Yield of tomato in Bangladesh compared to other country is not worth of mentioning. A huge amount of land is affected by salinity and drought that cause the lower yield of tomato in Bangladesh (Aditya, 1997).

Bangladesh is considered as one of the most climate vulnerable country in the world that includes salinity, storms, drought, irregular rainfall, high temperature, flash floods. Drought is linked to the soil moisture scarcity. Due to high level of drought huge amounts of land in northern region of Bangladesh remain uncultivable and drought affected area is increasing very rapidly due to climate change. Tomato is

commonly cultivated in rabi season when scarcity of water rises at its peak point. Drought is consiered one of the major reasons that minimizes the upland crop production in Bangladesh (Islam *et al*, 1982). 20% of total area of our country is occupied by coastal area that accounts 30% of our net cultivable area. Soil salinity is very much dominant in this region. Salinity affects the crop production in this area. The tomato needs a controlled supply of water throughout the growing period for high yield and good quality (FAO, 1996). Drought and salinity decreases agricultural production (Anonymous, 2006). Environmental constrains affect 70% crop production (Cramer *et al*., 2011; Boyer, 1982).

Temperature increase results in increased evapo transpiration that intensifies drought episodes (Zhao and Running, 2010) and increasses soil salinization, augmenting the 7% of the total and 30% of the irrigated agricultural land already affected by salinity (Munns and Tester, 2008). Salinity is an increasingly important environmental constraint to crop production worldwide (Ghassemi *et al.*, 1995). Morphology, physiology and biochemistry of plants is affected by salinity that reduces yield (Azammi *et al*., 2010; Amini and Ehsanpour, 2006). Vegetative growth of tomato, plant length and dry weight is adversely affected by salinity and drought (Omar *et al*., 1982; Adler and Wilcor, 1987). The tomato plant has ability to tolerate salinity up to 2.5-2.9 dS/m in root zone without yield losses. Salinity and drought combined cause adverse pleiotropic effects on plant growth and development at physiological and biochemical levels (Munns, 2002; Gorham, *et al.*, 1985 and Levitt, 1980). Tomato as well as other crops is sensitive to salt stress (Agong *et al*., 1997). Tomato shoot and roots, plant height, K^+ concentration, and K/Na ratio is affected by increasing NaCl concentration (Al-Karaki, 2000). K^+ has been considered often to play a role in osmotic stress and salt toxicity remediation, and some studies show inhibition of K^+ influx by NaCl in the cytosol (Bidel *et al*., 2007).

To overcome the negative effect of salinity and drought, Tomato plants develop some mechanism by altering its morphological, physiological and other traits. Changes of morphological, physiological and nutritional traits of tomato due to the genotypes-stress interaction as an indicator of stress tolerant mechanisms, Plant Breeders have experimented to develop stress tolerant variety. There are no worth mentioning salinity and drought tolerant tomato variety in our country. Thus due to unavailability

of stress tolerant tomato variety, the northern and southern coastal region remains uncultivated. Farmers in this area can not change their economic condition. As tomato is one of the most popular vegetables and can be cultivated under some lower extent of salinity and drought, it is time demanding to develop medium to high level of salinity and drought tolerant variety.

This study was conducted to analyze the agromorphogenic, physiological and nutritional traits to identify drought and salt stress tolerant tomato genotype. With envision of the above point of views, the present research work has been undertaken in order to achieve the following objectives:

- To determine the genotype × stress interaction of tomato under salinity and drought condition based on agromorphogenic, physiological and nutritional traits,
- To select the potential tomato genotypes for salinity tolerance based on agromorphogenic, physiological and nutritional traits,
- To select the best tomato genotypes for drought tolerance based on agromorphogenic, physiological and nutritional traits.

CHAPTER II

REVIEW OF LITERATURE

The tomato is grown worldwide for its edible fruits, with thousands of cultivars (Anonymous, 2016). As tomato is well studied crops, researcher has given much more attention for the improvement of tomato on various aspects of its production under various adverse climatic conditions especially salinity and drought. Drought, temperature, salinity, air pollution, heavy metals, and soil pH are major limiting factors that create limiting factor in crop production (Alqudah*et al*., 2011; Lawlor and Cornic 2002; Hernandez *et al.,* 2001). Drought and salinity stress are the main abiotic stress among them that limit the crop production (Forster, 2004). Various findings on interaction of tomato plant with salinity and drought with related examples are discussed in this chapter.

2. 1 Tomato

The tomato (*Solanum lycopersicum* L.), is an autogamous species which is 1-3 m tall. It has woody stem. Tomato is synonymous with the word of *"wolfpeach"* peach due to being round and luscious and wolf. This species was under nightshade family, Europeans thoughts tomato poisonous due to the leaf toxicity.

Tomato originated from part of Chile, Bolivia, Ecuador, Colombia and Peru. Mexico has been considered as the domestication of the origin of tomato and from Mexico it was transferred to Europe and then to Asia. Secondary origin of tomato is Spain and Germany (Gentilcore, 2010; Smith, 1994) But cultivated tomato was originated in Peru-Ecuador-Bolivia (Vavilov, 1951). Domestication of tomato had reached in its advance stage before taking to Europe but According to Khan *et al*. (2015) the native of tomato was Northern America. Spain, Brazil, Iran, Mexico, Greece, Russia, China, USA, India, Turkey, Egypt and Italy are the main tomato growing countries. There are one cultivated species and 12 wild relatives under *Solanum lycopersicum* L (Peralta *et al*., 2006) though there is limited variation among modern cultivars.

Tomato is considered as the most popular vegetables as soups, juice, ketchup, pickles, sauces, conserves, puree, paste, powder and other products can be produced from tomato. (Nahar and Ullah, 2011). Nutritious value of tomato is high due to presence of health building substances such as vitamins and minerals. Vitamin C, total

soluble solids (TSS) percent acidity, pH, Lycopene contents are commonly considered as fruit quality determining properties in tomato among them Vitamin C is considered as principal nutrient of tomato fruit. Among all vegetables tomato counts more than 7% vitamin C in Bangladesh. Other constitutes are 94 g water, 0.5 g minerals, 0.8 g fiber, 0.9 g protein, 0.2 g fat and 3.6 g carbohydrate. Tomato has some other elements like 48 mg calcium, 0.4 mg iron, 356 mg carotene, 0.12 mg vitamin B1, 0.06 mg vitamin B2 and 27 mg vitamin C in each 100 g edible ripen tomato (BARI, 2010).

Tomato has also some medicinal value due to the presence of lycopene which is considered as the most powerful natural antioxidant that prevents prostate, lung, stomach, pancreatic, colorectal, esophageal, oral, breast and cervical cancers, etc. Lycopene is related to beta carotene which has natural cancer-fighting properties. (Anonymous, 2016**)**. The red color of tomato and its byproduct is due to presence of lycopene (Helyes *et al*., 2012).

2.2 Salinity

Salinity is amount of salt dissolved in a body of water which is calculated as the amount of salt (in grams) dissolved in 1,000 grams (one kilogram) of seawater. Salinisation is the process of increasing the amount of salt in water. Salinity is considered as the most detrimental stress among all abiotic stress (Shrivastava and Kumar, 2015). There are very few plants that are insensitive to sail salinity and the amount of soil salinity is increasing nowadays. When salt is accumulated in soil surface it cases salinity and it can rise the soil surface by capillary pore and through evaporation. Due to use of potassium fertilizer causes salinity. Plant growth and development is very much affected by soil salinity (Vidal *et al*., 2009).

25% of the total irrigated land in the world has been damaged by salt (Cuartero *et al*, 2006). Salt stress has polymorphous effect on growth and yield of plant via three direct three ways. First, salinity restricts the uptakement of water that produces water stress which is referred as osmotic stress. Due to the ion uptakement in leaves it reduces the growth. Among all ions, Na+ reaches more toxic than other ions (Lopez-Climent *et al*., 2008).

2.2.1 Effects of salinity on different traits of tomato

Genotype stress interaction and variability among different genotypes for different traits are important for the selection of salinity tolerance genotypes. The traits are agromorphogenics, physiological and nutritional. Agromorphogenic traits include plant height, no. of leaves per plant, leaf area, no. of branches per plant, days to first flowering, days to first fruit setting, days to maturity, no. of cluster per plant, no. of flower per cluster, no. of fruit per cluster, no. of fruit per plant, fruit weight, fruit diameter, skin diameter of fruit, yield per plant, etc. Physiological traits include chlorophyll content, membrane stability index, ethylene content, relative water content, moisture and dry matter content in fruit, proline content, Na+ and K+ content, etc. Nutritional traits include Brix percent, pH of fruit, vitamin C content, lycopene content, titrable acidity, etc. These traits could be affected and altered due to salinity stress.

2.2.1.1 Effect of salinity on agromorphogenic traits of tomato plants

Hajer *et al*. (2006) performed an experiment to determine the effect of sea water salinity (1500, 2500 and 3500 ppm) on the growth of tomato cultivars (Trusl, Grace and Plitz) where sea water salinity affected less on grace germination stage. Based on dry weight of root, Plitz was tolerance to salinity.

An experiment run by Rush and Epstein (1981) on tomato and reported that there are some criteria to measure the salt tolerance in crop plants. It includes absolute growth, relative growth and survival rate under salinity and according to some scientists survival rate is the crucial traits for the screening of salinity tolerant genotypes.

Al-Yahyai *et al*. (2010) conducted an experiment with three levels of salinity (3, 6 and 9 dS/m) with three types of fertilizers to assess the performance of yield an yield quality of tomato an reported that under 3 and 6 dS/m condition, plants produce higher yield where as under 9 dS/m significantly decreased the final fruit number and fruit weight. He also reported that cow manure produced the least amount of yield loss compared to those with inorganic and mixed fertilizers.

The osmotic and ionic effects of the electrical conductivity (EC) of the nutrient solution and its interactions with climatic factors and cultural practices on tomato yield and fruit quality was studied by Dorai *et al*. (2001). He reported that high ECs,

reduced the fruit size but it increases the dry matter content of fruit. The rate of yield loss varies with interactions between cultivars, environmental factors, composition of the nutrient solution, and crop management. Under the condition like salinity more than 2.3–5.1 mS×cm–1 reduce the yield drastically but under ECs of 3.5–9.0 mS×cm–1 improve fruit quality. Siddiky *et al.* (2015) conducted an experiment with 16 tomato genotypes to find out the best salt tolerance genotypes. They reported that the fruit weight of tomato showed a significant variation among the germplasm and in general there was a significant decrease from the control to the high salt treated plants on fruits yield. The decrease was less prominent on BT14 and BHT5. The highest fruit yield was obtained in BT14 (1.55 kg/plant) followed by BHT5 (1.50 kg/plant) but they were statistically identical. At the same time BT7, BT2 and BHT4 produced fruit yield 1.20, 1.16 and 1.10 kg/plant, respectively and they were statistically similar. Rest of the germplasm produced lower fruit yield and their fruit yield were basically the same at high salinity while the lowest (0.26 kg/plant) fruit yield was obtained from C71. BT4, WP8 and WP7 did not get any fruit yield with high salinity.

Islam *et al*. (2011) reported that plant growth and development is affected by salinity. plant height, primary branches, cluster/plant, fruit/cluster, number of fruits and total yield/plant, individual fruit weight gradually decrease with the increase in salinity levels closing to higher salinity. He conducted his experiment with eight tomato genotype *viz*. J-5, 'Binatomato-5', 'BARI tomato-7', 'CLN-2026', 'CLN-2366', 'CLN-2413', 'CLN-2418' and 'CLN-2443' an found that agromorhpogenic traits are decreased wit increase salinity. Al-Ormran (2008), conducted an experiment on tomato yield in sandy calcareous soil to find out the effect of soil salinity and reported that yield loss was higher in saline water. Magan *et al*. (2008) conducted an experiment with seven level of salinity with two tomato cultivars and comparison of this with five levels of salinity uner soil less culture in plastic green house. With the increase of EC value, yield loss was higher . Above 3.2 and 3.3 dS/m yield loss was higher.

Abd-El-Warth (2005) conducted an experiment to find out the effect of surface and subsurface drip irrigation systems with different water salinity on the distribution of soil salinity and tomato yield in south sinai. He foun that under successive salinity stress yield loss increased. Agrawal *et al*. (2005) conducted an experiment on the

effect of water salinity on tomato under drip irrigation. He mentioned that hen the root zone is affected by salinity, tomato yield is drastically decreased along with the decrease the number of fruits/cluster, fruits/plant, fruit weight, fruit maturity and other yield contributing characters. Epheuvelink (2005) reported in his book "Tomatoes (Crop Production Science in Horticulture)" fruit growth rate and final fruit size is reduced by soil salinity as a result of an osmotic effect. High salinity decreases water potential in the plant and it reduces the water flow in the fruit and that therefore the rate of fruit expansion becomes decreased. Fruit yield because reduction of fruit size when EC value is 4.6-8 dS/m whereas ECs of 12 dS/m reduced number and size of fruit. Ghadiri *et al*. (2005) reported that restricted water uptake by salinity due to the high osmotic potential in soil created by soil salinity lower the water uptakement and may cause physiological disorders in plant tissues, fruit size and maturity as a result reduced yields.

Magan (2005) mentioned that with the increase of salinity, reduction of the number of flowers per tree is related with the reduction of the number of the fruit in plant. Reina-Sanchez *et al*. (2005) investigated that plant senescence is enhanced by salinity. Olympios *et al*. (2003) conducted an experiment with four levels of salinity (I: 1.7 dS/m (control), II : 3.7 dS/m, III : 5.7 dS/m and IV : 8.7 dS/m) and reported that size of the plant and total weight of fruits are negatively related. He also applied four numbers of treatments at the different stage of plant and reported that average fruit weight ere reduced when it was applied at an early stage. Plant height, fresh and dry weight of shoots, leaf area, yield, and average weight of fruits and the percentage of fruit with blossom-end-rot was less severe when fresh water was supplied at an early stage and followed by salinity water at later stage of plant life cycle.

Eltez *et al*. (2002) conducted an experiment on the effect of different EC level of nutrient solution on greenhouse tomato growing and found that under moderate salinity number of fruit was not reduced. Irshad *et al*. (2002) reported plant height, shoot and root dry weight and other yield contributing traits are reduced due to increase in plant height. Hao *et al*. (2000) claimed that total marketable yield and fruit size is reduced due to higher salinity but improves fruit quality.

Cuartero *et al*, (2003) conducted an experiment on tomato genotypes an salinity and reported that fruits number per plants, cluster number per plants are aversely related

with the salinity level. They also reported that other yield contributing characters also adversely react with the increasing salinity level. Vanleperen (1996); Adams and Ho (1989), executed three different experiments to determine the effect of salinity on tomato and they found separately that high salinity and long salinization periods in case of tomato reduces the number of cluster per plant. Whereas Grunberg *et al*. (1995) claimed that under saline condition, the number of leaves developed per plant, flowering from the number of clusters per plant and the number of flowers per cluster, the mean numbers of pollen grains per flower and fruit-set are reduced. He also found that the plants which were treated by salt produce 50% fewer flowers than the control plant. He also found that mean number of pollen grains per flower reduced significantly which was 30% of that control plants. He claimed that reduction of the number of fruits due to salinity was due to the reduction of flowers per plant.

Al-Yahyai (2010) executed an experiment on salinity tolerance in tomato associated with implication of potassium, calcium and phosphorus. They found that salinity reduced the leaf and stem dry weight significantly than the control plants. Lovelli *et al*. (2012) carried out an experiment on tomato plants with three salinity levels: 2.2, 10 and 15 dsm^{-1}, through NaCl addition. He reported that total weight and length of the root system was reduced due to increase in salinity and shallower root system was found in severe salinity treated plants. Adams and Ho (1992) conducted an experiment and mentioned that at 10 dS/m Ec value, fruit number was not affected but under 15 dS/m it was severely affected the crop yield. He considered three tomato cultivars and applied 5, 10 and 15 dS/m. Blossom end rot was found at higher saline treated plants and thus the yield was more. Shannon *et al*. (1987) found in his experiment that elongation rate of the main stem in tomato is reduced due to salinity. Among all the indicators, that shoot length is one of the responsive indicators for a wide range of tomato genotypes under salinity stress.

2.2.1.2 Effect of salinity on physiological traits of tomato plants

Physiological and biochemical processes are related with the genotype stress interaction to find out the salinity tolerance genotypes and the process is complex (Khan *et al*., 2010). Growth is the most dominant indicator of salinity tolerance which

is the consequences of physiological response (Jaleel *et al*., 2008), which is a consequence of several physiological responses that includes the modification of ion balance, water status, mineral nutrition, photosynthetic efficiency, carbon allocation and utilization, membrane instability, ethylene concentration and failure in the maintenance of turgor pressure (Yildirim *et al*., 2006).

There are some ions that present in higher concentration in saline condition specially Na^+ and Cl^- that produce a wide variety of physiological and biochemical changes and ultimately growth of plants is inhibited (Taffouo *et al*., 2010; Zadeh and Naeini, 2007). Mechanisms like low water potential, ion toxicity, interference of ions with the uptake of nutrients particularly K^+ are associated with salinity stress that inhibit the growth of plants (Tester and Davenport, 2003). As Na^+ and Cl^- ion concentration becomes higher in saline condition, nutrient imbalance and nutrient uptake are. Some parameters like membrane stability index, ethylene content, chlorophyll content, relative water content, moisture and dry matter content in fruit, Na+ and K+ ion content, etc are negatively affected by salinity stress (Turan *et al*., 2007). Plant genotypes and environmental condition determines the degree to which the factors affected (Zadeh *et al*., 2008).

Salt tolerance is associated with the degree to which the plant can survive without significant loss of its yield and with lower adverse effect though it is a relative term.. There is some physiological evidence that control of invasion of Na^+ is the key determinant of salt tolerance (Yeo and Flowers, 1986) though the mechanism is poorly understood. There is ongoing debate on the entry of Na^+ ions by K^+ ions transport system and what kind of transport system is involved (Rubio *et al*., 1995). There are two kinds of transports system that indicates that efficiency of Na+ is more than the K^+ in Aridopsis plant. A report presenting the effects of the over expression of a Na^+/H^+ tonoplastic antiporter in Arabidopsis has provided the first experimental evidence that control of Na^+ transport within tissues has a great effect on salt tolerance (Apse *et al*., 1999).

Raza et al (2016) conducted an experiment on screening of tomato genotypes for salinity tolerance based on early growth attributes and leaf inorganic osmolytes. The experiment containing three replicates of completely randomized factorial treatments was conducted in a glasshouse under controlled conditions with three simulated soil

salinity levels (control, 10 and 15 dS m−1). Morpho-physiological traits (i.e. lengths, fresh weights and dry weights of root and shoot, number of leaves, root/shoot ratio, shoot Na^+ accumulation, K^+/Na^+ ratio, $Ca2^+/Na^+$ ratio, membrane stability index, lycopene contents, chlorophyll-a and -b) were recorded to determine mechanism of salt tolerance of tomato at seedling stage. Principal component analysis (PCA) was used to express a three-way interaction of genotype × salinity level × traits that scattered the 25 tomato genotypes based on their morpho-physiological response to different NaCl levels. The negative association of Na^+ with all other traits except root/shoot ratio and the morpho-physiological response trend of genotypes exposed that probable mechanism of salt tolerance was initially Na^+ exclusion by abscising older leaves to have younger physiologically energetic, and lastly a higher activity of plants for root development to sustain them in saline soil. PCA three-way biplot efficiently recognized ANAHU, LA-2821, LO-2752, LO-2707, PB-017909, LO-2831-23 and 017860 as salt tolerant genotypes. On the other hand, ZARNITZA, GLACIER, LO-2692, LO-2576, BL-1079, 006233, 006232, 017856, NUTYT-701 and NAGINA were found to be salt susceptible.

Siddiky *et. al.* (2015) conducted an experiment with 16 Bangladeshi tomato genotypes for salinity tolerance genotypes with solution culture. They considered severity of leaf symptoms, shoot and root dry matter production, fruit yield, shoot Na^+, K^+, Ca^{2+} accumulation and their respective ratios as an indicators of salinity tolerance uner 120 mM NaCl salt. Based on the severity of leaf symptoms, "BT14 (BARI Tomato 14)" and "BHT5 (BARI Hybrid Tomato 5)" were found to be most tolerant germplasm to salinity with score 1.0. Reduction of dry weight was found to be 19% (shoot) and 15% (root) in BT14 and BHT5, 30 - 76% (shoot) and 27 - 83% (root) in other germplasm. Higher correlation was found between salinity tolerance scale classes and the reduction of shoot/root dry weight, Na+ concentration, K+/Na+, and Ca2+/Na+ ratios in BT14 and BHT5 germplasm. Ali and Ismail (2014) conducted an experiment on salinity (measured by adding 100 mM of NaCl to the nutrient solution) and spraying with sodium nitroprusside (10 μM of sodium nitroprusside, nitric oxide source) on fruit quality of tomato (Super Strain B) plants grown under field conditions. Fruit fresh and dry biomass was significantly suppressed which was irrigated by salinized nutrient solution. Significant increase of the Na accumulation, increase in total alkaloids, antioxidants, phenolic and flavinoids acted behind the

decrease of fresh and dry biomass of fruit. Various phenolic compounds were at their high levels under saline conditions but spraying with the salinized plants with sodium nitroprusside improved fruit quality.

Al-Busaidi *et al*. (2009) mentioned that under diluted seawater, tomato genotypes showed remarkable water evaporation rate increase and soil moisture, salt accumulation and plant biomass production were also affected. Higher saline irrigation showed les plant growth where as lower saline irrigation showed higher plant growth.

Edris *et al*. (2012) conducted an experiment on cherry tomato and reported that yield of cherry tomato was affected strongly by salinity though addition of supplemental Ca^+ and K^+ can ameliorate negative impact of high salinity. Leaf area was reduced and thus small fruit as developed due to lower photosynthetic rate. Siddiky *et al*. (2012) reported that tomato plant height, leaf area, plant growth, yield, dry matter plant, Na^+ and Cl^- accumulation in tomato tissues under different salinity level (2, 4, 8 and 12 dS/m). All plant parameters of tomato varieties were reduced under salt stress in comparison to control. With the increase of salinity levels, plant growth, fruit number, fruit size and yield were decreased gradually.

Saida *et al*. (2014) conducted an experiment on the interactive effects of salinity and potassium. He took some parameters like physio-morphological traits: chlorophyll a,b and chlorophyll total, carotene, pheophytin a, b and pheophytin total, the leaf weight ratio (LWR), the specific leaf area (SLA), the leaf area (LA) and proline content (Pr) in the leaf of seedling tomato (*Lycopersicon esculentum Mill.;* var: heintz). He conducted this experiment with completely randomized factorial design, including four levels of NaCl (0, 25, 50, 150) mM and four levels of potassium (0, 1.13, 1.76, 2.39) mEq/L, with three replicates in the sand with nutrient solution. They reported that chlorophyll a, b and total chlorophyll, carotene, pheophytin a, b and pheophytin total decreased with increasing salinity. They also reported that The leaf weight ratio, the specific leaf area, and the leaf area reduced with elevated salinity concentration whereas proline content was considerably increased when salinity levels increase, and deleterious effect of salinity was eliminated with the application of potassium. Gharsallah *et al*. (2016) conducted an experiment with twenty cultivars of tomato. According to their response to increased NaCl levels, they have clustered. From this

cluster three local tomato genotypes were further taken for experiment. Ion concentrations (Na^+ , K^+ and Ca^{2+}), proline content, enzyme activities (catalase, ascorbate peroxidase and guiacol peroxidase) were recorded during early (0 h, 6 h, 12 h) and later (7 days) stages of the response to salt treatment.

Hajiboland *et al*. (2010) conducted an experiment where they treated plants with arbuscular mycorrhizal fungi *Glomus intraradices* (+AMF)and it showed beneficial under salt condition. They reported that due to the variation in plant photosynthetic rate and translocation of photosynthetic element toward root, leaf, etc. reduced plant growth and yield. They also reported that stomatal conductance was elevated by Mycorrhization and thus the net assimilation rates were higher. Rafat and Rafiq (2009) mentioned that with the increase of salinity level up to 5.4 dS/m, total chlorophyll content in tomato plant proportionally decrease. Hajer *et al*. (2006) conducted with the treatment of sea water salinity (1500, 2500 and 3500 ppm) on the growth of tomato cultivars (Trust, Grace and Plitz) in Saudi Arabia. Seed germination was delayed and germination percentage was reduced with the increase of salinity. They also reported that salinity responded negatively on the leaf area, total chlorophyll and k^+ contents, fresh weight of areal parts and percentage of dry weight of areal parts, as well as yield and some areal quality. Al-Sobhi *et al*. (2005) reported that in higher saline condition, chlorophyll-a and b content of tomato cultivars leaves decreased and highest chlorophyll content was in Plitz cultivars leaves. They also reported that chlorophyll content of leaves of different tomato cultivars decreased by NaCl stress.

Taffouo *et al*. (2010) worked with six cultivars of tomato and they were that the performance of six cultivars of tomato var. Jaguar, Xewel, Nadira, Lindo, Mongal and Ninja) and they were subjected to salt stress during vegetative growth by three concentrations of salt solution 50, 100 and 200 mM NaCl and the control (Wacquant nutrient solution) were used in irrigation. They calculated some of the physiological traits like The total chlorophyll, the dry weight of seedlings (roots dry weight, stems dry weight and leaf dry weight), the plant height and the mineral nutrient concentrations (Na^+, K^+ and Ca^{2+}). They reported that results found that Na+ concentrations in roots were increased with the increase of salt concentration but whereas K+ and Ca^{2+} concentrations and K^+/Na^+ selectivity ratio of plants were

decreased with increase of salinity. They also reported that plant height and dry weight partitioning were reduced significantly. The plant height was less affected in case of Lindo and Ninja than the four other cultivars. They also supplied mineral nutrient with NaCl and they reported that leaf total chlorophyll content and plant organ dry weight of Lindo was not significantly affected at 100 mM NaCl salt treatments but Lindo cultivar could be cultivated in environments with relatively moderate salinity.

Juan *et al*. (2005) executed an experiment to find out some reliable nutritional and biochemical indicators for the purpose of developing salt tolerant tomato genotypes. They reported that reduced uptake and foliar accumulation of Na^+ and Cl^- , increased K^+ uptake, and greater synthesis of sucrose, carotenoids, and thiol groups were predominant traits in tomato salt tolerance. Akinci *et al*. (2004) conducted an experiment and reported that reduction in relative root; shoot and whole plant growth were due to salinity stress. They also showed that Na+ content was increased and K+ content was decreased under salinity condition. Dasgan *et al*. (2002) conducted an experiment with 55 tomato genotypes to investigate relationships among the salinity based on morphological and ion content and their ratios in different plant parts. They reported that higher Na^+ concentration on shoot of tomato indicated higher shoot damage. They found correlation among shoot K^+/Na^+ and Ca^+/ Na^+ ratios with the salinity scale classes. Munns (2002) mentioned that water uptakement was reduced that reduced plant growth rate.

Al-Rawahy (1989) executed two separate experiments one in the greenhouse and another one is in field condition. In his green house study, he treated tomato plants with saline water and dry matter content, yield and nitrogen uptake of water were taken as the indicators of salinity tolerance. He used low (control, 0.3 bar), medium (4.3 bars), and high (8.3 bars) salinity. He reported that dry matter production and nitrogen (total and ^{15}N) uptake were significantly lower for saline treatments as compared with the control. He found that the leaves were mostly affected by salinity and roots were intermediate. He found that stem was least affected by salinity. Faiz *et al*. (1994) conducted an experiment and reported that with the increase of salinity, fruit yield and plant dry weight was decreased. They also reported that N^+, K^+ and

Ca^{+2} were decreased in shoots. Johnson *et al*. (1992) reported reduction of driving force of sap flow into the fruit was due to low stem water potentials.

2.2.1.3 Effect of salinity on nutritional traits

The level of salinity plays a vital role change of nutritional value of many plant species (Sayed, 2003). Tomato fruit size, total yield, and photosynthesis and increases blossom end rot are greatly affected b higher salinity (Saito *et al*., 2006) but under moderate salinity condition, fruit quality is improved specially carotenoids and increase in total soluble solids which are important components of taste in tomatoes. Some secondary metabolites like phenolic compounds play an essential role in the regulation of plant growth and development and could be enhanced as powerful antioxidants in plant tissues salinity. Higher salinity leas to water stress leads to decreased yield, maximum accumulation of soluble solids and reduced viscosity. Long exposure to soil salinity reduce crop yield but results in enhanced soluble solids along with good viscosity.

Increase with the salinity titrable acidity reduces but potassium and nitrogen in the fruit is increased. Sweetness of tomato fruit is improved and fruit flavor also enhanced. To produce higher yield of fruit, high quality is to be maintained. Fruit quality can be improved with the increase of EC value of soil salinity (Dorai *et al*., 2001).

Anastasia *et al*. (2013) conducted an experiment with the application of moderate salt stress in tomato and found that lycopene with other antioxidant increases with the higher salinity. Lycopene content is increased from 20% to 80% if it is treated with higher salinity. Increase in antioxidant is the primary physiological response under salinity stress. Vijitha *et al*. (2010) conducted an experiment with randomized complete block design with five treatments with four replications to determine the changes of fruit quality of tomato such as vitamin C, total soluble solids (TSS) an acid contents of tomato during the ripening stage. Mitchell*et al*. (1991) conducted an experiment and showed that irrigation with saline drainage water on processing tomato *(Lycopersicon esculentum* Mill, cv. UC82B) yields, fruit quality, and fruit tissue constituents. He reported that irrigation with saline water had no effect on total fresh fruit yield or hexose concentration, but fruit water content was reduced that which contributed to increased inorganic ion concentrations. Starch concentration was

higher in higher salinity condition during early fruit development, but, concentrations were reduced to < 1%, regardless of treatment at maturity stage. Higher fruit acid concentrations resulted from water deficit irrigation and from irrigation with saline water relative to the control in one year out of two. They concluded that fruit quality may be achieved in saline condition.

Lycopene as well as other ntioxidants like vitamin-C play antagonistically against biotic and abiotic. Stress induced by NaCl treatment can be eliminated by the mechanism of antioxidative enzymes as a tolerance (Mittova *et al*., 2000). Šmídová and Izzo (2009) conducted an experiment to determine the changes in antioxidant content with the maturity stage under different levels of salinity. He considered were lipoic acid, vitamin C and vitamin E as the antioxidants parameters. Shi and Le Maguer (2000) mentioned deep red color is produced due to the activity of lycopene which has some physio-chemical properties against salinity stress. Yong-Gen *et al*. (2009) conducted an experiment to describe the mechanisms, of the transport of carbohydrates into tomato fruits and the regulation of starch synthesis during fruit development in tomato plants where he treated the tomato plants with higher salinity. Accumulation of starch became double at 160 mM compared to control plants and with the maturity of tomato soluble sugars increased. He also reported that under salinity stress, carbohydrate accumulation is increased with the increase of salinity.

Satio *et al*. (2008) conducted an experiment in hydroponic system with a salinity level of 50 mM NaCl to investigate the effect of salinity on the metabolites such as amino acids, soluble sugars and organic acids. They reported that Brix%, surface color density and membrane stability index were increased with the higher salinity but fruit enlargement was suppressed. They also reported that glucose and amino butyric acids were increased in higher saline condition.

Cuartero *et al*. (2003) conducted an experiment to determine the effect of salinity on tomato quality. He reported that tomato taste was enhanced with the increase of salinity levels by increasing sugars and ascorbic acids.

Flores *et al*. (2003) conducted an experiment with tomato plants under a nutrient solution containing 0, 30 and 60 mM NaCl with 14/0, 12/2 and 10/4 NO_3^-/NH_4^+ mM ratio to determine the effect of salinity on quality of tomato. Fruit quality was

increased with the increase of salinity and NH_4^+ by increasing the sugar contents, organic acids and antioxidants but yield was decreased with increase of salinity. They reported that fruit development was shortened the time of fruit set by 4 to 15%. Fruits of salt treated better than control plants but smaller in size. Compare to the control plants, percentage of dry weight, total soluble solids, and titratable acidity; content of reducing sugars, Cl1, Na+, and various pericarp pigments; and electrical conductivity of the juice were higher in fruits of saline-treated plants but the pH was lower. In case of salt treated plants, ethylene and CO2 evolution rates during ripening, as well as the activities of pectin methyl esterase, polymethylgalacturonase, and polygalacturonase; were also higher in fruits of the saline-treated plants.

De Pascale *et al.* (2001) conducted an experiment an experiment with high EC value that leads to increase the vitamin C and total soluble sugars in tomato fruit. Up to the salinity level to 6-7 dS/m lycopene increased but decreased with the increase of salinity levels. Compared with non salanized plants, ascorbic acid was 60% higher in salt treated plants at EC 15.7 dS/m. Giannakoula and Iliyas (2013) conducted an experiment with the application of moderate salt stress and concluded that lycopene content with other antioxidant was enhanced with increase of salinity condition. Lycopene varied from 20% to 80% in tomato plants grown under salinity condition that indicate that antioxidant increases with the increase of salinity level.

Petersen *et al*. (1998) carried out an experiment with tomato plants irrigated by different level of saline water. They mentioned that lycopene was increased with the higher salinity at 4-6 dS/m salinity level. As leaf area was smaller and sunlight increases the temperature of leaf and thus lycopene was increased. Vitamin-C content and brix% of tomatoes also increased with the increasing salinity level. Shenan *et al*. (1991) conducted an experiment on tomato plants to determine the effect of irrigation cut off and salinity on tomato yield and quality. In both years the irrigation cutoff treatments had more pronounced effects on the SSC in fruit than the salinity treatments. Fruit SSC increased rapidly after irrigations were withheld in comparison to the control and the salinity from-thinning treatment. Similar patterns of SSC changes were observed in both cutoff treatments; however, for clarity, only the 75 day cutoff. Increases in SSC in the cutoff treatments relative to the control were larger in 1986. Salinity increased SSC by 8% in both years; however, marketable soluble solids

were not significantly affected by either cutoff or salinity. Water content in fruit of plants exposed to deficit irrigation was lower than the control throughout development in 1986 and at maturity in 1985, and at maturity by salinity in 1985. *Fruit sugar, organic acid, and starch contents.* At maturity, irrigation cutoff had no effect on the accumulation of hexoses on a dry-weight basis, but significantly increased hexose concentrations on a tissue-water basis relative to the control .Salinity did not significantly affect hexose accumulation on either a dry-weight or a tissue-water basis. Sucrose concentrations were below detectable levels in all treatments. Fruit acid concentrations in the control and salinity treatments were similar and declined during the period of fruit development. The irrigation cutoff treatment increased titratable acidity levels and citrate concentrations during fruit development but not at maturity in 1986. In 1985, acidity was increased at maturity by both water deficit and saline irrigation. Malate accumulation reached levels roughly one-fifth those of citrate, but was unaffected by experimental treatment (data not shown). The starch content of fruit was unaffected by both the cutoff and salinity treatments throughout development. At maturity starch levels for all treatments had dropped to 1% fruit dry matter.

Akinci *et al.* (2004) carried out an experiment on salinity effect in the early stage of tomato plants. He reported that Characteristics of germination (percentage and period; length and fresh-dry weight of radicle and hypcotyl) and seedling (length and fresh-dry weight of root, shoot and whole plant; leaf number and area based on Relative Growth Rate); Na+ and K+ content of leaf; K^+/Na^+ rate of leaf are affected with the salinity.

2.3 Drought

A drought may be defined as the period that remains below average precipitation in a given area that results prolonged shortage of water in its water supply. A plant needs water to complete various events in its life cycle and if it does not have the availability of water, it reduces its growth and development. Morphological physiological and biochemical traits of plants become altered. According to a survey it is observed that up to 45% of the world agricultural lands are subjected to drought (Bot *et al*., 2000). Due to drought, most of the physiological and biochemical process of plants are altered and as a result plant growth becomes arrested (Boutraa, 2010).

Photosynthesis in plants is reduced due to drought (Cornic, 2000). Foliage begins to wilt and, if the plant is not irrigated, leaves will fall off and the plant will eventually die. Aside from the moisture content of the soil, environmental conditions of high light intensity, high temperature, low relative humidity and high wind speed will significantly increase plant water loss. The prior environment of a plant also can influence the development of drought stress. A plant that has been drought stressed previously and has recovered may become more drought resistant. Also, a plant that was well-watered prior to drought will usually survive drought better than a continuously drought-stressed plant. Drought is by far the most important environmental stress in agriculture and many efforts have been made to improve crop productivity under water-limiting condition.

Throughput the world drought occurs often becomes present with. Loss due to the combined of all abiotic stress is lower than the loss caused due to drought alone (Barnabas *et al.,* 2008). Day by day resources for irrigation becomes declined for crop production and thus development of more drought tolerant crops has become a global concern (Ludlow and Muchow, 1990). As drought is combined with high temperature and thus it becomes more (Barnabas *et al.,* 2008). Drought stress is the principal reasons that limit the crop production hampering the pollen grain availability, increasing pollen sterility, pollen grain germination, reduce megagametophytic process and restricts the pollen dehisce.

2.3.1 Effect of drought on different traits in tomato

Environmental conditions determine the agromorphogenic traits, physiological and nutritional traits of plant. Water is an essential element for the survival of plants and without water, every morphological, biochemical and physiological process of plants are arrested at different level. Genotype stress interaction and variability among different genotypes for different traits are important for the selection of drought tolerance genotypes. The traits are agromorphogenics, physiological and nutritional. Agromorphogenic traits include plant height, no. of leaves per plant, leaf area, no. of branches per plant, days to first flowering, days to first fruit setting, days to maturity, no. of cluster per plant, no. of flower per cluster, no. of fruit per cluster, no. of fruit per plant, fruit weight, fruit diameter, skin diameter of fruit, yield per plant, etc. Physiological traits include chlorophyll content, membrane stability index, ethylene

content, relative water content, moisture and dry matter content in fruit, content, K+ content, etc. Nutritional traits include Brix percent, pH of fruit, vitamin C content, lycopene content, titrable acidity, etc. These traits could be affected and altered due to drought stress as every process is controlled by water at cellular level.

2.3.1.1 Effect of drought on agromorphogenic traits in tomato

Different agromorphogenic traits such as plant height, number of leaf, leaf area, number of branches per plant, days to first flowering, days to first fruit setting, days to maturity, number of cluster per plant, number of flower and fruit per cluster, number of fruit per plant, yield per plant, fruit length and diameter, root length, root shoot ratio etc. are affected by drought stress. Wahb-Allah *et al.* (2011) reported drought stress affects the plant growth and development under field condition under field. Plant height, primary branches, cluster/plant, fruit/cluster, number of fruits and total yield/plant, individual fruit weight, amino acid content in leaves are decreased but total sugar and reducing sugar content in leaves are increased increase drought stress.

Paul *et al.* (2014) conducted an experiment to evaluate the variability among twenty eight tomato genotypes under different drought stress and he conducted his experiment with three replications. Kaushik *et al.* (2011) also conducted an experiment to evaluate 10 tomato genotypes in randomized block design with three replications. Shamim *et al*. (2014) carried out an experiment on local tomato genotypes to determine the drought tolerance under different field capacity condition. They determined the reduction of yield and crop growth 80% of field capacity (optimum watered) 60% and 40% of field capacity (water deficit) conditions. They found genotype *L. pennelli* out yielded followed by CLN1767 and *L. chilense* in terms of and fruits as compared to rest of the genotypes.CLN1767 and Lyallpur-1 were intermediate in total number of fruits. They reported that the tomato genotypes had considerable genetic variation in drought tolerance.

Kozlowski (1972) conducted an experiment and they estimated the number of fruit reduction in tomato under drought stress. He found that due to the drought during the fruiting stage, number of fruits per plant was reduced significantly. The fruit size of the treated plants was also smaller than the control plant. He reported that the

reduction of fruit number was due to the dropping of flower and fruit at immature stage. Wien *et al*. (1989) conducted an experiment in tomato under drought and mentioned that drought stress can increase leaf temperature that is harmful for plants. Under drought stress, leaf flower and fruit abscission occurs that lower the yield of tomato plants. Nyabundi and Hsiao (2009) reported that under different levels of water stress conditions, vegetative, reproductive growth and fruit development are inhibited. They conducted the experiment under four drought stress and each replication per treatment contained ten plants.

Sibomana and Aguyoh (2013) carried out a two-factor experiment to determine effects of drought stress on growth and yield of tomato. They reported that fruits per plant and average fruit diameter were significantly reduced in treated plants than control plants. They also reported that maturity time decreases with the increase of drought stress. About 25 to 34 % reduction of number of fruits per plant was also reported. Fruit diameter was reduced by 11.5% to 19% in drought stress treated plants compared to control plants. Shahabuddin (2012) carried out an experiment to determine the effect on tomato growth, yield and associated quality traits under different water stress with four irrigation intervals and three tomato varieties. Different agromorphogenic traits like the extent of plant growth, days to first flower opening, number of flower clusters per plant, number of flowers per cluster, number of flowers per plant, flowering duration, percent flower drop, number of fruits per plant, fruit volume and fruit pericarp thickness were affected significantly by drought stress. He concluded that irrigation interval with ten days may be used for maximum yield.

Srivastava *et al*. (2015) carried out experiment on tomato with different levels of water stress and reported that tomato size and average weight of fruit was significantly affected by drought stress. They also reported that drought causes high temperature in plants parts that enhances flower and fruit dropping at immature stage.

Kamrun *et al.* (2011) carried out experiment with tomato genotypes under drought stress and reported that no significant difference in case of plant was observed under different water stress condition. Mingo *et al*. (2004) reported that water stress cause significant reduction in some traits like plant height, fruit weight, etc. Under low irrigation rate, growth parameters and yield were significantly decreased. Pervez *et al*.

(2009) carried out an experiment to observe the reduction rate in yield, quality and vigor of tomato plants under drought condition with four treatments and each treatments and each replication consists of ten plants. In most of the cases, vegetative growth was reduced. Mahendran and Bandara (2000) reported severe flower and fruit dropping occur during flowering stage under water stress. He also reported the high reduction of fruit numbers that resulted in reduction in yield. He reported that plants that were experienced moisture stress showed yield reduction as a result of reduction of leaves development, twig and brances. Turner *et al.* (2010) mentioned water stress as principal cause of cell enlargement and vegetative growth.

Mahmoud *et al*. (2011) conducted an experiment on Drought Tolerance of Several Tomato Genotypes under Greenhouse Conditions. They used four commercial tomato cultivar under six irrigation treatments. They measured vegetative growth, flowering and yield traits. They reported that with the increase of deficit irrigation levels all vegetative and fruit traits were decreased. They found significant genotypes differences among all the traits under drought conditions.

2.3.1.2 Effect of drought on physiological traits

Drought stress affects some physiological traits in plants like relative water content , moisture and dry matter content in fruit, membrane stability index, ethylene concentration in leaf, proline content, chlorophyll content, etc. Among these traits relative water content, proline content and chlorophyll contents are the most indicators of drought tolerance. Due to the increase of temperature due to drought, plants suffer from dehydration and all metabolic process become arrested. Relative water content is the measurement of plant status in drought stress.

Sivakumar (2014) carried out an experiment to determine the consequences of drought stress with three treatments with three replications. He stated that under drought stress relative water content reduced than control. Kirnak *et al*. (2001) also reported that vegetative growth and relative water content decreases with the increase of drought stress. Haloi and Baldev (1986) commented that the plants that contain more the water it is considered more drought tolerance as it helps for better growth and development. Srivastava *et al.* (2012) mentioned water content and transpiration rate as the most important indicators for drought tolerance. They reported that control

plants showed higher transpiration rate than plants under drought stress. Jureková *et al*. (2011) carried out another experiment to determine the relative water content after 10, 17 and 23 days after treatment. They reported that relative water content was declined during the slow dehydration. With the decrease in relative water content leaf area was reduced.

Sivakumar (2014) carried out an experiment with 18 tomato genotypes to study the effect of drought on gas ethylene concentration in leaf and other physiological parameters in pot condition. He reported that relative water content decreased in treated plants than control. Jureková *et al*. (2011) conducted an experiment to determine the responses of tomato genotypes under water stress. They considered relative water content, leaf area and leaf proline as an indicator of drought tolerance. They concluded that RWC, leaf area decreased under water stress while proline content increased. Khan *et al*. (2015) reported that drought stress has significant impact on different physiological traits of tomato plants. He reported that due to the unavailability of water plants contain less water content in its parts than the control plants. Sibomana *et al*. (2013) determined the effects of water stress on the growth and yield of tomato under water stress. Leaf water content and leaf chlorophyll content was measured ad they found decrease in relative water content, chlorophyll content and vegetative growth. Chlorophyll content was reduced by 30% in comparison to control plants. 69% yield reduction was observed in the most drought stressed plant.

Among all physiological parameters proline content is one of the most physiological indicators for drought tolerance. Proline protects molecular denaturation during the drought stress and scavenges reactive oxygen species and interacts with phospholipids (Kavikishor and Sreenivasulu, 2014). Proline acts as osmolyte that protects sub cellular structures under stress condition. To maintain turgor pressure plants accumulate compatible solutes like proline, betaine and polyols in the cytosol (Rhodes and Samaras, 1994).

George *et al*. (2015) conducted an experiment with 20 genotypes of tomato by determining proline content. They reported that proline content increased in some tomato genotypes in drought stress condition than the control plants. Pan *et al*. (2006)

also determined the amount of proline in tomato leaf under drought stress and found that with the increase in drought stress proline content was increased.

2.3.1.3 Effect of drought on nutritional traits

Tomato contains antioxidants such as lycopene, vitamin C, and total soluble solids (% of brix) in human diet and that work against heart diseases, diabetes, prostate and various forms of cancer. Drought affects the nutritional traits in tomato such as vitamin C, lycopene, total soluble solids, pH of fruit, titrable acidity content, etc.

Saha *et al*. (2010) carried out an experiment to screen out 53 tomato genotypes under drought stress considering some nutritional parameters like total soluble solids (TSS) nutritional, phosphorus, potassium, iron, zinc, copper, manganese, titrable acidity, beta-carotene, lycopene and ascorbic acid. They found significant variation among the observed genotypes. They computed principal component analysis that explained 66% of the variation among different attributes. Kavitha *et al*. (2014) conducted an experiment to screen tomato genotypes including hybrids, varieties, cherry tomatoes, wild species, elite germplasm lines, interspecific hybrids and backcross populations for antioxidant activity and other nutritional parameters to select high-antioxidant lines with good total soluble solids (TSS) for further usage in crop improvement programs.

Vijitha and Mahendran (2010) conducted an experiment to determine the changes in fruit quality of tomato cv. KC-1 with moisture stress viz., determine the vitamin C, total soluble solids (TSS) and acid contents of tomato fruits during fruit ripening stage. He also determined the most critical stage to moisture stress in order to reduce the yield loss. He reported that plant that was face drought stage during the ripening stage showed less vitamin C than the control plant while total soluble solids and titrable acid content showed slightly reduction than the control plants. Plants under the moisture stress during the vegetative periods, Vitamin C, TSS and acid contents of fruits were unaffected compared to flowering and early fruiting stages.

Nahar and Gretzmacher (2002) carried out an experiment on tomato genotypes under moisture stress and reported that vitamin C increased under moisture stress than control plants. Grierson and Kader, (1986) determined ripeness classes of tomato. He mentioned that tomatoes were red 90% under stress compared to control condition.

Among all the nutritional traits, Lycopene is one of the most important parameters. It acts as a precursor of beta-carotene with powerful antioxidant activity and powerful health properties. There are some researches ongoing that focuses the physiochemical constituent of beta carotene. Although tomato contains the higher amount of lycopene among all fruits and vegetables on an average from 30 to 60 ug lycopene per fresh fruit of commercial cultivars.

Liu *et al.* (2011) conducted an experiment and reported that lycopene content is increased in irrigated and moderate stress condition compared to severe drought conditions. They conducted the experiment with ten genotypes and with four drought treatments Experiment conducted with 10 genotypes and 4 drought treatments entitled T1 treatment (control), T2 treatment (for 15days), T3 treatment (for 30 days) and T4(for 45 days). They found higher lycopene content under T2 treatment and lower under T4 drought treatment. Riggi *et al*. (2008) carried out an experiment on tomato under well irrigated and drought stress. They found that under well watered treatment showed higher amount of lycopene content regardless the ripening stage compared to drought stress. Favati *et al*. (2009) also mentioned that lycopene concentration was higher in moderate drought stress than well irrigate plants and lower in severe drought stress.

Among all nutrients of tomato fruit, Vitamin C is a principal component. Vitamin C accounts only very small portion of the total dry matter of tomato fruit but they are highly significant from the nutritional point of view. According to Kozlowski, (1972) fruit quality especially vitamin C content is changed due to moisture stress. He conducted an experiment to determine the changes in fruit quality of tomato under moisture stress under RCBD with five treatments and four replications. Drought stress was imposed on different stages like Moisture vegetative, flowering, early fruiting and fruit ripening stages of tomato for a period of four days in each growth stages. He mentioned that vitamin C was reduced when drought stress was imposed during ripening stage.

Vitamin C is produced from D-Glucose (Counsel and Horning, 1999). Under drought stress, stomata remain closed most of the time CO_2 can not enter into the cell and thus D-glucose synthesis is declined. During the period of stress D-glucose is reduced thus results in the production of vitamin C. Substrate concentration for vitamin c may be

reduced due to drought stress. That may be one of the reasons of reduction of photosynthesis rate. Torrecillas *et al.* (1995) reported that the concentration of vitamin C increased with increasing water stresses. A wide range of changes in physiological responses from a decrease in photosynthesis is occurred due to the lower of water potential. Due to decrease in turgor pressure, glucose, fructose and sucrose contents are increased and thus improve the quality by increasing the concentration of important acids like ascorbic acid, malic acid and citric acid.

Davies *et al.* (1991) reported that increase in temperature in leaf leads to reduction in vitamin C. As transpiration becomes lower and it results in increase in leaf temperature under drought stress. With the change of environmental conditions vitamin C synthesis is changed as it is very sensitive. Vitamin C gets oxidized due to high leaf temperature and concentration of vitamin C is reduced **(**Mahendran and Bandara, 2000). Vijitha and Mahendran (2010) carried out an experiment on the changes of quality parameters under moisture stress. They determined vitamin C, total soluble solids and acids contents of fruits under moisture stress. They reported that moisture stress during ripening stage slightly affected the total soluble solids contents while TSS content was unaffected by moisture stress during vegetative, flowering and early maturity stage.

CHAPTER III

MATERIALS AND METHODS

This chapter illustrates information concerning materials and methods that were used to conduct the experiment. The experiments were conducted from November 2018 to April 2019 and for two different abiotic stresses, salt and drought. The experiments for drought stress and salt stress were conducted as independent experiment. The different steps of salt experiment (Experiment 1) and drought experiment (Experiment 2) are stated here chronologically in section 3.1 and in 3.2.

3.1 Experiment 1: Genotype × stress interaction under salinity condition in tomato (*Solanum lycopersicum* L.)

This part comprises the methodology regarding locations of experimental site, planting materials, climate and soil, seed bed preparation, layout and design of the experiment, pot preparation, fertilizing, transplanting of seedlings, intercultural operations, harvesting, data recording procedure, physiological, nutritional and statistical analyses procedure, etc. Selection of salinity tolerant genotypes of tomato genotypes were done based on agro-morphogenic, physiological and nutritional traits. Agromorphogenic traits included such plant height, number of leaves per plant, leaf area, number of branches per plant, days to first flowering, days to first fruit setting, days to maturity, number of cluster per plant, number of flowers per cluster, number of fruits per cluster, number of fruits per plant, average fruit weight, fruit diameter, fruit length, skin diameter, root length, shoot root ratio, yield per plant. Physiological traits included such as Ethylene concentration in leaf, chlorophyll content in leaf, Membrane stability index (MSI), Relative water content (RWC), Moisture percentage in fruit, Dry mater percentage in fruit, Proline content, Na ion content, K ion content. Nutritional traits included such as Brix (%), Vitamin-C content (mg/100 g) and Lycopene content (mg/100 g), pH of fruit and titrable acidity (%).

3.1.1 Experimental Site:

The experiment was accomplished in the net house of the department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University, Dhaka-1207 during the periods from November 2018 to April 2019. Location of the site is 23°74' N latitude and 90°35' E longitude with an elevation of 8 meter from sea level (Anonymous,

2014) in Agro-ecological zone of "Madhupur Tract" (AEZ-28) (Anonymous, 1988). The experimental site is shown in Appendix I.

3.1.2 Planting materials

A total of eight genotypes were used in this experiment (Table 1). Seven genotypes were collected from Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University, Dhaka and one genotype were collected from Plant Genetic Resource Centre (PGRC) at Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh.

3.1.3 Treatments in the experiment

The two factorial experiment was conducted to select the tomato genotypes under different salt stress treatments . Factor A was tomato genotypes where eight tomato genotypes were used. Factor B was different sodium chloride (NaCl) salinity treatments. Four Salinity treatments were used named T_1 (control), T_2 (4 dS/m, mild salinity), T_3 (8dS/m, moderate salinity) and T_4 (12 dS/m, severe salinity).

3.1.4 Design and layout of the experiment

The experiment was laid out and evaluated during Rabi season in Completely Randomized Design (CRD) using two factors. Factor A included eight genotypes and Factor B included 4 different salinity treatments. The experiment was conducted in 3 replications and total 96 plastic pots were used.

3.1.5 Climate and soil

Experimental site was located in the subtropical climatic zone. Sunshine varied within experimental unit. Physicochemical properties of the soil are presented in Appendix III.

3.1.6 Raising of seedlings

Seeds of eight genotypes of tomato were sown on separate pot during the last week of November 2018. Seeds were treated with fungicides before sowing. Pots for seed germination were filled up with 7 kg soil and mixed with cowdung, Urea, Mutate of

Table 1. Name and source of collection of eight tomato genotypes used in experiment.

Sl. No.	Genotypes No.	Accession No./ Variety Name	Source of collection
01	G_1	SL 021	Department of Genetics and Plant Breeding, SAU.
02	G_2	SL 022	Department of Genetics and Plant Breeding, SAU.
03	G_3	SL 023	Department of Genetics and Plant Breeding, SAU.
04	G_4	SL 024	Department of Genetics and Plant Breeding, SAU.
05	G_5	SL 025	Department of Genetics and Plant Breeding, SAU.
06	G_6	SL 026	Department of Genetics and Plant Breeding, SAU.
07	G_7	SL 027	Department of Genetics and Plant Breeding, SAU.
08	G_8	BARI TOMATO-11	Plant Genetic Resource Centre, BARI

SAU= Sher-e-Bangla Agricultural University.

PGRC= Plant Genetic Resource Research Centre, Gazipur.

Potash and Triple super phosphate with a lower dose. Watering of Seedling was done carefully. Raising of seedlings are shown plate 1A.

3.1.7 Manure and fertilizers application

Soil was well pulverized and dried in the sun and only well decomposed cow dung was mixed with the soil according to the recommendation guide BARI, 2012. Well decomposed cow dung was calculated for each pot considering the dose of 1 hectare soil at the depth of 20 cm, one million kg. On an average each plastic pot was filled with soil containing 100 g decomposed cow dung (10 tons/hectare). Total decomposed cow dung was applied before transplanting the seedlings to plastic pots.

3.1.8 Pot preparation and transplanting of seedlings

Weeds and stubbles were completely removed from soil which was used for planting. Formaldehyde (45%) for 48 hours was used to treat the soil before filling plastic pots to make it free from pathogens. Before two days of transplanting pots were filled up with prepared soil. Each pot was filled with 7 kg of soil. The pot size was 20 cm in height, 30 cm in top diameter and 20 cm in bottom diameter. When the seedlings become 28 days old, they were transplanted in the main plastic pot (one plant/pot). Transplanting of seedlings is presented in plate 1B.

3.1.9 Application of salinity treatments

Eight genotypes were executed under four treatment of salinity (T_1: Control condition; T_2: 4 dS/m, T_3: 8 dS/m and T4: 12 dS/m). Plants in control treatments (T_1) were not exposed to salinity; whereas T_2, T_3 and T_4 plants were treated with 4 dS/m, 8 dS/m and 12 dS/m salinity level respectively. Salt was mixed with water and EC value was measured. Plants in control treatments (T_1) were always irrigated with fresh (non-saline water). Saline solution was applied to T_1, T_2, T_3 and T_4 at 10 DAT for the well establishment of young seedlings and later on each pot was watered as per treatment. Electrical conductivity of different salinity levels in soil was adjusted by a direct reading conductivity meter (EC-meter). Application of saline water is shown in plate 1C.

Plate 1. Different activities done during pot experiment in net house A. Raising of seedlings B. Transplanting of seedling C. Preparation of salt water solution D. Stalking the seedlings E. Weeding F. Data collection.

3.1.10 Intercultural operations

Necessary watering and intercultural operations were provided as and when required. Weeding was performed in all pots as and when required to keep plants free from weeds. Disease and pests is a limiting factor to tomato production. During this experiment no considerable infection was observed and no fungicides and pesticides were used. When plants were well established, stalking was done by bamboo stick between 25-30 DAT to keep the plants erect. Proper tagging and labeling were done for each plant. Plate 1 D shows intercultural operations done in salinity experiment.

3.1.11 Harvesting and processing

Harvesting of fruits was done after maturity stage. Mature fruits were harvested when fruits turned to red in color. The fruits per plant were allowed to ripe and then seeds were collected and stored at 4^{o}C for future use. Harvesting was started from February and completed by March.

3.1.12 Data recording

Data were recorded from each pot based on different yield and yield contributing, physiological and nutritional traits. A view of data collection in the net house is presented in plate 1E shows data recording in experimental site.

3.1.12.1 Agromorphogenic traits

Data related to yield and yield attributing traits such as plant height, number of leaves per plant, leaf area, number of branches per plant, days to first flowering, days to first fruit setting, days to maturity, number of cluster per plant, number of flowers per cluster, number of fruits per cluster, number of fruits per plant, average fruit weight, fruit diameter, fruit length, skin diameter, root length, shoot root ratio, yield per plant were recorded during conducting the experiment.

3.1.12.1.1 Plant Height (cm)

Plant height of each plant from each pot was measured during its mature stage by centimeter scale.

3.1.12.1.2 Number of leaves per plants

Number of leaves per plant was recorded during maturity stage of plants.

3.1.12.1.3 Leaf area (cm2)

Leaf area was measured by taking the breath and width of leaf and multiplying their value from each of the plant.

3.1.12.1.4 Number of branches per plant

Number of branches per plant was counted from each of the pot during its mature stage.

3.1.12.1.5 Days to first flowering

Number of days was counted from the date of tomato seedlings transplanting to date of first flowering.

3.1.12.1.6 Days to first fruit setting

Number of days was counted from the date of tomato seedlings transplanting to date of first fruit setting.

3.1.12.1.7 Days to Maturity

The number of days to maturity was counted from the date of tomato genotypes transplanting to date of first harvesting.

3.1.12.1.8 Number of clusters per plant

The number of clusters per plant was recorded at the time of harvesting.

3.1.12.1.9 Number of fruits per cluster

All fruits per cluster were recorded and then the average number of fruits per cluster was calculated by randomly selecting three clusters.

3.1.12.1.10 Number of flowers per cluster

Number of flowers per cluster was recorded during the flowering stage of plants. Randomly 3 clusters were selected and number of flowers per cluster was recorded by its mean.

3.1.12.1.11 Number of fruit per plant

The total number of marketable fruit from each plant was recorded during harvesting.

3.1.12.1.12 Average fruit weight (g)

Five fruits from each plants were measured and their average was taken..

3.1.12.1.13 Average fruit length and diameter

Fruit length and diameter were measured using Digital Caliper-515 (DC-515) in millimeter (mm). Later it was converted to centimeter (cm).

3.1.12.1.14 Average fruit weight

Fruit weight was measured by electric precision balance. Average fruit weight per plant was recorded by randomly selecting five fruits per plant and mean value was calculated.

3.1.12.1.15 Yield per plant

Yield per plant was recorded from all harvests of each plant and expressed in kilogram (kg) per plant.

3.1.12.1.16 Root length (cm)

At the end of the season each plant were uprooted from the pot and their root was cut and washed by water. Length of root was measured by centimeter scale.

3.1.12.1.17 Shoot root ratio

After measuring the root length, shoot root ratio was measure by dividing the shoot by root length.

3.1.12.1.18 Skin diameter of fruit (mm)

Each fruit of each plant was cut into equal part and their skin diameter was measured by using Digital Caliper-515 (DC-515) in millimeter (mm).

3.1.12.2 Physiological traits

Physiological traits such as Ethylene concentration in leaf, chlorophyll content in leaf, Membrane stability index (MSI), Relative water content (RWC), Moisture percentage in fruit, Dry mater percentage in fruit, Na ion content, K ion content were recorded. Differents physiological experiments are illustrated in Plate 2.

3.1.12.2.1 Determination of Ethylene concentration (ppm)

Ethylene concentration was measured by GAS Detector device with ethylene escape box. Leaf of single plant was taken inside the box for few minutes. After few minutes, one of the pores of ethylene escape box was removed and the sensor antenna of the GAS Detector device was placed through the pore. Then the reading was taken as the ethylene concentration of leaf in parts per million (ppm). Plate 2 shows the steps in ethylene concentration measurement.

3.1.12.2.2 Determination Membrane Stability Index (MSI)

Membrane stability index (MSI) was measured from fully expanded fresh leaves that were plucked at least after four weeks of nursery transplantation into a saline soil. After plucking the third leaf from five plants within each treatment, leaves were washed using distilled water and dried with tissue paper separately. Then 2 g of leaf sample of each treatment within each replication was placed in a test tube containing 10 ml of distilled water. These test tubes were placed in a water bath for 30 min having 40°C temperature. After the prescribed time passed test tubes were taken out, cooled at room temperature and electrical conductivity (EC) of water extract within the tubes was determined using HANNA EC meter (Model HI763064, HANNA Instruments,) which considered as EC_1. Subsequently, same test tubes were once more placed in a water bath at 100°C. Test tubes were again taken out after 30 min, cooled at room temperature and EC_2 of water extract within the tubes was determined. Both EC_1 and EC_2 were used to determine MSI of each genotype for all levels of salinity after following the equation given by Sairam (1994);

$$MSI = (1 - \frac{EC1}{EC2}) \times 100$$

3.1.12.2.3 Measuring of chlorophyll content

Leaf chlorophyll content was measured by using SPAD-502 plus Portable Chlorophyll meter. The chlorophyll content was measured from leaves stressed at different drought treatments from four different portion of the leaf and then averaged for analysis. Measuring of chlorophyll content by SPAD meter is shown in Plate 2.

3.1.12.2.4 Determination of Relative Water Content (RWC)

The relative water content (RWC) was estimated according to Barrs and Weatherly (1962). The fresh weight of the whole plant was recorded. The plant was floated in water under light until the weight stayed constant to attain full turgid and turgid weight was recorded. Then the plant was kept in hot air oven at 80°C for 48 hours and the dry weight was recorded. The relative water content (RWC) was calculated by using following formula,

$$\text{Relative water content (\%)} = \frac{\text{Fresh weight} - \text{Dry weight}}{\text{Turgid weight} - \text{Dry weight}} \text{x } 100$$

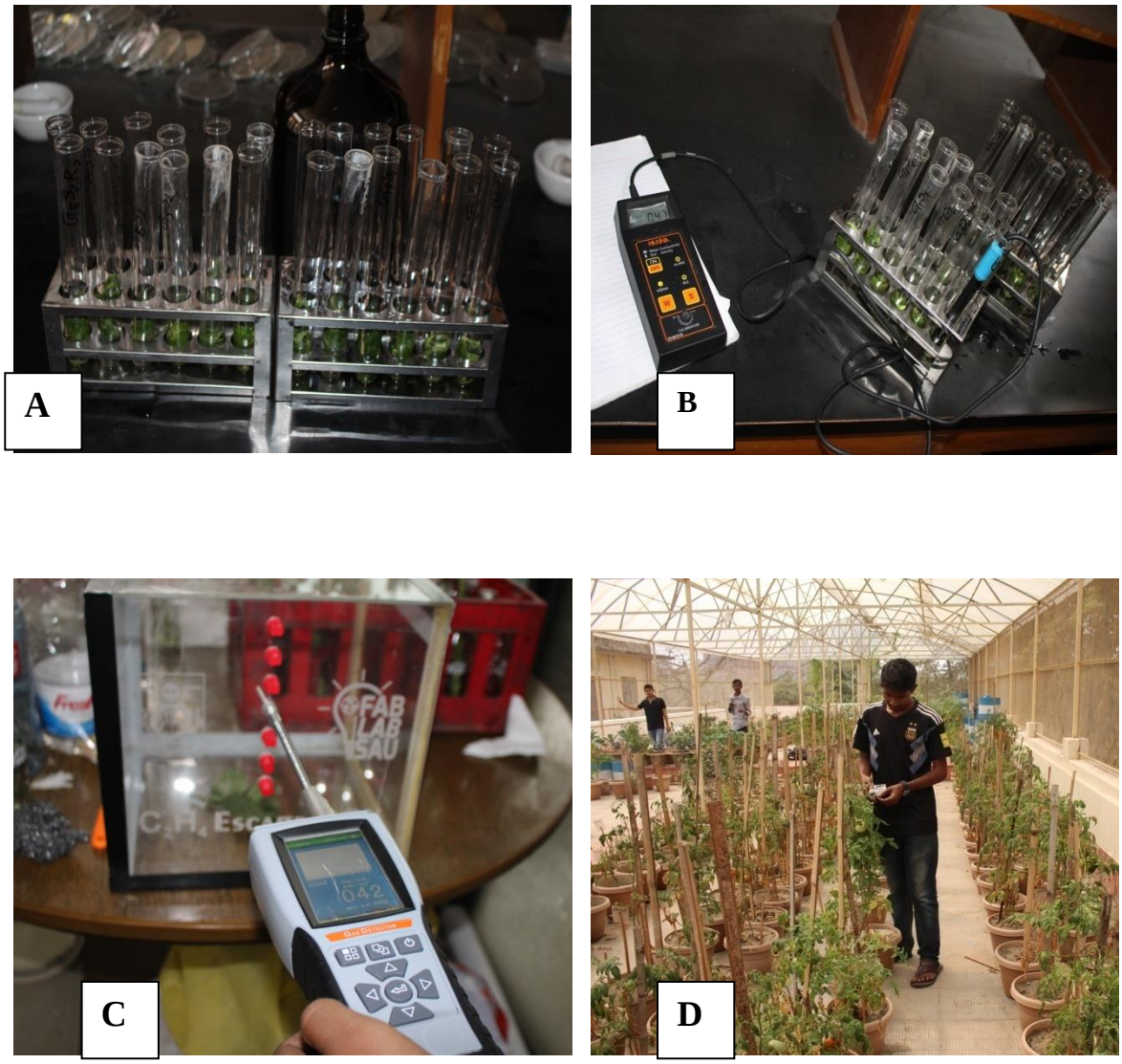

Plate 2. Different types of physiological analysis and data recording A. Leaf sample preparation for %MSI determination B. Estimation of % MSI by using EC meter C. Estimation of ethylene concentration by using ethylene box and ethylene detector meter D. Determination of chlorophyll content SPAD-502 plus portable chlorophyll meter.

3.1.12.2.5 Determination of Percent Moisture and Dry Matter Content in Fruit

Wight of fresh fruit of each plant was taken. Fruit was pressed so that some moisture was released and it was kept in hot air oven at 80°C for 48 hours. After 48 hours, dry weight of fruit was measured and percentage of Moisture content was measured by following formula;

$$\%\text{Moisture Content} = \frac{\text{weight of freash fruit} - \text{Weight of oven dry fruit}}{\text{Weight of freash fruit}} \times 100$$

Dry Matter content was determined by following formula;

% Dry Matter Content= 100-%Moisture content

3.1.12.2.7 Determination of Na+ and K+ Content

Oven-dried (70^{o}C) tomato plants shoot samples were ground in a Wiley Hammer Mill, passed through 40 mesh screens, mixed well and stored in plastic vials. The ground plant samples were digested by Micro-Kjeldahl method (Thomas and Nambisan, 1999). One gram oven-dried tomato plant shoot samples were taken in kjeldahl flasks. About 15 mL of diacidic mixture (HNO_3 : 60% $HClO_4$ = 2:1) were taken in a digestion tube and left to stand for 20 minutes and then transferred to digestion block and continued heating at 100^{o}C. The temperature was increased to 365^{o}C gradually to prevent frothing (50^{o}C steps) and left to digest until yellowish color of the solution turned to whitish color. Then the digestion tubes were removed from the heating source and allowed to cool to room temperature. About 40 mL of de-ionized water was carefully added to the digestion tubes and the contents filtered through Whatman no. 40 filter paper into a 100 mL volumetric flask and the volume up to the mark with de-ionized water. The samples were stored at room temperature in labeled containers. Content of Na^+ and K^+ were determined by Flame Photometer.

3.1.12.3 Nutritional traits

Data were recorded on the basis of different nutritional traits using ripe fruits viz., Brix (%), Vitamin-C content (mg/100 g) and Lycopene content (mg/100 g), pH of fruit and titrable acidity (%). Different study of nutritional analysis is illustrated in Plate 4 and Plate 5.

3.1.12.3.1 Determination of Brix %

Brix percentages were measured by Portable Refractometer (ERMA, Tokyo, Japan) at room temperature. Single fruit was blend and juice was collected to measure Brix percentage. Determination of Brix percentage is shown in plate 3.

3.1.12.3.2 Determination of Vitamin C (mg/100 g fruit)

Vitamin-C was measured by Oxidation Reduction Titration Method (Tee *et al*., 1988). Determination of vitamin C is shown in plate 3.

3.1.12.3.2.1 Dye preparation

260 mg 2, 6-dichloro indophenols with 210 mg sodium bicarbonate were mixed with one litter of distilled water. It was used in burette.

3.1.12.3.2.2 5% oxalic acid preparation

50 mg oxalic acid was mixed with one litter of distilled water and it was used for washing the fruit and for the preparation of fruit juice preparation.

3.1.12.3.2.3 L-ascorbic acid preparation

10 mg of granular L-ascorbic acid was mixed with 100 ml oxalic acid solution. 5 ml was taken and volume was made up to 100 ml. from this solution, 5 ml was taken for titration against 2,6-dichloro indophenol from burette for 3 times and their mean was recorded as the required amount of dye for titrating L-ascorbic acid.

3.1.12.3.2.4 Preparation of tomato solution

Single fruit was weighted and was blend with some drops of oxalic acid solution. It was filtered through whatman filter paper and the juice was collected. Volume was made up to 100 ml with oxalic acid. 5 ml was taken from that solution and titrated against dye solution. The required amount of dye was recorded for titrating tomato solution. The amount of vitamin C was determined by following formula;

$$\text{Vitamin C} = \frac{0.5 \times dye\ required\ for\ tomato\ juice \times 100 \times 100}{dye\ required\ for\ L\text{-}ascorbic\ acid \times 5 \times weight\ of\ fruit}$$

3.1.12.3.3 Determination of Lycopene content

Absorption determination for lycopene content was estimated following the method of Alda *et al*. (2009) by using T60 UV-Visible Spectrophotometer. Determination of lycopene content is shown in plate 3. Lycopene in the tomato was extracted using hexane: ethanol: acetone (2:1:1) (v/v) mixture. One gram juice of the each sample were homogenized with 25ml of hexane: ethanol: acetone, which were then placed on the orbital shaker for 30 min., adding 10 ml distilled water and was continued agitation for another two min. The solution was then left to separate into distinct polar and non- polar layers. The absorbance was measured at 472 nm and 502 nm, using hexane as a blank. The lycopene concentration was calculated using its specific extinction coefficient (E 1%, 1cm) of 3450 in hexane at 472 nm and 3150 at 502 nm. The lycopene concentration was expressed as mg/100 g product.

$$\text{At } \lambda = 472 \text{ nm: lycopene content (mg/100g)} = \frac{E}{3.45} \cdot \frac{20}{m}$$

$$\text{At } \lambda = 502 \text{ nm: lycopene content (mg /100g)} = \frac{E}{3.15} \cdot \frac{20}{m}$$

Where, m = the weight of the product (g)

E = extinction coefficient

3.1.12.3.4 Determination of Fruit pH

Fruit pH was determined by using REX pH meter model –PHS-3C. Single fruit was blended and then it was filtered through whatman filter paper and juice was collected. The electrode was inserted into the juice and pH was recorded.

3.1.12.3.5 Determination of Titrable acidity

Firstly 0.1 N NaOH solutions was prepared by taking 4 gm NaOH pellet into 1000 ml distilled water. It was used in burette. Single fruit was weighted and it was blended. Fruit juice was collected by passing it through whatman filter paper. Volume was made up to 50 ml by adding distilled water. 10 ml solution was taken and 2 drops of Phenolphthalein was added. It was titrated against 0.1 N NaOH and required amount of NaOH was recorded. Titrable acidity was determined by following formula;

$$\%\text{Acidity} = \frac{titrate \times Normality\ of\ alkali \times vol.made\ up \times Equivalent\ wt.of\ acid \times 100}{Volume\ of\ sample\ taken \times weight\ of\ sample \times 1000}$$

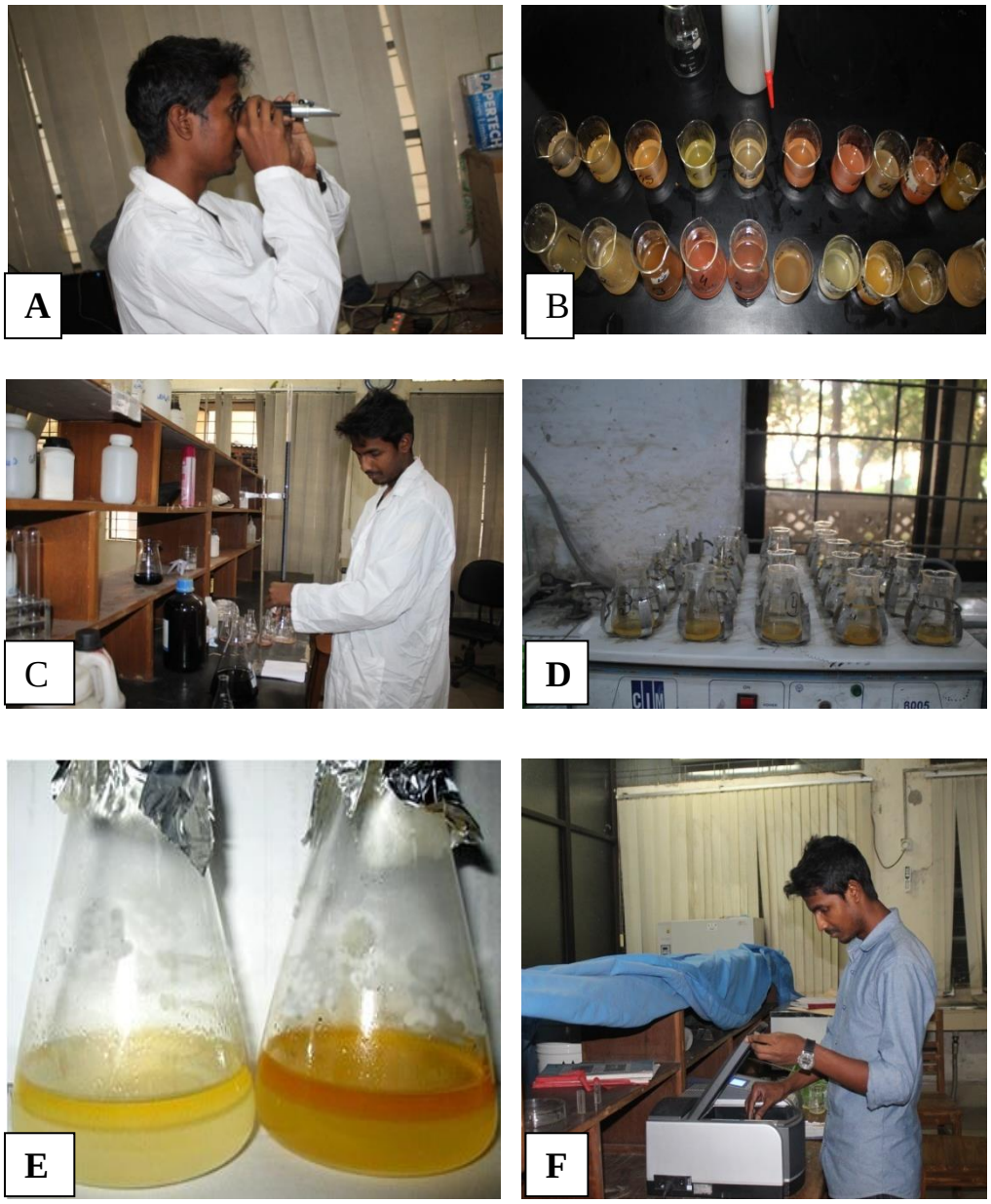

Plate 3. Nutritional analysis in lab A. Determination of Brix% B. Juice of tomato for vitamin C determination C. Titration of tomato juice with dye for vitamin C determination D. Tomato juice with solution on orbital shaker for lycopene content E. development of layer containing lycopene after removing from orbital shaker F. Spectrophotometer reading for lycopene content determination.

Plate 4. Determination of pH and titrable acidity content A. preparation of tomato juice for pH determination B. Estimation of fruit pH by using REX pH meter model –PHS-3C C. Preparation of fruit juice for titratble aciity determination D. Titration for determination of % titrable acidity.

3.1.13 Statistical analysis

Collected data were statistically analyzed using Statistix 10 program. Mean for every treatments were calculated and analysis of variance for each character was performed. Genotype treatment interaction was also performed. Comparison among all treatments was assessed by Least Significant Difference (LSD) test at 5% level of significance (Gomez and Gomez, 1984).

3.2 Experiment 2: Genotype × stress interaction under drought condition in tomato *(Solanum lycopersicum* L.*)*

This part comprises the methodology regarding locations of experimental site, planting materials, climate and soil, seed bed preparation, layout and design of the experiment, pot preparation, fertilizing, transplanting of seedlings, intercultural operations, harvesting, data recording procedure, physiological, nutritional and statistical analyses procedure, etc. Selection of drought tolerant genotypes of tomato were done based on agro-morphogenic, physiological and nutritional traits. Agromorphogenic traits included such plant height, number of leaves per plant, leaf area, number of branches per plant, days to first flowering, days to first fruit setting, days to maturity, number of cluster per plant, number of flowers per cluster, number of fruits per cluster, number of fruits per plant, average fruit weight, fruit diameter, fruit length, skin diameter, root length, shoot root ratio, yield per plant. Physiological traits included such as Ethylene concentration in leaf, chlorophyll content in leaf, Membrane stability index (MSI), Relative water content (RWC), Moisture percentage in fruit, Dry mater percentage in fruit, Proline content. Nutritional traits included such as Brix (%), Vitamin-C content (mg/100 g) and Lycopene content (mg/100 g), pH of fruit and titrable acidity (%). Experimental site, planting materials are same as described in section 3.1.1 and 3.1.2 respectively. The climate and soil, raising of seedlings, manures and fertilizer application, pot preparation and transplanting of seedlings are same as described in section 3.1.5, 3.1.6, 3.1.7 and 3.1.8 respectively. Intercultural operations, harvesting and processing are same as described in section 3.1.10 and 3.1.11 respectively.

3.2.1 Treatments in the experiment

The two factorial experiment was conducted to select the tomato genotypes under different drought treatments . Factor A was tomato genotypes where eight tomato genotypes were used. Factor B was drought treatments. Four drought treatments were used named T_1 (0 days witholding of water /control), T_2 (10 days witholding of water, mild drought), T_3 (20 days witholding water, moderate drought) and T_4 (30 days witholding of water, severe drought).

3.2.2 Design and layout of the experiment

The experiment was laid out and evaluated during Rabi season in Completely Randomized Design (CRD) using two factors. Factor A included eight genotypes and Factor B included 4 different drought treatments. The experiment was conducted in 3 replications and total 96 plastic pots were used.

3.2.3 Application of drought treatments

Eight genotypes were executed under four treatment of drought treatment (T_1: 0 days withholding of water/ Control condition; T_2: 10 days withholding of water, T_3: 20 days withholding of water, and T4: 30 days withholding of water). Plants in control treatments (T_1) were not exposed to drought whereas T_2, T_3 and T4 plants were exposed to 10 dyas, 20 days and 30 days drought stress. Drought treatment was started after 10 DAT for the well establishment of young seedlings and later on each pot was watered as per treatment.

3.2.4 Data recording

Data were recorded from each pot based on different yield and yield contributing, physiological and nutritional traits. Data were recorded in respect of the following parameters:

3.2.4.1 Agromorphogenic traits

Data related to yield and yield attributing traits such as plant height, number of leaves per plant, leaf area, number of branches per plant, days to first flowering, days to first fruit setting, days to maturity, number of cluster per plant, number of flowers per cluster, number of fruits per cluster, number of fruits per plant, average fruit weight, fruit diameter, fruit length, skin diameter, root length, shoot root ratio, yield per plant

were recorded during conducting the experiment are same as described in section 3.1.12.1.1, 3.1.12.1.2, 3.1.12.1.3, 3.1.12.1.4, 3.1.12.1.4, 3.1.12.1.5, 3.1.12.1.6, 3.1.12.1.7, 3.1.12.1.8, 3.1.12.1.9, 3.1.12.1.10, 3.1.12.1.11, 3.1.12.1.12, 3.1.12.1.13, 3.1.12.1.14, 3.1.12.1.15, 3.1.12.1.16, 3.1.12.1.17 and 3.1.12.1.18 respectively. Some view of research and uring different stages of plant life cycle is presented in Plate 5.

3.2.4.2 Physiological traits

Physiological traits such as Ethylene concentration in leaf, chlorophyll content in leaf, Membrane stability index (MSI), Relative water content (RWC), Moisture percentage in fruit, Dry mater percentage in fruit, Proline content. Ethylene concentration in leaf, Membrane stability index (MSI), Relative water content (RWC), chlorophyll content in leaf, Moisture percentage in fruit, Dry mater percentage in fruit are same as mentioned in section 3.1.12.2.1, 3.1.12.2.2, 3.1.12.2.3, 3.1.12.2.4, 3.1.12.2.5 respectively.

3.2.12.2.6 Determination of Proline Content

3.2.12.2.6.1 Proline extraction

Proline accumulation was determined by the method as described by Sadasivam and Manickam (1996). Fresh leaves (0.5 g) were grinded in mortar and pestle with 10 mL of 3% sulphosalicyclic acid and the homogenate was centrifuged at 18000×g. The homogenate was filtered and 2 mL of filtrate was added to the 2 mL of glacial acetic acid and 2 mL of acid ninhydrin and test tubes were kept for 1h at 100°C in water bath, followed by ice bath. The reaction mixture was vortexed with 4 mL of toluene. Toluene layer was separated and absorbance was read at 520 nm. A standard curve of proline was used for calibration.

3.2.12.2.6.2 Preparation of proline standard curve

80 mg of pure proline was dissolved into 100 mL of distilled water to get 800 ppm proline stock solution for preparing proline standard curve. By diluting this solution, 50 ppm, 100 ppm, 200 ppm, 400 ppm and 800 ppm solution were prepared in 20 mL each. The absorbance was measured with the help of Spectrophotometer at 520 nm. By plotting the concentration of proline (ppm) in ‘X’ axis and obtained absorbance reading in ‘Y’ axis a standard curve was prepared (Appendix VIII) From the

Plate 5. Research area view in different stage of plant life cycle A. Partial field view during fruit development stage B. Field visit by respected Supervisor C. Field view during first harvesting stage D. Field view during last harvesting stage.

absorbance reading obtained from samples, their respective proline content was estimated in ppm by using proline standard curve and converted into micro gram per gram (µg/g) unit using the following formula:

$$\text{Amount of proline}(\mu g/g) = \frac{x}{2} \times \frac{10}{500} \times 1000$$

3.2.12.3 Nutritional traits

Data were recorded on the basis of different nutritional traits using ripe fruits viz., Brix (%), Vitamin-C content (mg/100 g) and Lycopene content (mg/100 g), pH of fruit and titrable acidity (%) are same as described in section 3.1.12.3.1, 3.1.12.3.2, 3.1.12.3.3, 3.1.12.3.4 and 3.1.12.3.5 rspectively

3.2.13 Statistical analysis

Collected data were statistically analyzed using Statistix 10 program. Mean for every treatments were calculated and analysis of variance for each character was performed. Genotype treatment interaction was also performed. Comparison among all treatments was assessed by Least Significant Difference (LSD) test at 5% level of significance (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The experiments were conducted to determine the genotypes stress interaction of tomato genotypes under salinity and drought condition based on agromorphogenic, physiological and nutritional traits. Two separate experiments were conducted with eight genotypes of tomato using CRD design with three replications. In salinity experiment, four treatment as T_1; control, T_2; 4 dS/m, T_3; 8 dS/m and T_4; 12 dS/m were applied. In drought experiment, four drought treatments like T_1; control; T_2; 10 days withhold of water, T_3; 20 days withhold of water and T_4; 30 days withhold of water was applied. ANOVA and reduction percentage for salinity are presented in appendix IV and Appendix V respectively. ANOVA and reduction percentage for drought experiment are arranged in appendix VI and appendix VII respectively. Data are presented in tables and figures for both salinity and drought experiment. Results have been presented, discussed under the following headlines.

4.1 Experiment 1: Genotype × stress interaction under salinity condition in tomato (*Solanum lycopersicum* L.)

This part discusses the genotypes stress interaction under salinity condition in eight genotypes of tomato based on their agromorphogenic, physiological and nutritional traits. Four salinity treatments like T_1; control, T_2; 4 dS/m, T_3; 8 dS/m and T_4; 12 dS/m were applied. CRD was followed with three replications. Genotype performance, Salinity treatment performance and genotype stress interaction are presented in different tables and figures for better understanding. The observed results are presented here under the following headlines.

4.1.1 Agromorphogenic traits

Agromorphogenic traits such as plant height, no. of leaves, leaf area, no. of branches per plant, days to first flowering, days to first fruit setting , days to maturity, no,. of cluster per plant, no. of flowers per cluster, no. of fruits per clusters, no. of fruits per plant, fruit length, fruit diameter, average fruit weight, yield per plant, skin diameter of fruit, root length, shoot root ratio have been discussed. Data are presented in table, figures for better understanding.

4.1.1.1 Plant height (cm)

It was observed from the result of the experiment that plant height showed statistically significant variation among eight genotypes of tomato (Appendix IV). The tallest plant was obtained from G_1 (66.33 cm) (Table 2) whereas shortest plant was found in G_7 (53.5 cm) which was statistically similar with G_6 (53.67 cm) (Table 2).

The tomato genotypes showed statistically significant variation to salinity treatment in terms of plant height (Appendix IV). The tallest plant was found in T_1 treatment (67.21cm) (Table 3) whereas the shortest plant was found in T_4 (53.62 cm). This showed that plant height was gradually decreased with the increase in salinity treatment. Similar result was also found by Begum (2016). The unavailability of water due to the salinity stress may be one of the main reasons for the decrease of plant height with increase of salinity level (Munns *et al* , 2002).

Appendix IV showed that significant variation was found in genotypes and salinity interaction in case of plant height. The tallest plant was found in G_1T_1 (77.33 cm) (Table 4) whereas the shortest plant was found in G_6T_4 (47 cm).

Plant height was decreased with the increase of salinity levels. Plate 6 showed the plant height of eight genotypes under different salinity level. The reduction percentage in plant height with increase in salinity was shown in Appendix V. The highest reduction percentage was found in G_2 (36.4%) in T_2 treatment whereas the lowest reduction percentage was observed in G_6 (4%) under T_1 treatment (Appendix V and Figure 1).

4.1.1.2 Number of leaves per plant

Tomato genotypes showed significant variation in case of number of leaves per plant (Appendix IV). The highest leaf number was found in G_2 (45.5) and G_5 (42.42) whereas the lowest leaf number was observed in G_3 (18.00) which was statistically similar to G_4 (20.83) and G_6 (18.42) (Table 2).

Eight genotypes of tomato showed significant variation in term of number of leaves per plant under different salinity treatment (Appendix IV). The highest leaf number

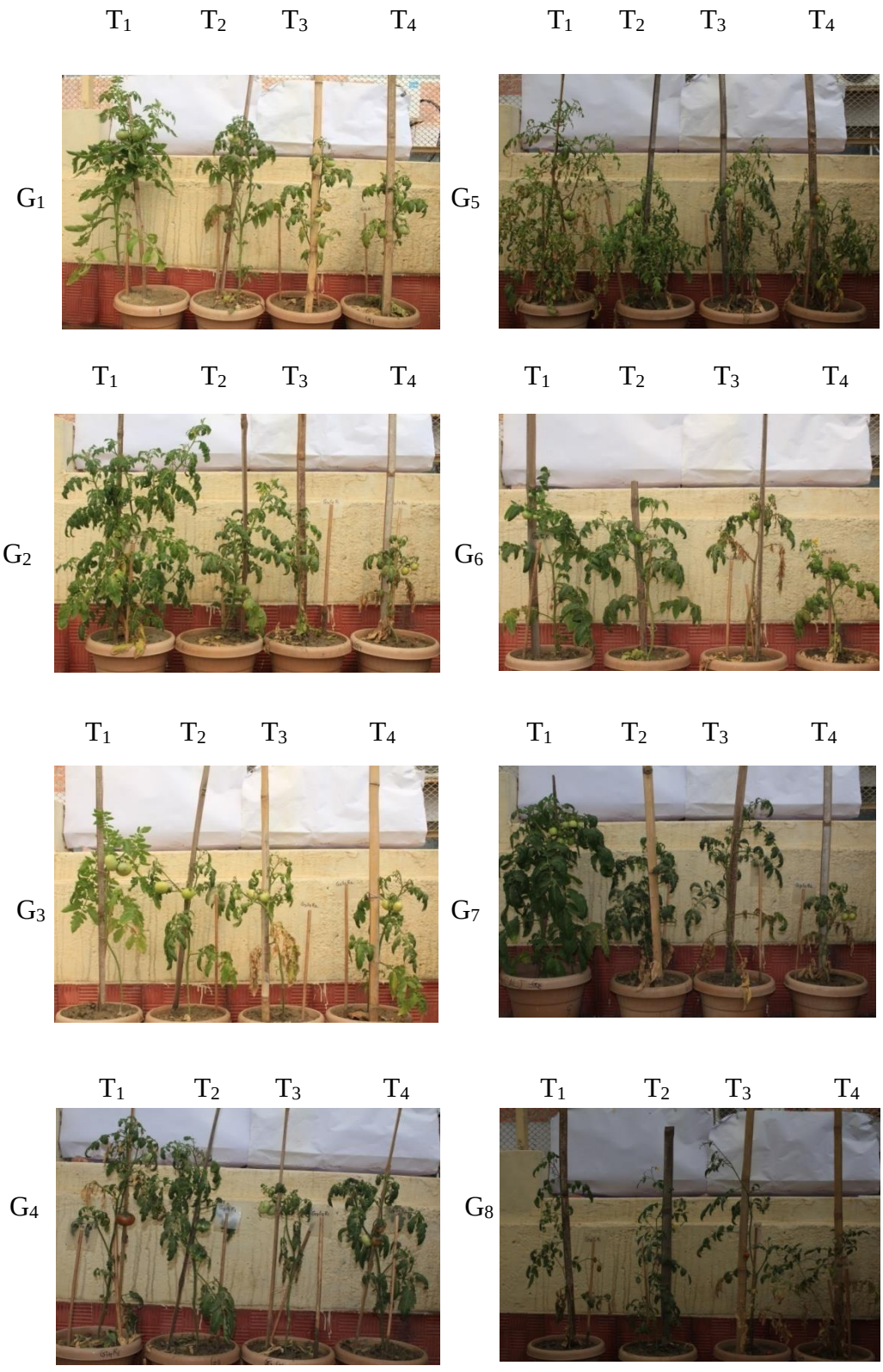

Plate 6. Morphological comparison of eight tomato genotypes under Control and salinity treatments.

was found in T_1 (40.21) whereas the lowest leaf number was found in T_4 (19.79) which was statistically similar with T_3 (22.71) (Table 3). It was observed from the table that leaves number was decreased with the increased of salinity.

Genotype salinity interaction was found significant in term of number of leaf per plant (Appendix IV). The highest number of leaves was observed in G_2T_1 (69.33) and G_5T_1 (69.33) whereas the lowest leaf number was found in G_3T_4 (13.33) which was statistically similar with G_6T_3 (13.67) (Table 4). From this table it was found that genotypes showed negative interaction with the increase of salinity level in terms of number of leaves per plant.

Number of leaves per plant was found decrease with the increase of salinity. The highest reduction percentage was found in G_1 (57.27%) and G_8 (57.27%) under T_4 treatment whereas the lowest reduction percentage was found in G_3 (17.12%) (Appendix V) (Figure1).

4.1.1.3 Leaf area

Eight tomato genotypes showed significant variation in terms of leaf area (Appendix IV). The highest leaf area was found in G_3 (394.25 cm^2) which was statistically similar with G_6 (389.17 cm^2) (Table 2).

The eight tomato genotypes showed no significant variation in terms of leaf area under salinity treatment (Appendix IV). The lowest leaf area was found in T_4 (276.21 cm^2) and the highest leaf area was observed in T_1 (305.21 cm^2) (Table 3). It was observed from the table that leaf area was reduced under the increase of salinity.

Leaf area performed no significant variation among interaction between genotypes and salinity (Appendix IV). The highest leaf area was found in G_3T_1 (415 cm^2) whereas the lowest leaf area was found in G_2T_4 (124 Cm^2) (table 4).

Leaf area was reduced under different salinity treatment. The highest reduction percentage in case of leaf was found in G_5 (16.80%) in T_4 treatment whereas the lowest reduction percentage was found in G_7 (1.17%) under T_1 treatment (Appendix V and Figure 1)

Table 2. Performance of tomato genotypes on plant height, number of leaves and leaf area[Y]

Genotype [X]	Plant height (cm)	Number of leaves per plant	Leaf area (cm^2)
G_1	66.33 a	27.42 b	337.50 b
G_2	61.00 bc	45.50 a	128.58 d
G_3	57.08 cd	18.00 c	394.25 a
G_4	56.67 cd	20.83 c	143.58 d
G_5	58.58 c	42.42 a	373.75 ab
G_6	53.67 d	18.42 c	389.17 a
G_7	53.5 d	27.00 b	341.83 b
G_8	64.83 ab	22.92 bc	208.17 c
CV%	10.03	15.82	16.33
LSD 0.05	4.83	5.41	43.32

[X]Eight tomato genotypes coded from G_1 to G_8

[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Table 3: Performance of salinity treatments on plant height, number of leaves per plant and leaf area[Y]

Salinity treatments[X]	Plant height (cm)	Number of leaves per plant	Leaf area (cm^2)
T_1	67.21 a	40.21 a	305.21
T_2	58.92 b	28.54 b	293.92
T_3	56.08 bc	22.71 c	283.08
T_4	53.62 c	19.79 c	276.21
CV%	10.03	15.82	16.33
LSD0.05	3.41	3.82	30.64

[X]Four salinity treatments viz. T_1, Control; T_2, 4 dS/m; T_3, 8dS/m; T_4, 12dS/m.

[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Table 4. Interaction effect of tomato genotypes and salinity treatments on plant Height, Number of leaves per plant and Leaf area[Y]

Interaction[X]	Plant height (cm)		Number of leaves/plant		Leaf area (cm^2)
G_1T_1	77.33	a	41.33	bc	355.33
G_1T_2	71.67	ab	31.67	cdefg	342.67
G_1T_3	63.00	bcde	19.00	hijk	330
G_1T_4	53.33	fghi	17.67	ijk	322
G_2T_1	79.67	a	69.33	a	135
G_2T_2	57.33	defgh	43.33	b	129.33
G_2T_3	50.67	ghi	37.00	bcd	126
G_2T_4	56.33	defghi	32.33	cdef	124
G_3T_1	62.67	bcdef	23.33	fghijk	415
G_3T_2	58.67	cdefg	19.33	hijk	396.67
G_3T_3	55.33	efghi	16.00	jk	388
G_3T_4	51.67	ghi	13.33	k	377.33
G_4T_1	62.67	bcdef	28.00	defghi	150
G_4T_2	58.33	cdefg	21.00	ghijk	146
G_4T_3	51.33	ghi	18.00	ijk	142
G_4T_4	54.33	efghi	16.33	jk	136.33
G_5T_1	67.33	bc	63.33	a	412.33
G_5T_2	56.67	defgh	40.00	bc	390
G_5T_3	58.67	cdefg	35.00	bcde	349.33
G_5T_4	51.67	ghi	31.33	cdefgh	343.33
G_6T_1	58.00	cdefg	25.33	efghij	406.67
G_6T_2	55.67	defghi	19.33	hijk	390.67
G_6T_3	54.00	efghi	15.33	jk	386
G_6T_4	47.00	i	13.67	k	373.33
G_7T_1	58.00	cdefg	36.67	bcd	350.67
G_7T_2	48.00	hi	29.00	defgh	346.67
G_7T_3	56.67	defgh	23.33	fghijk	337.33
G_7T_4	51.33	ghi	19.00	hijk	332.67
G_8T_1	72.00	ab	34.33	bcde	216.67
G_8T_2	65.00	bcd	24.67	efghij	209.33
G_8T_3	63.33	bcde	18.00	ijk	206
G_8T_4	59.00	cdefg	14.67	jk	200.67
CV%	10.03		15.82		16.33
LSD O.05	9.65		10.81		86.04

[X]fifteen genotypes coded from G_1 to G_8 and four salinity treatments viz. T_1, Control; T_2, 4dS/m; T_3, 8dS/m; T_4, 12 dS/m.

[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

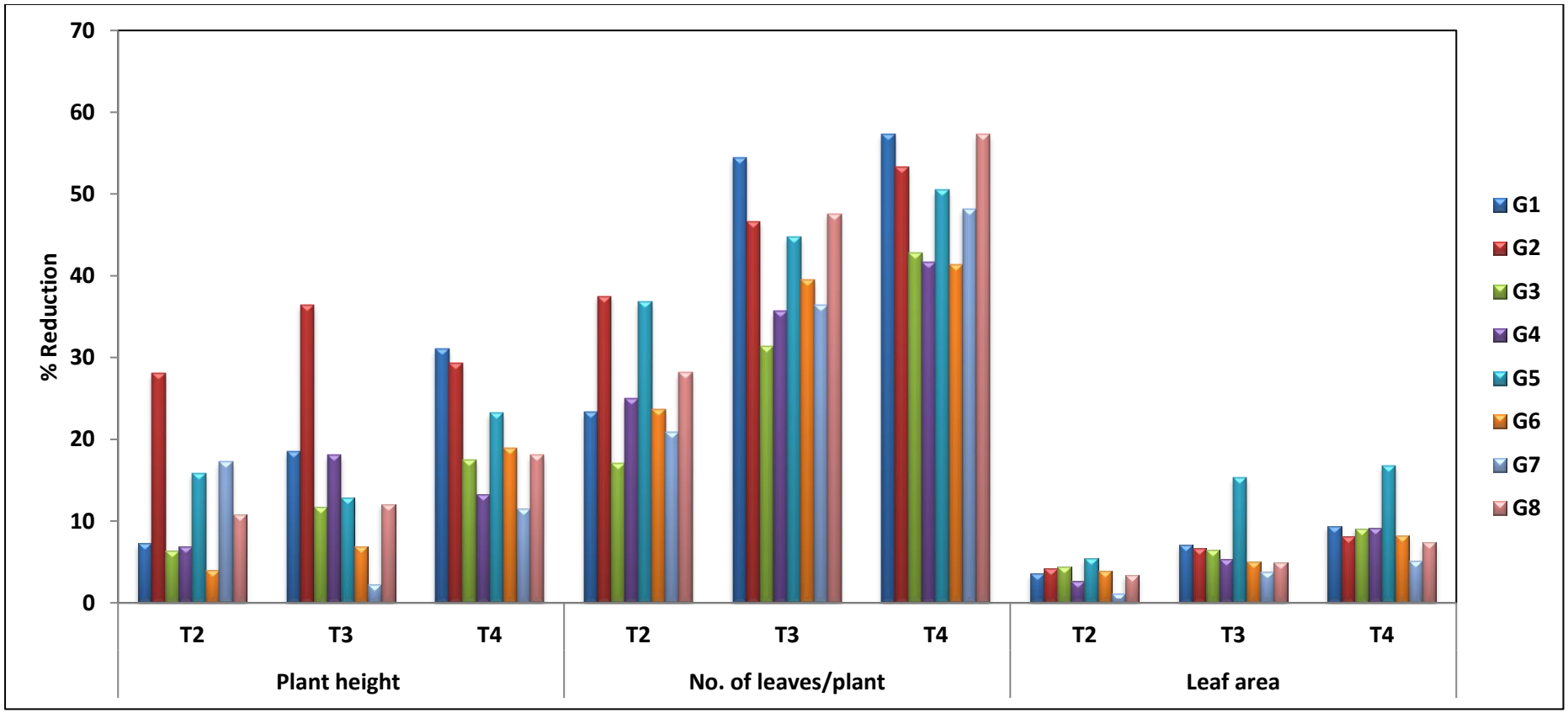

Figure 1. Reduction percentage in Plant height, No. of leaves/plant and leaf area under increase in salinity.

4.1.1.4 Number of branches per plant

Number of branches per plant was found significant among eight genotypes of tomato (Appendix IV). The maximum number of branches per plant was found in G_2 (5.92) whereas the minimum number of branches per plant was found d G_6 (4.17) (Table 5).

The branches per plant showed significant variation in genotypes under salinity treatment (Appendix IV). The maximum number of branches was found in T_1 (7.04) whereas the minimum branches per plant was found in T_4 (3.62) (Table 6). From this table it was shown that number of branches per plant was reduced with the increase the salinity level.

The number of branches per plant was found statistically significant in interaction among salinity and genotypes (Appendix IV). The highest number of branches per plant was found in G_2T_1 (9.00) whereas the lowest number was found in G_6T_4 (3.00) (table 7).

Number of branches per plant was reduced with the increase of salinity. Reduction percentage in number of branches per plant was shown in Appendix V. The highest reduction percentage was found in G_2 (59%) in T_4 whereas the lowest reduction percentage was found in G_6 (6.%) (Appendix V and Figure 2).

4.1.1.5 Days to first flowering

Eight genotypes were found statistically significant in terms of days to first flowering (Appendix IV). The longest time for days to flowering was found in G_6 (37 days) whereas the shortest time for days to first flowering was found in G_4 (18.17 days) (Table 5).

Days to first flowering was found statistically insignificant under different salinity treatment (Appendix IV). The longest time for days to first flowering was found in T_2 (28.87 days) whereas the shortest time was found in T_3 (24.46 days) (Table 6).

Interaction of tomato genotypes and salinity treatments affected statistically significant in terms of days to first flowering (Appendix IV). The longest time for

days to first flowering was found in G_2T_2 (42 days) whereas the shortest days to first flowering was found in G_1T_1 (15.67 days) (Table 7).

The eight genotypes of tomato were found variation with the increase of salinity level. The shortest days to first flowering (maximum reduction percentage) was found in G_2 (27.38%) in T_3 treatment and the longest days to first flowering (minimum reduction percentage) was found in G_2 (-32.62%) in T_2 treatment (Appendix V and Figure 2).

4.1.1.6 Days to first fruit setting

Tomato genotypes showed significant variation in term of days to first fruit setting (Appendix IV). The longest days to first fruit setting was found in G_6 (60.42 days) and the shortest days to first fruit setting was found in G_3 (37.92 days) which was similar in G_1 (38.58 days) and G_3 (39.17 days) (Table 5).

Days to first fruit setting was found insignificant under salinity treatment (Appendix IV). The longest days to first flowering was found in T_2 (48.58 days) whereas the shortest days to first fruit setting was found in T_3 (46.62 days) (Table 6).

Interaction of tomato genotypes and salinity treatments were affected significantly in terms of days to first fruit setting (Appendix IV). The longest days to first fruit setting was found in G_2T_2 (67.67 days) which was statistically similar with G_6T_4 (66.67 days) whereas the shortest days to first fruit setting was observed in G_1T_1 (35.67 days) which was statistically significant with G_5T_1 (35.67 days) and G_4T_2 (36 days) (Table 7). Days to first fruit setting showed reduction under salinity condition. The shortest days to first flowering was found in G_2 (30.07%) under T_3 salinity treatment and whereas G_5 genotypes under T_3 delayed (-43.90%) (Appendix V and Figure 2).

4.1.1.7 Days to maturity

Eight genotypes found significant in terms of days to maturity (Appendix IV). The longest days to maturity was found in G_6 (83.08 days) whereas the shortest days to maturity was found GG_5 (68.58 days) (Table 8).

Days to maturity was affected significantly under salinity treatments (Appendix IV). The longest period for days to maturity was found in T_2 (76.13 days) whereas the shortest period for maturity was found in T_4 (69.67 days) (Table 9). Maturity time decreases with the increase of salinity treatment (Agrawal *et al*., 2005).

Table 5. Performance of tomato genotypes on No. of branches per plant, Days to first flowering, days to first fruit setting[Y]

Genotype [X]	No. of branches /plant	Days to first flowering	Days to first fruit setting
G_1	5.33 abc	18.75 d	38.58 e
G_2	5.92 a	30.00 b	52.42 b
G_3	5.08 bcd	23.75 c	39.17 e
G_4	4.67 cde	18.17 d	37.92 e
G_5	5.5 ab	24.42 c	43.25 de
G_6	4.17 e	37.00 a	60.42 a
G_7	4.42 de	29.25 b	51.50 bc
G_8	4.75 cde	26.92 bc	46.17 cd
CV%	17.30	15.38	15.12
LSD 0.05	0.70	3.27	5.70

[X]Eight tomato genotypes coded from G_1 to G_8
[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Table 6: Performance of salinity treatments on No. of branches per plant, Days to first flowering, days to first fruit setting[Y]

Salinity treatments[X]	No. of branches /plant	Days to first flowering	Days to first fruit setting
T_1	7.04 a	24.87	44.71
T_2	5.00 b	28.87	48.58
T_3	4.25 c	24.46	46.62
T_4	3.62 d	25.92	44.79
CV%	17.3	15.38	15.12
LSD0.05	0.50	2.31	4.03

[X]Four salinity treatments viz. T_1, Control; T_2, 4 dS/m; T_3, 8dS/m; T_4, 12dS/m
[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Table 7. Interaction effect of tomato genotypes and salinity treatments on No. of branches per plant, days to first flowering and days to first fruit setting[Y]

Interaction[X]	No. of branches /plant	Days to first flowering	Days to first fruit setting
G_1T_1	8.33 ab	15.67 n	35.67 l
G_1T_2	5.33 efgh	18.67 klmn	40.67 ijkl
G_1T_3	4.00 hij	20.33 jklmn	39.00 jkl
G_1T_4	3.67 ij	20.33 jklmn	39.00 jkl
G_2T_1	9.00 a	31.67 cde	57.67 abcde
G_2T_2	5.67 defg	42.00 a	67.67 a
G_2T_3	5.33 efgh	23.00 hijklm	40.33 ijkl
G_2T_4	3.66 ij	23.33 hijklm	44.00 hijkl
G_3T_1	6.66 cde	22 .00 ijklmn	37.67 kl
G_3T_2	5.00 fghi	24.00 ghijkl	40.33 ijkl
G_3T_3	4.66 ghi	24.00 ghijkl	40.33 ijkl
G_3T_4	4.00 hij	25.00 fghijk	38.33 kl
G_4T_1	6.66 cde	17.00 mn	38.33 kl
G_4T_2	4.67 ghi	18.33 lmn	36.00 l
G_4T_3	3.67 ij	18.33 lmn	39.33 jkl
G_4T_4	3.67 ij	19.00 klmn	38.00 kl
G_5T_1	7.33 bc	22.33 hijklm	35.67 l
G_5T_2	5.67 defg	22.33 hijklm	41.00 ijkl
G_5T_3	4.67 ghi	28.33 defghi	51.33 cdefghi
G_5T_4	4.33 ghij	24.67 fghijkl	45.00 ghijkl
G_6T_1	5.00 fghi	35.33 bc	55.67 bcdefg
G_6T_2	4.67 ghi	41.00 ab	62.33 abc
G_6T_3	4.00 hij	31.00 cdef	57.00 abcdef
G_6T_4	3.00 j	40.67 ab	66.67 ab
G_7T_1	6.33 cdef	28.67 defgh	47.00 efghijkl
G_7T_2	4.67 ghi	30.00 cdefg	52.67 cdefgh
G_7T_3	3.67 ij	28.00 efghi	60.67 abcd
G_7T_4	3.00 j	30.33 cdefg	45.67 fghijkl
G_8T_1	7.00 bcd	26.33 efghij	50.00 defghij
G_8T_2	4.33 ghij	34.67 bcd	48.00 efghijk
G_8T_3	4.00 hij	22.67 hijklm	45.00 ghijkl
G_8T_4	3.67 ij	24.00 ghijkl	41.67 hijkl
CV%	17.3	15.38	15.12
LSD O.05	1.41	6.54	11.40

[X]fifteen genotypes coded from G_1 to G_8 and four salinity treatments viz. T_1, Control; T_2, 4dS/m; T_3, 8dS/m; T_4, 12 dS/m.

[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

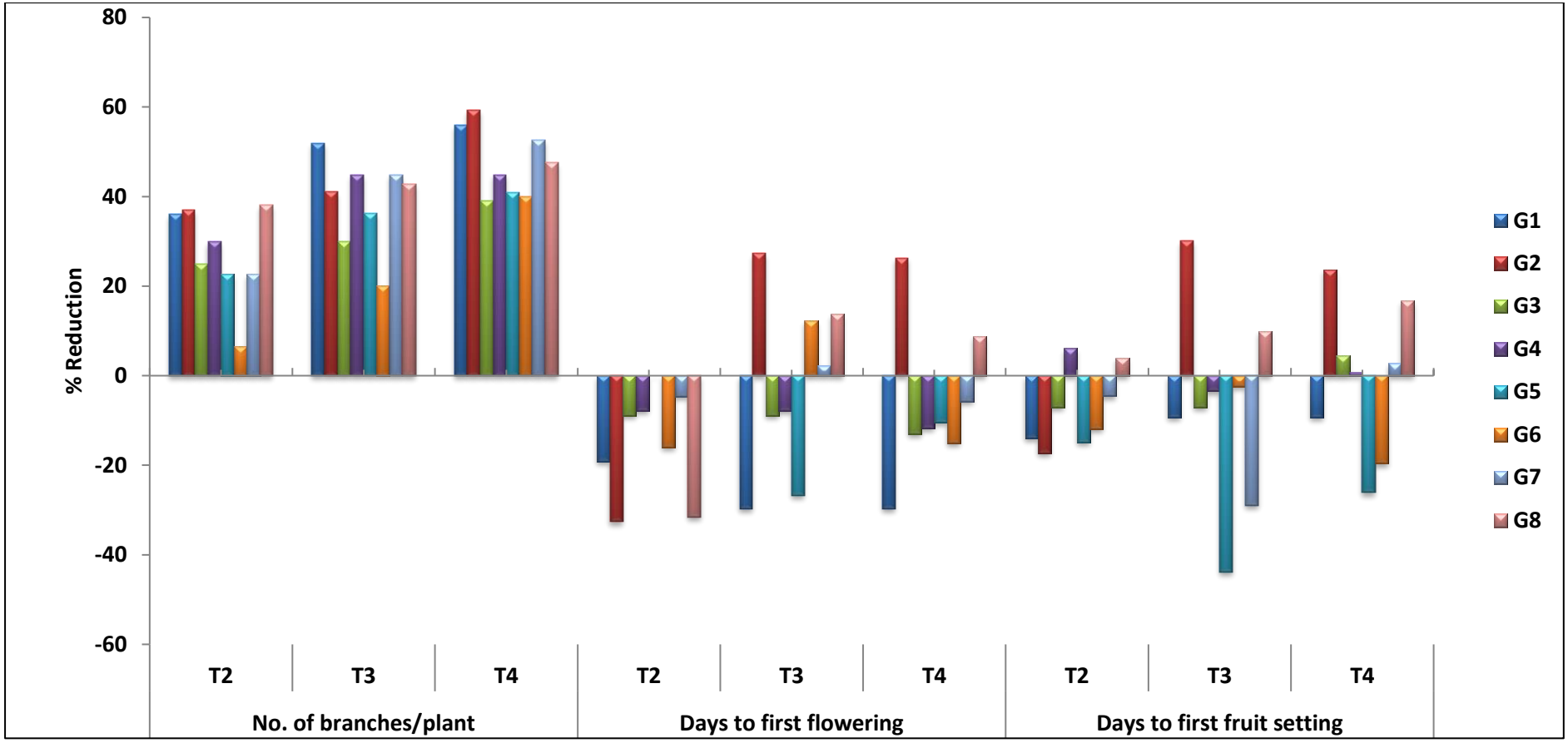

Figure 2. Reduction percentage in No. of branches/plant, Days to first flowering and days to first fruit setting under increasing salinity.

Interaction of genotypes and salinity was found significant in case of days to maturity (Appendix IV). The shortest period for days to maturity was found in G_2T_2 (89.00 days) which was statistically similar with G_6T_1 (84.67 days) whereas the shortest period for days to maturity was found in G_8T_4 (65 days) (table 10).

The eight genotypes showed significant variation under salinity treatments in case of days to maturity. Maximum reduction was found (early maturity) in G_2 (17.60%) under T_4 whereas the minimum reduction was found (late maturity) in G_2 (-6.80%) under T_2 treatment (Appendix V and Figure 3).

4.1.1.8 Number of clusters per plant

Eight tomato genotypes showed significant variation in term of number of clusters per plant (Appendix IV). The maximum cluster was found in G_8 (6.58) which was statistically similar with G_7 (6.33) and G_5 (6.55) whereas the minimum cluster was found in G_2 (5.32)) and G_4 (5.42) (Table 8).

Number of cluster per plant showed statistically significant variation among salinity treatments (Appendix IV). The highest number of cluster per plant was found in T_1 (8.08) whereas the lowest number of cluster in T_4 (4.49) (Table 9). It was observed that number of cluster per plant was found decrease with the increase of salinity level. Higher level of salinity decreases the number of cluster per plant (Islam *et al*., 2011). Begum (2016) found that with the increase of salinity level, number of cluster per plant decreased.

Number of cluster per plant performed significant variation among the interaction of tomato genotypes and salinity (Appendix IV). The lowest number of cluster per plant was found in G_2T_1 (8.33), G_5T_1 (8.33), G_6T_1 (8.33), G_8T_1 (8.33) whereas G_2T_4 (3.67) showed the lowest number of clusters per plant (Table 10)

Significant reduction was found among eight genotypes of tomato under different salinity levels (Appendix V and Figure 3). Resuction percentage in number of cluster per plant with the increasing salinitywas shown in Appendix V. The maximum reduction (55.94%) was found in G_2 under T_4 and the lowest reduction (12.5%) was found in G_8 under T_2 treatments.

4.1.1.9 Number of flowers per cluster

Eight genotypes showed significant variation in term of number of flowers per cluster (Appendix IV). The maximum flowers per cluster was found in G_8 (5.75) whereas the minimum number of flowers per cluster was found in G_4 (4.08) (Table 8).

Number of flowers per cluster showed statistically significant variation among salinity treatments (Appendix IV). The highest number of flowers per cluster was found in T_1 (6.08) whereas the lowest number was found in T_4 (3.04) (table 9). It was found that number of flowers per cluster decreased with increase of salinity level (Begum, 2017). Salt treated plant produced fewer flowers per plant than control plant

Number of flowers per cluster showed statistically significant variation among the interaction of tomato genotypes and salinity treatment (Appendix IV). The lowest flowers per cluster was found in G_6T_4 (2.67) which was statistically significant with G_1T_4 (3.00) whereas the highest number of flowers per cluster was found in G_1T_1 (8.33) (Table 10).

Number of flowers per cluster decreased with the increase of salinity level (Appendix V and Figure 3)). The highest reduction (63.98%) was found in G_8 under T_4 treatment whereas the lowest reduction (11.17%) was found in G_2T_2 and G_5T_2.

4.1.1.10 Number of fruit per cluster

Eight tomato genotypes showed statistically significant variation (Appendix IV). The highest number of fruits per cluster was found in G_8 (3.50) which was statistically similar with G_4 (3.42) whereas the lowest number of fruits per cluster (2.75) was found in G_2 and G_5 (Table 11).

Number of fruit per cluster shows statistically significant variation among salinity treatments (Appendix IV). The highest number of fruits per cluster (4.75) was found in T_1 whereas the lowest number of fruits per cluster (1.58) was found in T_4 (table 12). The number of fruits was decreased with the increase of salinity. Same result was also found by Begum (2017). Sidiky *et al.* (2012) found the same result under salinity condition.

Table 8. Performance of tomato genotypes on Days to maturity, No. of cluster per plant and No. of flowers per cluster[Y]

Genotype [X]	Days to maturity	Number of clusters per plant	Number of flowers per cluster
G_1	73.67 cd	5.58 c	4.5 c
G_2	78.25 b	5.42 c	5.00 b
G_3	70.17 de	6.00 abc	4.25 cd
G_4	71.92 cde	5.42 c	4.08 d
G_5	68.58 e	6.33 ab	4.58 c
G_6	83.08 a	5.75 bc	4.42 cd
G_7	75.00 bc	6.33 ab	4.25 cd
G_8	71.33 cde	6.58 a	5.75 a
CV%	6.77	14.63	10.28
LSD 0.05	4.09	0.71	0.39

[X]Eight tomato genotypes coded from G_1 to G_8

[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Table 9: Performance of salinity treatments on Days to maturity, No. of cluster per plant and No. of flowers per cluster[Y]

Salinity treatments[X]	Days to maturity	Number of clusters per plant	Number of flowers per cluster
T_1	77.96 a	8.08 a	6.08 a
T_2	76.13 a	6.04 b	5.17 b
T_3	72.25 b	5.12 c	4.12 c
T_4	69.67 b	4.49 d	3.04 d
CV%	6.77	14.63	10.28
LSD0.05	2.89	0.50	0.27

[X]Four salinity treatments viz. T_1, Control; T_2 4 dS/m; T_3, 8dS/m; T_4 ,12dS/m

[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Table 10. Interaction effect of tomato genotypes and salinity Days to maturity, No. of cluster per plant and No. of flowers per cluster[Y]

Interaction[X]	Days to maturity	Number of clusters per plant	Number of flowers per cluster
G_1T_1	78.33 bcdefg	8.00 ab	6.00 c
G_1T_2	75.33 defghi	5.67 efgh	5.00 def
G_1T_3	71.33 ghijk	5.00 fghij	4.00 ghi
G_1T_4	69.67 hijk	3.67 j	3.00 jk
G_2T_1	83.33 abcd	8.33 a	6.00 c
G_2T_2	89.00 a	5.33 efghi	5.33 cde
G_2T_3	72.00 ghijk	4.33 hij	5.00 def
G_2T_4	68.67 hijk	3.67 j	3.67 hij
G_3T_1	75.00 efghi	7.67 abc	5.33 cde
G_3T_2	72.00 ghijk	6.00 defg	4.67 efg
G_3T_3	67.67 ijk	5.67 efgh	4.00 ghi
G_3T_4	66.00 jk	4.67 ghij	3.00 jk
G_4T_1	76.33 cdefgh	7.67 abc	5.67 cd
G_4T_2	72.67 ghijk	5.33 efghi	4.33 fgh
G_4T_3	69.00 hijk	4.67 ghij	3.33 ijk
G_4T_4	69.67 hijk	4.00 ij	3.00 jk
G_5T_1	69.67 hijk	8.33 a	6.00 c
G_5T_2	68.00 ijk	6.33 cdef	5.33 cde
G_5T_3	69.33 hijk	5.67 efgh	4.00 ghi
G_5T_4	67.33 ijk	5.00 fghij	3.00 jk
G_6T_1	84.67 ab	8.33 a	6.00 c
G_6T_2	82.67 abcde	5.67 efgh	4.67 efg
G_6T_3	81.33 abcdef	4.33 hij	4.33 fgh
G_6T_4	83.67 abc	4.67 ghij	2.67 k
G_7T_1	78.33 bcdefg	8.00 ab	5.33 cde
G_7T_2	75.33 defghi	6.67 bcde	4.67 efg
G_7T_3	79.00 bcdefg	5.67 efgh	4.00 ghi
G_7T_4	67.33 ijk	5.00 fghij	3.00 jk
G_8T_1	78.00 bcdefg	8.33 a	8.33 a
G_8T_2	74.00 fghij	7.33 abcd	7.33 b
G_8T_3	68.33 hijk	5.67 efgh	4.33 fgh
G_8T_4	65.00 k	5.00 fghij	3.00 jk
CV%	6.77	14.63	10.28
LSD O.05	8.17	1.42	0.73

[X]fifteen genotypes coded from G_1 to G_8 and four salinity treatments viz. T_1, Control; T_2, 4dS/m; T_3 8dS/m; T_4, 12 dS/m.

[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

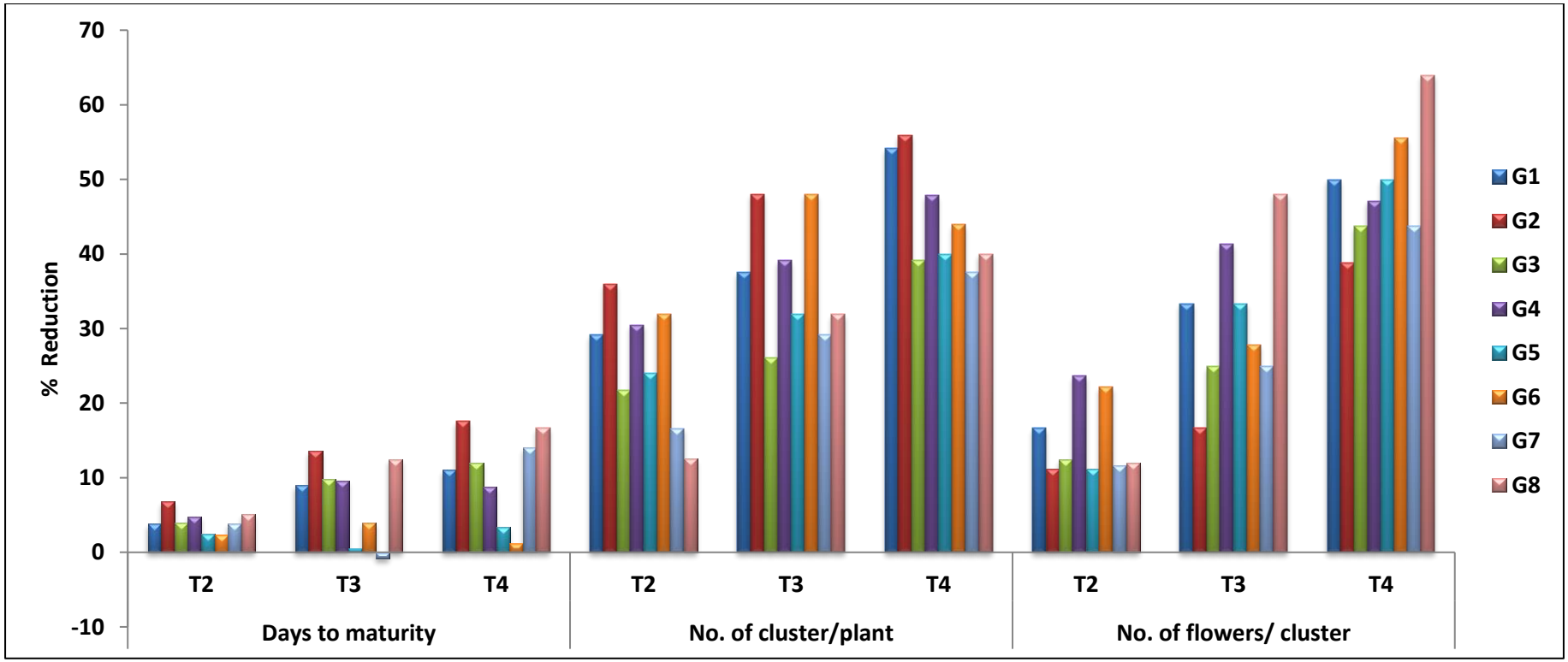

Figure 3. Reduction percentage in days to maturity, no. of cluster/plant and No. of flowers/cluster under increasing salinity treatment

Number of fruits per plant showed statistical significant variation among the interaction of tomato genotypes and salinity treatment (Appendix IV). The lowest number of fruits (1.33) was found in G_1T_4, G_2T_4, G_5T_4, G_7T_4 whereas the highest number of fruits per cluster was found in G_1T_1 (5.00), G_3T_1 (5.00) G_8T_1 (5.00) which were statistically similar with G_2T_1 (4.33) (Table 13).

Significant reduction was found among the genotypes under different salinity treatment (Appendix V and Figure 4). The highest reduction (73.4%) was found in G_1T_4 , G_3T_4 whereas the lowest reduction (26.6%) was found in G_4T_2.

4.1.1.11 Number of fruit per plant

Eight genotypes of tomato showed statistically significant variation under salinity treatments (Appendix IV). The maximum number of fruits per plant (16.25) was found in G_8 whereas the minimum number of fruits per plant (10) was found in G_2 (table 11).

The number fruits per plant showed significant variation among the salinity treatments (Appendix IV). The lowest number of fruits per plant (5.37) was found in T_4 treatment while the highest number of fruit (18.79) was found in T_1 treatment (Table 12). The data showed that number of fruits per plant decreased with the increase of salinity level. Begum (2016) showed that fruit number was reduced with the increase of salinity level. Number of cluster pr plant, number of flowers per cluster and number of fruit per cluster were found decreased that made less number of fruit in plant.

Number of fruit per plant was affected significantly by interaction among the tomato genotypes and salinity level (Appendix IV). The maximum number of fruits per plant (23.67) was found in G_8T_1 whereas G_5T_4 (4) produced minimum number of fruits per plant which are statistically similar with G_7T_4 (5.00), G_4T_4 (5.00) (Table 13).

Significant reduction was found among genotypes with the increase of salinity level (Appendix V and Figure 4). The maximum reduction (78.18%) was found in G_5 under T_4 treatment whereas the minimum reduction (22.26%) was found in G_8 under T_2 treatment.

4.1.1.12 Length of fruit (mm)

Eight genotypes of tomato showed statistically significant variation under salinity condition in term of fruit length (Appendix IV). The maximum fruit length (82.24 mm) was found in G_5 whereas the minimum fruit length (31.47 mm) was found in G_8 (Table 11).

Fruit length showed insignificant variation among salinity treatment (Appendix IV). The lowest fruit length (51.82 mm) was found in T_4 treatment while the highest fruit length (54.94 mm) was found in T_1 treatment (Table 12).

Statistical significant variation was found among the interaction of tomato genotypes and salinity treatment (Appendix IV). The maximum fruit length (83.94 mm) was found in G_5T_1 which was statistically similar with G_5T_1, G_5T_2,G_5T_4 whereas the minimum fruit length (30.08 mm) was found in G_8T_1 which was statistically significant with G_8T_2, G_8T_3, G_8T_4 (Table 13).

Significant reduction was observed in case of fruit length under salinity level (Appendix V and Figure 4). The maximum reduction percentage (8.65 %) was found in G_5 under T_4 treatment and minimum reduction percentage (1.73%) was found in G_5 and G_6 under T_2 treatment.

4.1.1.13 Fruit diameter (mm)

Fruit diameter showed statistically significant variation among eight tomato genotypes (Appendix IV). The highest fruit length (77.49 mm) was found in G_4 while the lowest fruit diameter (22.23 mm) was found in G_8 (Table 14).

Fruit diameter showed statistical significant variation among salinity treatments (Appendix IV). The highest fruit diameter (55.58 mm) was found in T_1 treatment while the lowest fruit diameter (51.88 mm) was found in T_4 treatment. It was found that with the increase of salinity level, fruit diameter reduced.

Table 11. Performance of tomato genotypes on Number of fruits per cluster, number of fruits per plant and length of fruit[Y]

Genotype [X]	Number of fruit per cluster	Number of fruit per plant	Length of fruit (mm)
G_1	2.92 c	11.33 b	45.09 d
G_2	2.75 c	10.00 d	63.65 b
G_3	2.83 c	10.08 cd	54.50 c
G_4	3.42 ab	11.67 b	54.19 c
G_5	2.75 c	10.83 bcd	82.24 a
G_6	3.00 bc	11.42 b	46.36 d
G_7	2.58 c	11.08 bc	48.55 d
G_8	3.50 a	16.25 a	31.47 e
CV%	17.23	10.79	10.31
LSD 0.05	0.42	1.02	4.48

[X]Eight tomato genotypes coded from G_1 to G_8

[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Table 12: Performance of salinity treatments on Number of fruits per cluster, number of fruits per plant and length of fruit[Y]

Salinity treatments[X]	Number of fruit per cluster	Number of fruit per plant	Length of fruit (mm)
T_1	4.75 a	18.79 a	54.94
T_2	3.12 b	13.12 b	53.58
T_3	2.42 c	9.04 c	52.69
T_4	1.58 d	5.37 d	51.82
CV%	17.23	10.79	10.31
LSD0.05	0.29	0.72	3.17

[X]Four salinity treatments viz. T_1, Control; T_2 4 dS/m; T_3, 8dS/m; T_4 , 12dS/m

[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Table 13. Interaction effect of tomato genotypes and salinity treatments on Number of fruits per cluster, number of fruits per plant and length of fruit[Y]

Interaction[X]	Number of fruit per cluster	Number of fruit per plant	Length of fruit (mm)
G_1T_1	5.00 a	19.00 bc	47.04 ghijk
G_1T_2	3.00 cde	13.00 e	45.69 ijkl
G_1T_3	2.33 efg	8.67 hi	44.08 kl
G_1T_4	1.33 h	4.67 k	43.55 l
G_2T_1	4.33 ab	17.00 cd	65.88 b
G_2T_2	3.00 cde	11.33 efg	63.95 bc
G_2T_3	2.33 efg	7.67 ij	63.00 bcd
G_2T_4	1.33 h	4.00 k	61.75 bcde
G_3T_1	5.00 a	16.67 d	56.55 cdef
G_3T_2	3.00 cde	10.67 fgh	54.75 defgh
G_3T_3	2.00 fgh	8.00 i	54.01 efghij
G_3T_4	1.33 h	5.00 k	52.68 fghijk
G_4T_1	5.00 a	19.33 b	55.77 cdefg
G_4T_2	3.67 bc	13.33 e	54.44 defghij
G_4T_3	3.00 cde	9.00 hi	53.75 efghij
G_4T_4	2.00 fgh	5.00 k	52.80 efghijk
G_5T_1	4.67 a	18.33 bcd	83.94 a
G_5T_2	3.00 cde	12.67 ef	82.49 a
G_5T_3	2.00 fgh	8.33 i	81.78 a
G_5T_4	1.33 h	4.00 k	80.76 a
G_6T_1	4.67 a	18.33 bcd	47.48 ghijkl
G_6T_2	3.33 cd	12.67 ef	46.66 hijkl
G_6T_3	2.33 efg	9.00 hi	45.92 hijkl
G_6T_4	1.67 gh	5.67 jk	45.36 jkl
G_7T_1	4.33 ab	18.00 bcd	49.89 fghijkl
G_7T_2	2.67 def	13.00 e	48.67 fghijkl
G_7T_3	2.00 fgh	8.33 i	48.09 fghijkl
G_7T_4	1.33 h	5.00 k	47.57 ghijkl
G_8T_1	5.00 a	23.67 a	32.93 m
G_8T_2	3.33 cd	18.33 bcd	32.00 m
G_8T_3	3.33 cd	13.33 e	30.86 m
G_8T_4	2.33 efg	9.67 ghi	30.08 m
CV%	17.23	10.79	10.31
LSD O.05	0.83	2.039	8.96

[X]fifteen genotypes coded from G_1 to G_8 and four salinity treatments viz. T_1, Control; T_2, 4dS/m; T_3 8dS/m; T_4, 12 dS/m.

[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

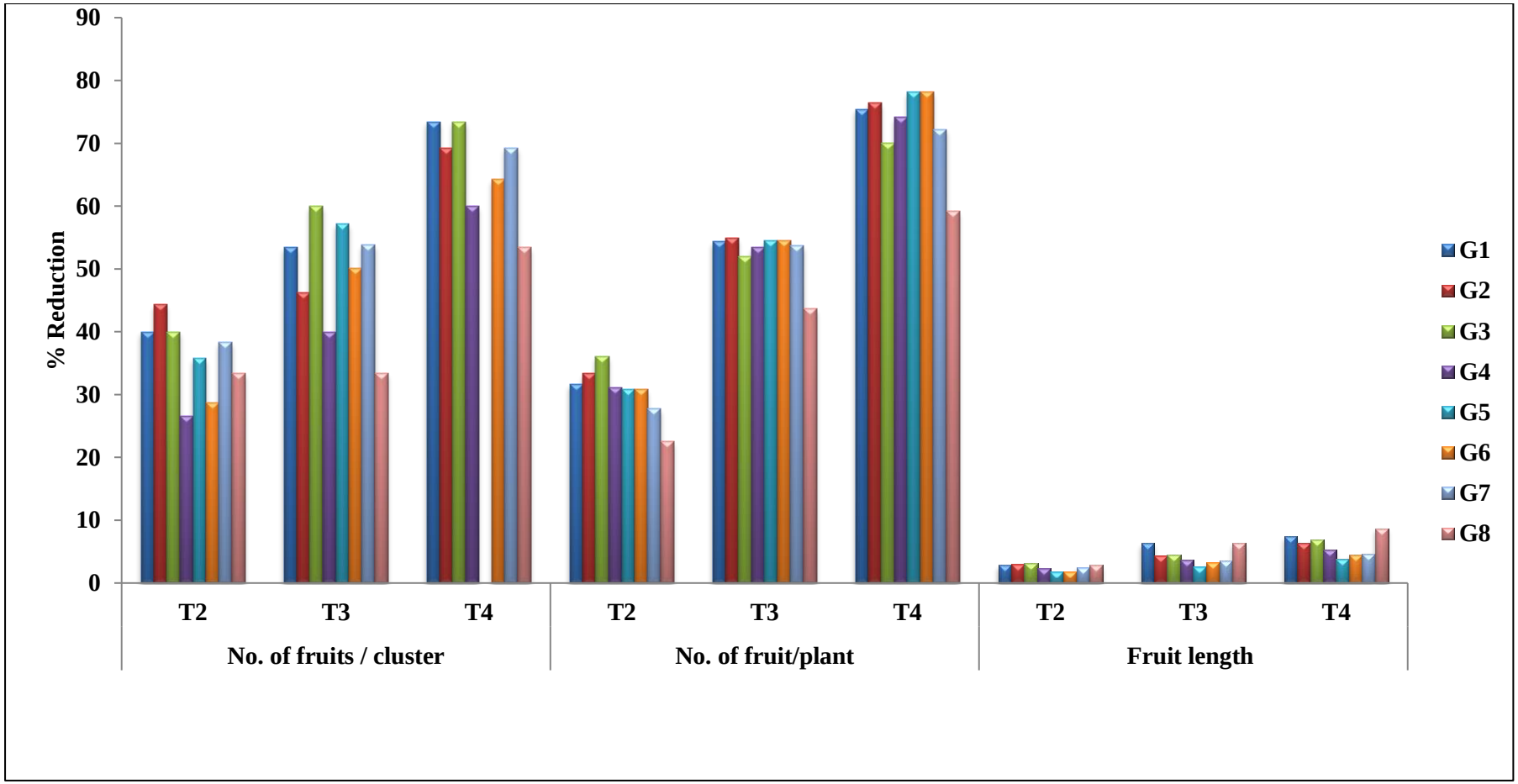

Figure 4. Reduction percentage in no. of fruits/cluster, no. of fruits/plant and fruit length under increasing salinity treatment.

Fruit diameter showed statistically significant variation in term of interaction among genotypes and salinity levels (Appendix IV). The highest fruit diameter (79.87 mm) was found in G_4T_1 which was statistically similar with G_4T_2 (78.00 mm) whereas the lowest fruit diameter (20.83 mm) was found in G_4T_4 which was statistically similar with G_4T_3 and G_4T_4 (Table 16).

Fruit diameter showed reduction with the increase of salinity level (Appendix IV and Figure 5). The maximum reduction (13.50%) was found in G_8 under T_4 treatment whereas the minimum reduction (2.34%) was found in G_4 under T_2 treatment.

4.1.1.14 Average fruit weight (gm)

Eight genotypes of tomato showed statistically significant variation in terms of averge fruit weight (Appendix IV). The maximum average fruit weight (44.33 g) was found in G_4 whereas the minimum average fruit weight (4.39 g) was found in G_8 (Table 14).

Average fruit weight showed significant variation among salinity treatments (Appendix IV). The highest average (38.12 g) was found in T_1 Treatment while the lowest average fruit weight (20.79 g) was found in T_4 treatment (Table 15). This table showed that average fruit weight was reduced with the increase of salinity treatment. Begum (2017) found similar result under increasing salinity condition.

Average fruit weight showed significant variation among the interaction of tomato genotypes and salinity treatments (Appendix IV). The highest average fruit weight (58.00 g) was found in G_1T_1 which is statistically similar with G_4T_1 (56.33 g) (Table 16) and the lowest average fruit weight (2.88 g) was found in G_8T_4 which is similar with G_8T_1 (6.67 g), G_8T_2 (4.33 gm) and G_8T_3 (3.67 g) (Table 16).

Significant reduction was found in tomato genotypes under salinity condition (Appendix IV and Figure 5). Highest reduction percentage (60.34%) was found in G_1 under T_4 and lowest reduction (13.89%) was found in G_6 under T_2 treatment.

4.1.1.15 Yield per plant (Kg/Plant)

Eight tomato genotypes showed statistically significant variation in term of yield per plant (Appendix IV). The highest yield (0.56 Kg/Plant) was found in G_4 which was

Table 14 . Performance of tomato genotypes on fruit diameter, average fruit weight and yield per plant[Y]

Genotype [X]	Fruit diameter (mm)	Average fruit weight (g)	Yield per plant (Kg/plant)
G_1	72.05 b	38.32 b	0.51 a
G_2	40.43 g	27.33 cd	0.31 bc
G_3	65.57 c	29.64 c	0.33 bc
G_4	77.49 a	44.33 a	0.56 a
G_5	46.31 e	26.79 cd	0.32 bc
G_6	58.15 d	30.00 c	0.36 b
G_7	46.43 e	24.42 d	0.29 c
G_8	22.23 g	4.39 e	0.08 d
CV%	8.31	15.33	14.02
LSD 0.05	3.64	3.52	0.06

[X]Eight tomato genotypes coded from G_1 to G_8
[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Table 15. Performance of salinity treatments on fruit diameter, average fruit weight and yield per plant[Y]

Salinity treatments[X]	Fruit diameter (mm)	Average fruit weight (g)	Yield per plant (Kg/plant)
T_1	55.58 a	38.12 a	0.70 a
T_2	54.01 ab	28.83 b	0.36 b
T_3	52.86 b	24.87 c	0.21 c
T_4	51.88 b	20.79 d	0.10 d
CV%	8.31	15.33	14.02
LSD0.05	2.57	2.49	0.04

[X]Four salinity treatments viz. T_1, Control; T_2, 4 dS/m; T_3, 8dS/m; T_4 12dS/m.
[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Table 16. Interaction effect of tomato genotypes and salinity treatments on fruit diameter, average fruit weight and yield per plant[Y]

Interaction[X]	Fruit diameter (mm)	Average fruit weight (g)	Yield per plant (Kg/plant)
G_1T_1	74.02 abcd	58.00 a	1.10 a
G_1T_2	72.33 bce	40.67 bcd	0.53 d
G_1T_3	71.33 bcdef	31.60 efgh	0.28 efghi
G_1T_4	70.53 cdefg	23.00 ijk	0.11 klmn
G_2T_1	41.90 klmn	38.67 cd	0.66 bc
G_2T_2	41.00 lmn	28.33 fghi	0.32 efg
G_2T_3	40.00 mn	23.00 ijk	0.17 hijkl
G_2T_4	38.83 n	19.33 k	0.07 lmn
G_3T_1	67.87 defg	43.27 bc	0.73 b
G_3T_2	66.00 efgh	27.63 ghij	0.29 efgh
G_3T_3	64.67 fgh	26.33 hijk	0.21 ghijk
G_3T_4	63.75 ghi	21.33 ijk	0.11 klmn
G_4T_1	79.87 a	56.33 a	1.09 a
G_4T_2	78.00 ab	46.00 b	0.63 bcd
G_4T_3	76.67 abc	41.00 bcd	0.37 ef
G_4T_4	75.42 abc	34.00 defg	0.17 hijklm
G_5T_1	48.01 kl	35.00 def	0.64 bcd
G_5T_2	46.75 klm	28.00 fghi	0.35 ef
G_5T_3	45.83 klmn	23.33 ijk	0.19 hijkl
G_5T_4	44.67 klmn	20.83 jk	0.08 lmn
G_6T_1	60.51 hij	36.00 de	0.65 bcd
G_6T_2	59.00 hij	31.00 efgh	0.39 e
G_6T_3	57.00 ij	28.00 fghi	0.25 fghij
G_6T_4	56.08 j	25.00 hijk	0.14 jklmn
G_7T_1	48.34 k	31.00 efgh	0.56 cd
G_7T_2	46.67 klm	24.67 hijk	0.32 efg
G_7T_3	45.74 klmn	22.00 ijk	0.18 hijkl
G_7T_4	44.96 klmn	20.00 k	0.10 klmn
G_8T_1	24.08 o	6.67 l	0.16 ijklm
G_8T_2	22.33 o	4.33 l	0.08 lmn
G_8T_3	21.67 o	3.67 l	0.05 mn
G_8T_4	20.83 o	2.88 l	0.03 n
CV%	8.31	15.33	14.02
LSD O.05	7.27	7.04	0.12

[X]fifteen genotypes coded from G_1 to G_8 and four salinity treatments viz. T_1, Control; T_2, 4dS/m; T_3 8dS/m; T_4, 12 dS/m.

[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

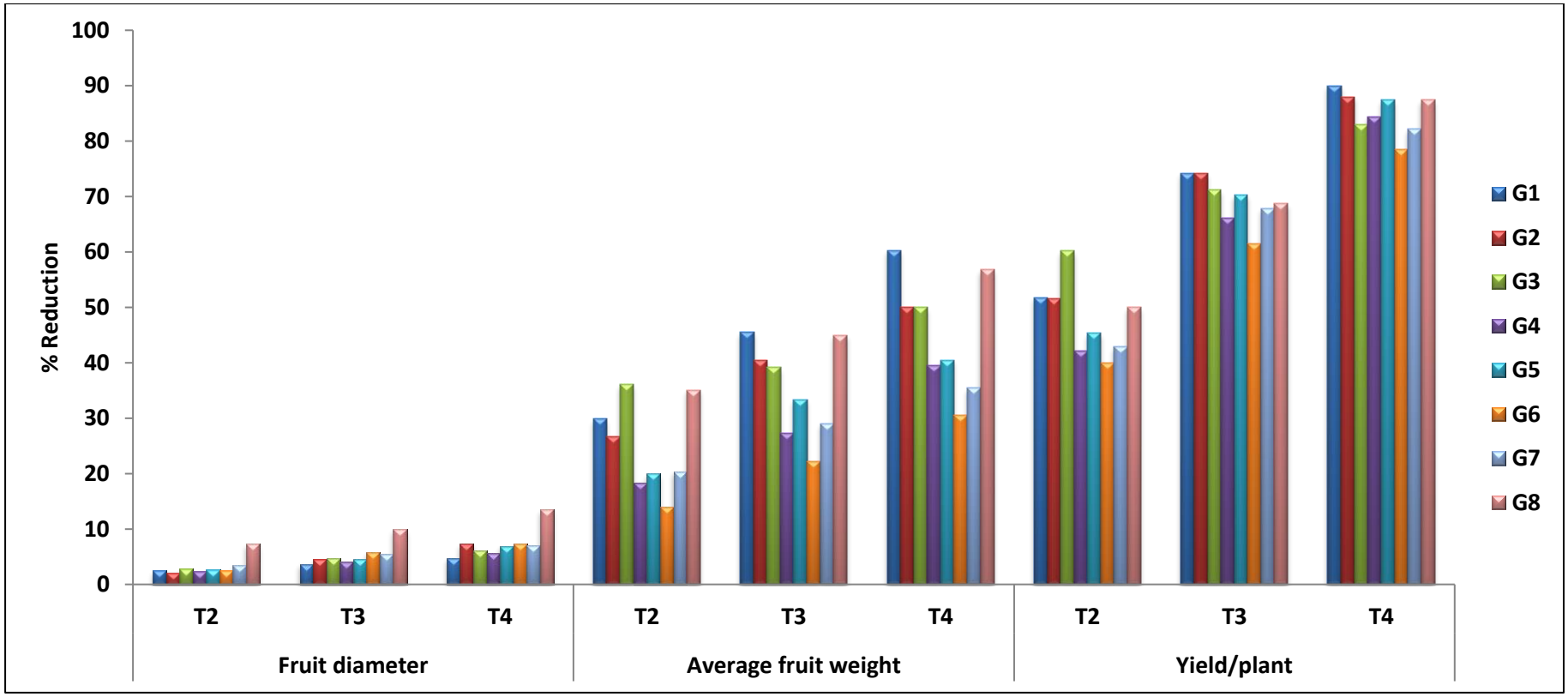

Figure 5: Reduction percentage in Fruit diameter, average fruit weight and yield per plant under increasing salinity treatment.

statistcally similar with G_1 (0.51 Kg/plant) whereas the lowest yield was (0.08 Kg/plant) in G_8 (Table 16).

Yield per plant showed statistically significant variation among different salinity treatments (Appendix IV). The highest yield (0.70 Kg/plant) was found in T_1 treatment whereas the lowest yield (0.10 Kg/plant) was found in T_4 treatment (Table 15). It was found that yield per plant was reduced with the increase of salinity. Yield reduced with the increase of salinity due to the reduction of number of leaves per plant, number of cluster per plant, number of fruits per cluster, average fruit weight and dropping of flowers and fruits with the increase of salinity. Begum (2016) found same result under salinity condition.

Yield per plant showed statistically significant variation among the interaction of tomato genotypes and salinity condition ((Appendix IV). The lowest yield per plant (0.03 kg/plant) was found in G_8T_4 whereas the highest yield per plant (1.10 Kg/plant) was found in G_1T_1 which was statistically similar with G_4T_1 (1.09 Kg/plant) (Table 16).

Significant reduction was observed among the yield of genotypes under increasing salinity treatment (Appendix V and Figure 5). The highest reduction was (90%) was found in G_1 under T_4 treatment whereas the lowest reduction (40%) was found in G_6 under T_2 treatment.

4.1.1.18 Root length (cm)

Eight genotypes of tomato showed statistically significant variation in terms of root length Appendix IV). The highest root length (14.79 cm) was found in G_1 whereas the lowest root length (11.34 cm) was found in G_8 (Table 17).

Root length showed statistically insignificant variation among the salinity treatments (Appendix IV). The highest root length (12.80 cm) was found in T_2 treatments which was statistically similar with T_3 treatments whereas the lowest root length (12.26 cm) was found in T_4 treatment (Table 18). Similar result was also found by Begum (2016) under salinity condition. Water unavailability reduced the root length growth.

Root length showed significant variation among the interaction between tomato genotypes and salinity treatments (Appendix IV). The maximum root length (17 cm)

Plate 7. Morphological variation among root of eight genotypes of tomato under four salinity treatments.

was found in G_1T_4 whereas the minimum root length (8.33 cm) was found in G_7T_4 (Table 19).

Root length showed significant reduction under different salinity levels (Appendix V and Figure 6). The maximum reduction percentage (29.58%) in G_7 under T_4 treatment whereas the minimum reduction percentage (-34.44%) was found in G_8 under T_4 treatment.

4.1.1.17 Shoot root ratio

Eight tomato genotypes showed statistically significant variation in case of shoot root ratio (Appendix IV). The highest shoot root ratio (5.83) was found in G_8 genotypes whereas the lowest shoot root ratio (4.40) was found in G_6 genotype (Table 17).

Shoot root ratio showed insignificant variation among the salinity treatments (Appendix IV). The lowest shoot root ratio (4.40) was found in T_4 whereas the highest shoot root ratio (5.45) was found in T_1 treatment.

Shoot root ratio length showed statistically significant variation among interaction between genotypes and salinity treatments (Appendix IV). The highest shoot root ratio (7.51) was found in G_8T_1 whereas the lowest (3.15) was found in G_1T_4 (Table 19).

Significant reduction was found in term of shoot root ratio under salinity treatments (Appendix V and Figure 6). The lowest reduction (-3.85%) was found in G_4 under T_2 whereas the highest (39.56%) was found in G_2 under T_2 treatments.

4.1.1.18 Skin diameter of fruit (mm)

Eight genotypes showed statistically significant variation in term of skin diameter of fruit (Appendix IV). The highest skin diameter (8.08 mm) was found in G_5 which was statistically similar with G_2 (8.04 mm) whereas the lowest skin diameter (2.86 mm) was found in G_8 which was statistically similar with G_1 (2.91 mm) and G_4 (2.87 mm) (Table 17).

Skin diameter of fruits showed statistically significant variation among salinity treatments (Appendix IV). The lowest skin diameter (4.60 mm) was found in T_4

Table 17. Performance of tomato genotypes root length, shoot root ratio and skin diameter of fruit[Y]

Genotype [X]	Root length (cm)	Shoot root ratio	Skin diameter of fruit (mm)
G_1	14.79 a	4.56 bc	2.91 e
G_2	13.14 b	4.69 bc	8.04 a
G_3	11.81 de	4.88 b	4.33 c
G_4	12.43 c	4.57 bc	2.87 e
G_5	13.07 b	4.48 bc	8.08 a
G_6	12.21 cd	4.40 c	3.63 d
G_7	12.04 cd	4.67 bc	5.67 b
G_8	11.34 e	5.83 a	2.86 e
CV%	5.99	11.73	7.30
LSD 0.05	0.62	0.45	0.28

[X]Eight tomato genotypes coded from G_1 to G_8
[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Table 18: Performance of salinity treatments on root length, shoot root ratio and skin diameter of fruit[Y]

Salinity treatments[X]	Root length (cm)	Shoot root ratio	Skin diameter of fruit (mm)
T_1	12.58	5.45	5.07 a
T_2	12.80	4.67	4.82 b
T_3	12.78	4.40	4.71 bc
T_4	12.26	4.52	4.60 c
CV%	5.99	11.73	7.30
LSD0.05	0.44	0.32	0.20

[X]Four salinity treatments viz. T_1, Control; T_2 4 dS/m; T_3, 8dS/m; T_4 , 12dS/m
[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Table 19. Interaction effect of tomato genotypes and salinity treatments on root length, shoot root ratio and skin diameter of fruit[Y]

Interaction[X]	Root length (cm)		Shoot root ratio		Skin diameter of fruit (mm)	
G_1T_1	15.00	b	5.16	cde	3.03	gh
G_1T_2	14.33	bcd	5.00	def	2.93	h
G_1T_3	12.83	fghij	4.92	defg	2.86	h
G_1T_4	17.00	a	3.15	k	2.80	h
G_2T_1	12.53	ghijk	6.37	b	8.50	a
G_2T_2	14.87	bc	3.85	ijk	8.10	ab
G_2T_3	12.83	fghij	3.95	hijk	7.89	b
G_2T_4	12.33	hijk	4.58	efghi	7.68	b
G_3T_1	11.50	klm	5.49	bcd	4.77	d
G_3T_2	11.70	jklm	5.02	de	4.40	de
G_3T_3	13.00	efghi	4.28	efghij	4.20	de
G_3T_4	11.03	lm	4.72	defghi	3.95	ef
G_4T_1	13.50	defgh	4.67	defghi	3.03	gh
G_4T_2	12.10	ijklm	4.85	defgh	2.89	h
G_4T_3	11.90	ijklm	4.31	efghij	2.82	h
G_4T_4	12.23	ijkl	4.44	efghi	2.75	h
G_5T_1	14.17	bcde	4.77	defgh	8.67	a
G_5T_2	11.80	ijklm	4.79	defgh	8.10	ab
G_5T_3	13.67	cdefg	4.29	efghij	7.88	b
G_5T_4	12.67	fghijk	4.08	ghij	7.68	b
G_6T_1	12.50	ghijk	4.65	defghi	3.87	ef
G_6T_2	12.83	fghij	4.34	efghij	3.60	fg
G_6T_3	12.00	ijklm	4.50	efghi	3.54	fg
G_6T_4	11.50	klm	4.09	fghij	3.52	fg
G_7T_1	11.83	ijklm	4.91	defg	5.77	c
G_7T_2	13.83	bcdef	3.49	ik	5.67	c
G_7T_3	14.17	bcde	3.98	hijk	5.62	c
G_7T_4	8.33	o	6.31	b	5.61	c
G_8T_1	9.63	n	7.51	a	2.93	h
G_8T_2	10.90	m	5.97	bc	2.88	h
G_8T_3	11.83	ijklm	4.99	defg	2.85	h
G_8T_4	13.00	efghi	4.84	defgh	2.80	h
CV%	5.99		11.73		7.30	
LSD O.05	1.23		0.91		0.57	

[X]fifteen genotypes coded from G_1 to G_8 and four salinity treatments viz. T_1, Control; T_2, 4dS/m; T_3 8dS/m; T_4, 12 dS/m.

[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

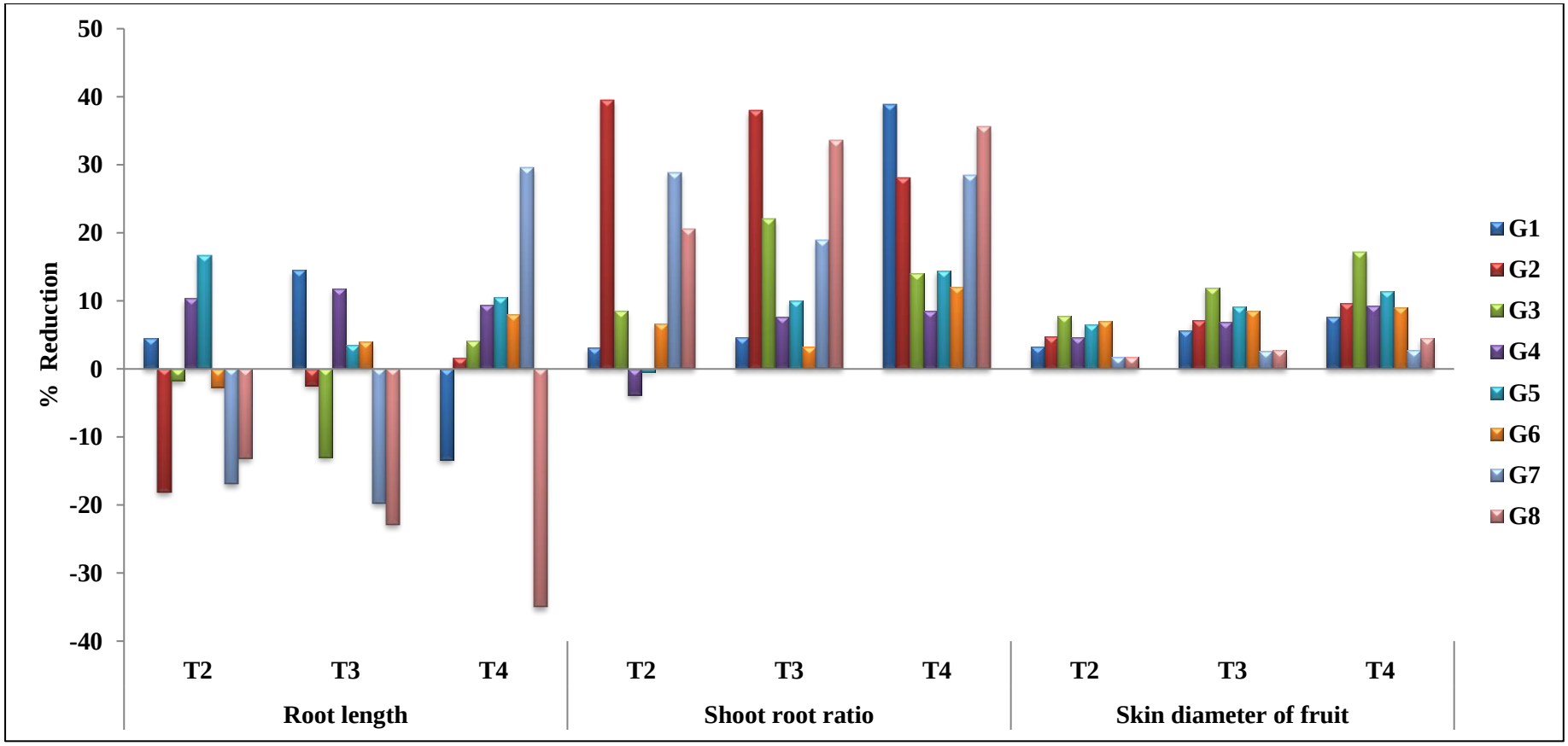

Figure 6: Reduction percentage in root length, shoot root ratio and skin diameter of fruit under increasing salinity treatments.

Whereas the highest skin diameter (5.07 mm) was found in T_1 treatment (Table 18). It was found that skin diameter decreased with increase of salinity levels. Due to the unavailability of water, skin of fruits became shrinked.

Skin diameter of fruit showed significant variation among the interaction of genotypes and salinity treatments (Appendix IV). The highest skin diameter (8.67 mm) was found in G_5T_1 which was statistically significant with G_2T_1 (8.50 mm) whereas the lowest skin diameter was (2.75 mm) was found in G_4T_4 combination (Table 19). Significant reduction was found among the genotypes under salinity treatments inn case of skin diameter of fruit (Appendix V and figure 6). The highest reduction was ((17.19%) was found in G_3 under T_4 treatments whereas the lowest reduction (1.71%) was found in G_8 under T_2 salinity treatments.

4.1.2 Physiological traits

Genotype stress interaction was determined based on some physiological traits like ethylene concentration, % Membrane Stability Index, Chlorophyll content, relative water content, % Moisture content, % Dry matter content, Na++ content and K+ content. ANOVA is presented in Appendix IV and data are presented in figures and graph. Reduction percentage is presented in Appendix V.

4.1.2.1 Ethylene concentration (ppm)

Eight genotypes showed statistically significant in term of ethylene concentration in leaf (Appendix IV). The highest ethylene concentration (0.18 ppm) was found in G_5 which was statistically similar with G_2 and G_6 (Table 20) whereas the lowest ethylene concentration (0.16 ppm) was found in G_4 genotypes.

Ethylene concentration showed statistically significant variation among salinity treatments (Appendix IV). The highest ethylene concentration (0.21 ppm) was found in T_4 whereas the lowest ethylene concentration (015 ppm) was found in T_1 treatments (Table 21). It was observed that ethylene concentration increased with the increase of salinity treatments. Salinity stress created shortage of water and due to the unavailability of water, plant produces more ethylene than control.

Ethylene concentration showed statistically significant variation among the interaction of genotypes and salinity (Appendix IV). The highest ethylene concentration (0.22

ppm) was found in G_2T_4 which was statistically similar with G_5T_4 (0.21 ppm) whereas the lowest ethylene concentration (0.13 ppm) was found in G_8T_1 (Table 22).

Significant increase was observed in genotypes under salinity treatments in case of ethylene concentration (Appendix V and Figure 7). The lowest reduction percentage (-6.67%) was found in G_4 under T_2 treatment whereas the highest reduction percentage (-0.53.85%) was found in G_8 under T_4 treatments.

4.1.2.2 % Membrane Stability Index

Genotypes of tomato showed insignificant variation in term of %Membrane Stability Index (Appendix IV). The highest MSI (51.00%) was found in G_1 whereas the lowest MSI (47.52%) was found in G_5 genotypes (Table 20).

%MSI showed statistically significant variation among salinity treatments (Appendix IV). The highest %MSI (63.71%) was found in T_1 whereas T_4 showed lowest MSI (35.12%) (Table 21). With the increase of salinity treatments, %MSI decreased. Same result was also found by Reza *et al.* (2016).

% MSI showed insignificant variation among the interaction of salinity treatment and genotypes (Appendix IV). The highest %MSI (65.67%)) was found in G_1T_1 whereas lowest MSI (32.33%) was found in G_5T_4 combination (Table 22).

Significant reduction was found among the genotypes under salinity treatments in case of % MSI (Appendix V and Figure 7). The highest reduction (49.49 %) was found in G_5 under T_4 salinity treatments whereas the lowest reduction (14.21%) was shown in G_6 genotype under T_2 tretment.

4.1.2.3 Chlorophyll content

Eight genotypes showed statistically significant variation in term of chlorophyll content (Appendix IV). The maximum chlorophyll content (52.58) was found in G_1 whereas the minimum chlorophyll content (36.5) was found in G_8 genotypes which were statistically similar with G_7 (36.75) (Table 20).

Table 20. Performance of tomato genotypes ethylene concentration, Membrane Stability Index and chlorophyll content [Y]

Genotype [X]	Ethylene concentration (ppm)	% Membrane Stability Index	Chlorophyll content (%)
G_1	0.17 bc	51.00	52.58 a
G_2	0.18 ab	48.25	50.58 b
G_3	0.18 abc	48.92	40.33 d
G_4	0.16 c	48.75	44.67 c
G_5	0.18 a	47.42	49.33 b
G_6	0.18 ab	49.08	50.33 b
G_7	0.17 abc	48.75	36.75 e
G_8	0.17 bc	49.50	36.5 e
CV%	7.52	5.60	4.79
LSD 0.05	0.02	2.24	1.76

[X]Eight tomato genotypes coded from G_1 to G_8
[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Table 21. Performance of salinity treatments on ethylene concentration, MembraneStability Index and chlorophyll content [Y]

Salinity treatments[X]	Ethylene concentration (ppm)	% Membrane Stability Index	Chlorophyll content (%)
T_1	0.15 d	63.71 a	48.21 a
T_2	0.17 c	53.08 b	45.79 b
T_3	0.18 b	43.92 c	44.00 c
T_4	0.21 a	35.12 d	42.54 d
CV%	7.52	5.60	4.79
LSD0.05	7.62	1.58	1.25

[X]Four salinity treatments viz. T_1, Control; T_2 4 dS/m; T_3, 8dS/m; T_4 12dS/m.
[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Table 22. Interaction effect of tomato genotypes and salinity treatments ethylene concentration, Membrane Stability Index and chlorophyll content [Y]

Interaction[X]	Ethylene concentration (ppm)	% Membrane Stability Index	Chlorophyll content (%)
G_1T_1	0.14 mno	65.67	56.00 a
G_1T_2	0.16 ijklm	53.33	53.33 abcd
G_1T_3	0.18 defghi	44.33	51.67 bcdef
G_1T_4	0.20 abcde	40.67	49.33 efgh
G_2T_1	0.15 klmno	62.33	54.00 abc
G_2T_2	0.17 ghijk	52.67	51.67 bcdef
G_2T_3	0.19 cdefgh	43.33	49.00 efghi
G_2T_4	0.22 a	34.67	47.67 ghijk
G_3T_1	0.14 mno	61.33	43.00 mno
G_3T_2	0.17 ghijk	51.67	41.33 nop
G_3T_3	0.18 defghi	45.00	39.33 pqr
G_3T_4	0.21 abc	37.67	37.67 qrs
G_4T_1	0.15 klmno	64.00	45.67 ijklm
G_4T_2	0.16 jklmn	53.33	45.00 jklm
G_4T_3	0.17 ghijk	43.68	44.33 klmn
G_4T_4	0.19 cdefgh	34.00	43.67 lmno
G_5T_1	0.15 klmno	64.00	52.33 bcde
G_5T_2	0.18 efghij	51.33	50.00 defgh
G_5T_3	0.19 bcdefg	42.00	48.33 fghij
G_5T_4	0.21 ab	32.33	46.67 hijkl
G_6T_1	0.15 lmno	63.33	54.67 ab
G_6T_2	0.18 fghij	54.33	50.67 cdefg
G_6T_3	0.20 bcdef	45.68	49.00 efghi
G_6T_4	0.21 abc	33.00	47.00 hijkl
G_7T_1	0.14 no	65.00	39.33 pqr
G_7T_2	0.16 ijklm	53.00	37.33 qrs
G_7T_3	0.19 cdefgh	43.00	35.67 st
G_7T_4	0.21 abc	34.00	34.67 st
G_8T_1	0.13 o	64.00	40.67 opq
G_8T_2	0.17 hijkl	55.00	37.00 rst
G_8T_3	0.19 cdefgh	44.33	34.67 st
G_8T_4	0.20 abcd	34.67	33.67 t
CV%	7.52	5.60	4.79
LSD O.05	0.02	4.47	3.54

[X]fifteen genotypes coded from G_1 to G_8 and four salinity treatments viz. T_1, Control; T_2, 4dS/m; T_3 8dS/m; T_4, 12 dS/m.

[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

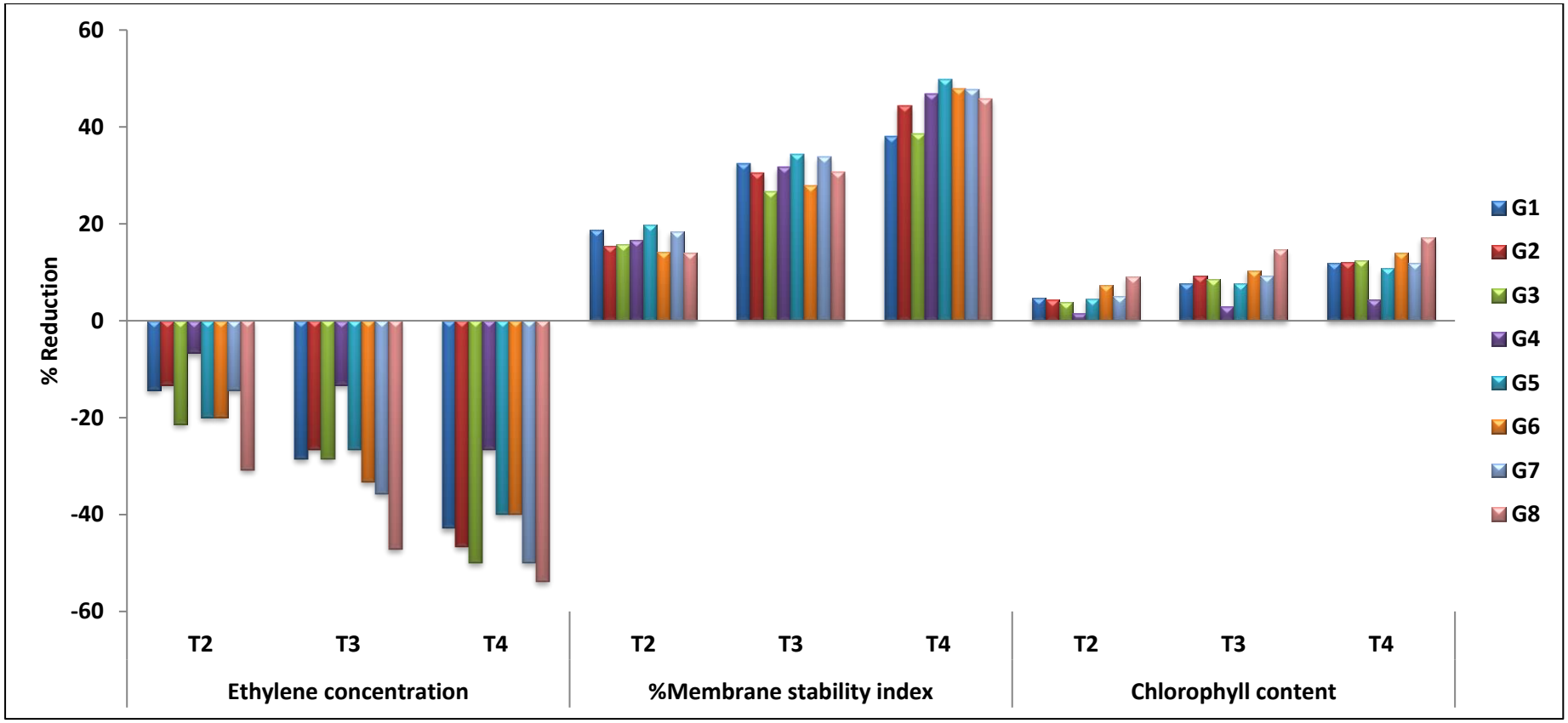

Figure 7. Reduction percentage in ethylene concentration, % membrane stability index and chlorophyll content under increasing Salinity treatments.

Chlorophyll content showed statistically significant among the treatments (Appendix IV). The highest chlorophyll content (48.21 %) was found in T_1 treatment whereas the lowest chlorophyll content (42.54 %) was found in T_4 salinity treatments (Table 21).The table showed that chlorophyll content decreased with the increase of salinity treatments. Gradual decrease occurred with the increase of salinity treatments (Hajer *et al*, 2006). Begum (2016) also found the same result under increase of salinity. Reduction of chlorophyll content is due to the fraction of pigment under salinity treatments.

Chlorophyll content showed statistical significant variation among the interactions of salinity and genotypes (Appendix IV). The highest Chlorophyll content (56.00) was found in G_1T_1 which was statistically similar with G_6T_1 (54.67 %) whereas the lowest chlorophyll content (33.67 %) was found in G_8T_4 combination (Table 22)

Significant reduction was found among genotypes under different salinity treatments in case of chlorophyll content (Appendix V and figure 7). The lowest reduction (1.46%) in case of chlorophyll content in G_4 under T_2 treatment whereas the highest reduction (17.21 %) was found in G_8 genotypes under T_4 treatment (Figure 7).

4.1.2.4 Relative Water Content

Genotypes of tomato showed statistical significant variation in term of relative water content (Appendix IV). The highest relative water content (60.42 %) was found in G_2 which was statistically similar with G_7 (60%) (Table 23).

Relative water content showed statistically significant variation among salinity treatments (Appendix IV). The highest relative water content (54.54 %) was found in T_1 whereas the lowest (48.92 %) was found in T_4 treatment (Table 24). It was showed that relative water content decreased with the increase of salinity level. Due to physiological drought caused by salinity treatment water uptake is reduced and result in reduction in relative water content.

Relative water content showed significant variation among the interaction of salinity and genotypes (Appendix IV). The highest relative water content (65%) was found in G_7T_1 which was statistically similar with G_2T_1 ((64 %) whereas the lowest relative water content (33.33%) was found in G_1T_4 (Table 25).

Significant reduction was found among the genotypes under different level of salinity in case of relative water content (Appendix V and Figure 8). The maximum reduction (16.67 %) was found in G_1 under T_4 treatment whereas the minimum reduction (3.80%) was found in G_6 under T_2 treatment.

4.1.2.5 Moisture in fruit (%)

Eight genotypes of tomato showed statistically significant variation in case of moisture in fruit (Appendix IV). The highest moisture content in fruit (92.12 %) was found in G_8 genotypes which was statistically similar with G_6 (91.71 %) whereas the lowest moisture content in fruit (90.65 %) was found in G_2 which was statistically similar with G_3 (90.65 %) (Table 23).

Moisture in fruit showed statistically significant variation among salinity treatments (Appendix IV). The highest moisture in fruit (93.45 %) was found in T_1 whereas the lowest (89.68 %) was found in T_4 treatment (Table 24). With the increase of salinity level, moisture in fruit decreased due to physiological water deficit.

Moisture in fruit showed statistically significant variation among the interaction of salinity and genotypes (Appendix IV). The highest moisture content in fruit (94.12 %) was found in G_6T_1 which was statistically similar with G_4T_1 (93.71 %), G_5T_1 (93.67 %), G_8T_1 (93.85 %) whereas the lowest moisture content in fruit (88.98 %) was found in G_3T_4 which was statistically similar with G_2T_4 (89.33 %) (Table 25).

Significant reduction was observed among the genotypes under different level of salinity (Appendix V and Figure 8). The highest reduction (4.51 %) was found in G_4 under T_4 salinity treatments whereas the lowest reduction (1.15 %) was found in G_1 under T_2 treatments.

4.1.2.6 Dry matter content in fruit (%)

Eight genotypes of tomato showed statistically significant variation in case of dry matter content in fruit (Appendix IV). The highest dry matter (9.53 %) was found in G_2 which was statistically similar with G_3 (9.34 %) whereas the lowest dry matter content (7.88 %) was found in G_8 which was statistically similar with G_6 (8.13 %).

Table 23. Performance of tomato genotypes on Relative water content of plant, %Moisture content and % dry matter content in fruit[Y]

Genotype [X]	Relative water content	% Moisture in fruit	% dry matter in fruit
G_1	36.58 f	91.59 bc	8.41 bc
G_2	60.42 a	90.47 d	9.53 a
G_3	50.58 c	90.65 d	9.34 a
G_4	60.58 a	91.52 c	8.48 b
G_5	43.67 d	91.63 bc	8.37 bc
G_6	41.75 e	91.87 ab	8.13 cd
G_7	60.00 a	91.71 bc	8.29 bc
G_8	57.75 b	92.12 a	7.88 d
CV%	3.76	0.44	4.69
LSD 0.05	1.58	0.38	0.33

XEight tomato genotypes coded from G1 to G8.
YIn a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Table 24: Performance of salinity treatments on Relative water content of plant, %Moisture content and % dry matter content in fruit[Y]

Salinity treatments[X]	Relative water content	% Moisture in fruit	% dry matter in fruit
T_1	54.54 a	93.45 a	6.55 d
T_2	51.87 b	91.97 b	8.03 c
T_3	50.33 c	90.68 c	9.32 b
T_4	48.92 d	89.68 d	10.32 a
CV%	3.76	0.44	4.69
LSD0.05	1.12	0.23	0.23

[X]Four salinity treatments viz. T_1, Control; T_2 4 dS/m; T_3, 8dS/m; T_4 12dS/m.
[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Table 25. Interaction effect of tomato genotypes and salinity treatments on Relative water content of plant, %Moisture content and % dry matter content in fruit[Y]

Interaction[X]	Relative water content	% Moisture in fruit	% dry matter in fruit
G_1T_1	40.00 opq	93.40 bc	6.60 mn
G_1T_2	38.00 qr	92.33 de	7.67 kl
G_1T_3	35.00 rs	90.83 ghi	9.18 ghi
G_1T_4	33.33 s	89.80 klmn	10.2 bcde
G_2T_1	64.00 ab	92.28 de	7.72 kl
G_2T_2	61.33 bcd	90.28 ijk	9.72 efg
G_2T_3	59.00 defg	89.99 jklm	10.01 cdef
G_2T_4	57.33 fgh	89.33 no	10.67 ab
G_3T_1	53.00 ij	92.87 cd	7.13 lm
G_3T_2	50.00 jk	91.43 fg	8.57 ij
G_3T_3	50.33 jk	89.34 mno	10.66 abc
G_3T_4	49.00 kl	88.98 o	11.01 a
G_4T_1	62.67 abc	93.71 ab	6.29 no
G_4T_2	61.00 bcde	92.33 de	7.67 kl
G_4T_3	59.67 cdefg	90.57 hij	9.43 fgh
G_4T_4	59.00 defg	89.48 lmno	10.52 abcd
G_5T_1	46.33 lm	93.67 ab	6.33 no
G_5T_2	44.33 mn	92.24 de	7.76 kl
G_5T_3	42.67 no	90.82 ghi	9.18 ghi
G_5T_4	41.33 nop	89.78 klmn	10.22 bcde
G_6T_1	44.00 mn	94.12 a	5.88 o
G_6T_2	42.33 nop	92.39 de	7.61 kl
G_6T_3	41.33 nop	90.96 gh	9.04 hi
G_6T_4	39.33 pq	90.00 jkl	10.00 def
G_7T_1	65.00 a	93.73 ab	6.27 no
G_7T_2	60.00 cdef	92.15 e	7.85 k
G_7T_3	58.00 efgh	90.96 gh	9.04 hi
G_7T_4	57.00 fgh	90.00 jkl	10.00 def
G_8T_1	61.33 bcd	93.85 ab	6.15 no
G_8T_2	58.00 efgh	92.59 de	7.40 kl
G_8T_3	56.67 gh	91.97 ef	8.03 jk
G_8T_4	55.00 hi	90.08 jkl	9.92 def
CV%	3.76	0.44	4.69
LSD O.05	3.16	0.65	0.65

[X]fifteen genotypes coded from G_1 to G_8 and four salinity treatments viz. T_1, Control; T_2, 4dS/m; T_3, 8dS/m; T_4, 12 dS/m.

[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

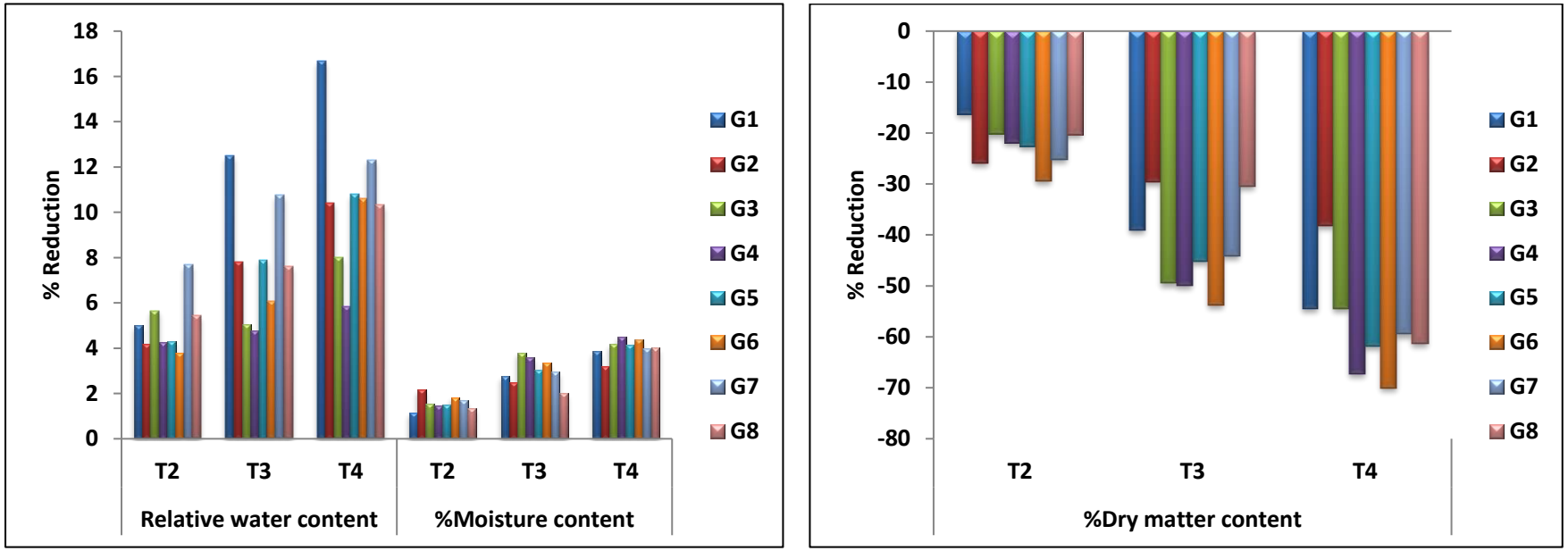

Figure 8. Reduction percentage in Relative moisture content, % moisture content and % dry matter under increasing Salinity treatments

% Dry matter content showed significant variation among salinity treatments (Appendix IV). The highest dry matter content (10.32%) was found in T_4 treatment where the lowest dry matter content (6.55 %) was found in T_1 treatment (Table 24). From the table it was clear that dry matter content was increased with the increase in salinity content.

Dry matter content showed statistically significant variation among the interaction of genotypes and salinity treatments (Appendix IV). The highest dry matter content (11.01 %) was found in G_3T_4 combination which was statistically similar with G_2T_4 (10.67 %) whereas lowest dry matter content (5.88 %) was found in G_6T_1 which was statistically similar with G_7T_1 (6.27 %) , G_5T_1 (6.33 %) (Table 25).

Significant increase in dry matter content was found in all genotypes (Appendix V and Figure 8). The lowest increase (-16.21 %) was found in G_1 under T_2 treatment whereas the highest increase (-70.07 %) was found in G_6 under T_4 treatment.

4.1.2.7 Na^+ content (%)

Eight genotypes of tomato showed statistically significant variation in term of Na+ ion content (Appendix IV). The highest Na+ content (1.26%) was found in G_4 whereas the lowest Na+ content (1.15 %) was found in G_5 genotypes (Table 26).

Na+ ion content showed statistically significant variation among salinity treatments (Appendix IV). The highest Na+ content (1.33 %) was found in T_4 treatment while the lowest Na+ content (1.08 %) was found in T_1 salinity treatment (Table 27). With the increase of salinity, Na+ ion content increased. Shawon (2016) found same result under salinity treatment. When excessive amounts of salt enter the plant, salt will eventually rise to toxic levels in the older transpiring leaves, causing premature senescence, and increase the Na+ concentration in both shoot and root zone of tomato plant (Siddiky *et al*., 2012).

Na+ content showed statistically significant variation among the salinity and genotypes interaction (Appendix IV). The highest Na+ content (1.40 %) was found in G_4T_3 which was statistically similar with G_8T_3 (1.37 %) whereas the lowest Na+ content (1.07 %) was found in G_5T_1, G_6T_1 which was statistically significant with G_1T_1 (1.08 %), G_2T_1 (1.09 %) and G_8T_1 (1.08 %) (Table 28).

Table 26. Performance of tomato genotypes on Na^+ and K^+ content in tomato plant[Y]

Genotype [X]	Na^+ content in plant	K^+ content in plant
G_1	1.24 b	1.52 de
G_2	1.24 b	1.51 e
G_3	1.22 c	1.53 bc
G_4	1.26 a	1.53 b
G_5	1.15 e	1.58 a
G_6	1.23 b	1.52 cde
G_7	1.19 d	1.52 de
G_8	1.24 b	1.53 bcd
CV%	1.56	0.74
LSD 0.05	0.02	9.22

[X]Eight tomato genotypes coded from G_1 to G_8
[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Table 27. Performance of salinity treatments on on Na^+ and K^+ content in tomato plant[Y]

Salinity treatments[X]	Na^+ content in plant	K^+ content in plant
T_1	1.08 d	1.59 a
T_2	1.19 c	1.55 b
T_3	1.28 b	1.50 c
T_4	1.33 a	1.47 d
CV%	1.56	0.74
LSD0.05	0.01	6.52

[X]Four salinity treatments viz. T_1, Control; T_2 4 dS/m; T_3, 8dS/m; T_4 12dS/m.
[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Table 28: Interaction effect of tomato genotypes and salinity treatments on on Na^+ and K^+ content in tomato plant[Y]

Interaction[X]	Na^+ content in plant	K^+ content in plant
G_1T_1	1.08 n	1.60 bc
G_1T_2	1.21 jk	1.54 gh
G_1T_3	1.35 bc	1.47 lm
G_1T_4	1.33 cde	1.46 lmn
G_2T_1	1.09 n	1.59 bc
G_2T_2	1.23 ij	1.52 l
G_2T_3	1.33 cde	1.47 kl
G_2T_4	1.30 efg	1.46 lm
G_3T_1	1.08 n	1.59 bc
G_3T_2	1.17 l	1.55 fgh
G_3T_3	1.33 cde	1.50 j
G_3T_4	1.28 gh	1.47 kl
G_4T_1	1.09 n	1.62 a
G_4T_2	1.22 ijk	1.55 efg
G_4T_3	1.40 a	1.50 j
G_4T_4	1.35 bcd	1.46 lmn
G_5T_1	1.07 n	1.60 ab
G_5T_2	1.13 m	1.59 cd
G_5T_3	1.23 ijk	1.57 de
G_5T_4	1.20 kl	1.56 ef
G_6T_1	1.07 n	1.59 bc
G_6T_2	1.24 ij	1.55 efg
G_6T_3	1.34 cd	1.49 j
G_6T_4	1.28 g	1.45 n
G_7T_1	1.07 n	1.59 bc
G_7T_2	1.13 m	1.53 hi
G_7T_3	1.32 def	1.49 jk
G_7T_4	1.25 hi	1.45 mn
G_8T_1	1.08 n	1.59 bcd
G_8T_2	1.21 jk	1.55 efg
G_8T_3	1.37 ab	1.49 j
G_8T_4	1.29 fg	1.46 lmn
CV%	1.56	0.74
LSD O.05	0.03	0.09

[X]fifteen genotypes coded from G_1 to G_8 and four salinity treatments viz. T_1, Control; T_2, 4dS/m; T_3 8dS/m; T_4, 12 dS/m.

[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

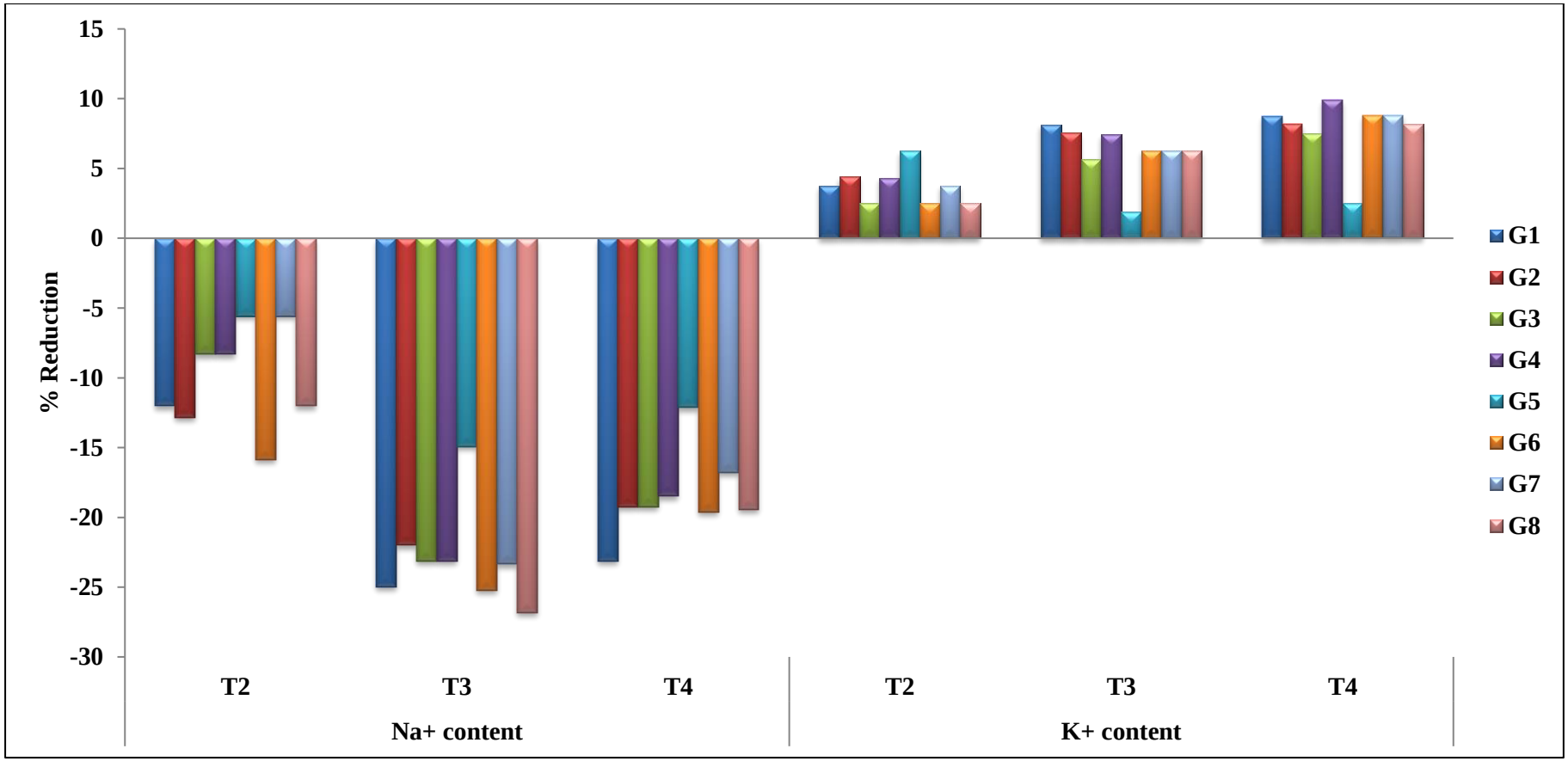

Figure 9. Reduction percentage in Na^+ and K^+ content under increasing salinity treatment

Na+ showed significant reduction among the genotypes (Appendix V and Figure 9). The maximum Na+ uptake (-28.44 %) was found in G_4 under T_4 treatment while the minimum Na+ uptake (-5.6 %) was found in G_5 and G_7 under T_2.

4.1.2.8 K+ content (%)

K+ content showed statistically significant variation among eight genotypes of tomato (Appendix IV). The highest k+ content (1.58 %) was found in G_5 genotype whereas the lowest K+ content (1.51%) was found in G_2 genotype (Table 26).

K+ content showed statistically significant variation among salinity treatment (Appendix IV). The highest K+ (1.59 %) was found in T_1 whereas the lowest K+ content (1.47 %) was found in T_4 treatment (Table 27). With the increase of salinity treatment K+ content decreased. Similar result also found by Shawon (2016) and Begum (2016). Due to increase the Na+ content around the root zone, K+ uptake decreased (Edris *et al*., 2012).

K+ content showed statistically significant variation among the interaction of tomato genotypes and salinity treatment (Appendix IV). The highest k+ content (1.62 %) was found in G_4T_1 which was statistically similar with G_5T_1 (1.60 %) whereas the lowest K+ content (1.52 %) was found in G_2T_2 combination (Table 28).

K+ content showed significant reduction among genotypes under salinity treatments (Appendix V and Figure 9). The highest reduction percentage (9.88 %) was found in G_4 under T_4 salinity treatment whereas the lowest reduction (1.87 %) was found in G_5 genotypes under T_3 salinity treatments.

4.1.3 Nutritional traits

Nutritional traits such as % Brix content, pH of fruit, % titrable acidity, Vitamin c content and Lycopene content were presented and discussed in this part. Appendix IV present the ANOVA for nutritional traits and their reduction percentage is presented in Appendix V. The data are arranged under genotypic performance, treatment performance and their interaction are presented in table and figure.

4.1.3.1 % Brix content

Eight genotypes showed statistically significant variation in term of %Brix xonten (Appendix IV). The highest %Brix content (7.28 %) was found in G_1 genotype which was statistically similar with G_4 genotype whereas the lowest % Brix (5.46 %) was found in G_8 genotypes (Table 29).

% Brix content showed statistically significant variation among the salinity treatments (Appendix IV). The maximum % Brix (6.59%) was found in T_4 treatment whereas minimum % Brix (6.59 %) was found in T_1 treatment (table 30). %Brix content was shown increase with the increase of salinity level. Increase of %Brix with the increase of salinity level was also found by Begum (2016). Salinity stress enhanced carbohydrate accumulation as starch during the early development stages and it is responsible for the increase in soluble sugars in ripe fruit (Yong-Gen *et al*., 2009).

% Brix content showed statistically significant variation among the interaction of tomato genotypes an salinity treatment (Appendix IV). The highest %Brix content (7.58 %) was found in G_1T_4 which was statistically similar with G_4T_4 (7.39 %) and whereas the lowest % Brix content (5.13 %) was found in G_8T_1 which was statistically similar with GG_8T_2 ((5.42 %) (Table 31).

Eight genotypes showed significant variation under salinity treatment in case of % Brix content (Appendix V and Figure 10). The maximum increase in % Brix (-12.28 %) was found in G_8 under T_4 treatment whereas the minimum increase (-1.47 %) was found in G_6 under T_2 treatments.

4.1.3.2 pH of fruit

Eight genotypes of tomato showed statistically significant variation in term of pH of fruit (Appendix IV). The highest pH (4.76) was found in G_7 which is statistically similar with G_8 (4.75) whereas the lowest pH of fruit (4.41) was found in G_1 which was statistically similar with G_3 (4.47) and G_4 (4.48) (Table 29).

pH of fruit showed statistically insignificant among the salinity treatments (Appendix IV)). Maximum pH of fruit (4.65) was found in T_1 and T_3 whereas minimum pH (4.5) was found in T_4 treatment (Table 30).

pH of fruit shows statistically significant variation among interaction of genotypes and salinity treatments (Appendix IV). Maximum pH of fruit (5.01) was found in G_8T_1 which was statistically similar with G_7T_1 (4.93), G_5T_3 (4.94) whereas the minimum pH of fruit (4.10) was found in G_1T_4 which was statistically similar with G_1T_1 (4.27) (Table 31).

pH of fruit showed significant changes under different salinity treatment among eight genotypes (Appendix V and Figure 10). The lowest reduction percentage (-12.41%) was found in G_1 under T_2 treatment whereas the highest reduction (6.7 %) was found in G_7 under T_2 treatment.

4.1.3.3 % Titrable acidity

Eight genotypes of tomato showed statistically significant variation in term of % Titrable acidity (Appendix IV). The highest % titrable acidity (0.61 %) was found in G_8 which was statistically similar with G_7 (0.60 %) whereas the lowest % titrable acidity (0.32 %) was found in G_2 (Table 29).

% Titrable acidity showed statistically significant variation among salinity treatments among eight genotypes (Appendix IV). The highest % titrable acidity (0.59 %) was found in T_4 treatment whereas the lowest (0.34 %) was found in T_1salinity treatment (Table 30). With the increase of salinity level, %% titrable acidity increased.

% titrable acidity showed statistically significant variation among the interaction of tomato genotypes and salinity treatments (Appendix IV). The highest % titrable acidity (0.73 %) was found in G_7T_4, G_5T_4 whereas the lowest % titrable acidity (0.18 %) was found in G_2T_2 which was statistically similar with G_2T_1 (0.20 %) (Table 31).

Eight tomato genotypes showed significant increase in % titrable acidity under salinity treatments (Appendix V and Figure 11). The maximum reduction percentage (-160.7 %) was found in G_7 under T_4 and T_2 treatments respectively.

Table 29. Performance of tomato genotypes on %Brix, pH of fruit and %titrable aciity[Y]

Genotype [X]	% Brix	pH of fruit	% Titrable acidity
G_1	7.28 a	4.41 d	0.40 e
G_2	6.94 bc	4.65 ab	0.32 f
G_3	6.89 bc	4.47 cd	0.46 cd
G_4	7.23 a	4.48 cd	0.44 d
G_5	7.03 b	4.65 ab	0.52 b
G_6	7.02 b	4.60 bc	0.49 c
G_7	6.82 c	4.75 a	0.60 a
G_8	5.46 d	4.76 a	0.61 a
CV%	3.40	3.40	7.62
LSD 0.05	0.19	0.13	0.03

[X]Eight tomato genotypes coded from G_1 to G_8.
[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

Table 30.Performance of salinity treatments on %Brix, pH of fruit and %titrable aciity[Y]

Salinity treatments[X]	% Brix	pH of fruit	% Titrable acidity
T_1	6.59 d	4.65	0.34 c
T_2	6.76 c	4.59	0.49 b
T_3	6.91 b	4.65	0.49 b
T_4	7.07 a	4.50	0.59 a
CV%	3.40	3.40	7.62
LSD0.05	0.13	0.05	0.02

[X]Four salinity treatments viz. T_1, Control; T_2 4 dS/m; T_3, 8dS/m; T_4 12dS/m .
[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

Table 31. Interaction effect of tomato genotypes and salinity treatments on %Brix, pH of fruit and %titrable aciity[Y]

Interaction[X]	% Brix		pH of fruit		% Titrable acidity	
G_1T_1	7.01	bcdefghijk	4.27	lm	0.39	gh
G_1T_2	7.18	bcdefg	4.88	abc	0.44	efg
G_1T_3	7.37	abc	4.42	ijkl	0.33	ij
G_1T_4	7.58	a	4.10	m	0.43	g
G_2T_1	6.73	jkl	4.71	bcdefg	0.20	lm
G_2T_2	6.86	fghijkl	4.60	defghijk	0.18	m
G_2T_3	7.01	cdefghijk	4.75	bcdef	0.35	hi
G_2T_4	7.15	bcdefgh	4.57	defghijk	0.55	c
G_3T_1	6.67	kl	4.38	jkl	0.25	kl
G_3T_2	6.79	hijkl	4.38	jkl	0.41	g
G_3T_3	6.96	defghijk	4.54	defghijk	0.66	b
G_3T_4	7.11	bcdefghij	4.59	defghijk	0.53	cd
G_4T_1	7.02	bcdefghijk	4.49	ghijkl	0.31	ij
G_4T_2	7.22	abcdef	4.52	efghikl	0.34	hi
G_4T_3	7.29	abcd	4.54	defghijkl	0.40	gh
G_4T_4	7.39	ab	4.37	kl	0.72	a
G_5T_1	6.83	ghijkl	4.72	bcdefg	0.25	kl
G_5T_2	6.95	defghijk	4.50	fghijkl	0.66	b
G_5T_3	7.09	bcdefghij	4.94	ab	0.43	fg
G_5T_4	7.26	abcde	4.45	hijkl	0.73	a
G_6T_1	6.79	hijkl	4.69	bcdefgh	0.49	def
G_6T_2	6.89	efghijkl	4.63	cdefghij	0.50	cde
G_6T_3	7.13	bcdefghi	4.59	defghijk	0.42	g
G_6T_4	7.26	abcde	4.46	hijkl	0.54	cd
G_7T_1	6.52	l	4.93	ab	0.28	jk
G_7T_2	6.77	ijkl	4.60	defghijk	0.73	a
G_7T_3	6.92	defghijk	4.77	abcd	0.65	b
G_7T_4	7.09	bcdefghij	4.72	bcdefg	0.73	a
G_8T_1	5.13	n	5.01	a	0.55	c
G_8T_2	5.42	mn	4.61	defghijk	0.69	ab
G_8T_3	5.53	m	4.64	cdefghi	0.66	b
G_8T_4	5.76	m	4.76	abcde	0.53	cd
CV%	3.40		3.40		7.62	
LSD O.05	0.04		0.25		0.06	

[X]fifteen genotypes coded from G_1 to G_8 and four salinity treatments viz. T_1, Control; T_2, 4dS/m; T_3. 8dS/m; T_4, 12 dS/m.

[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

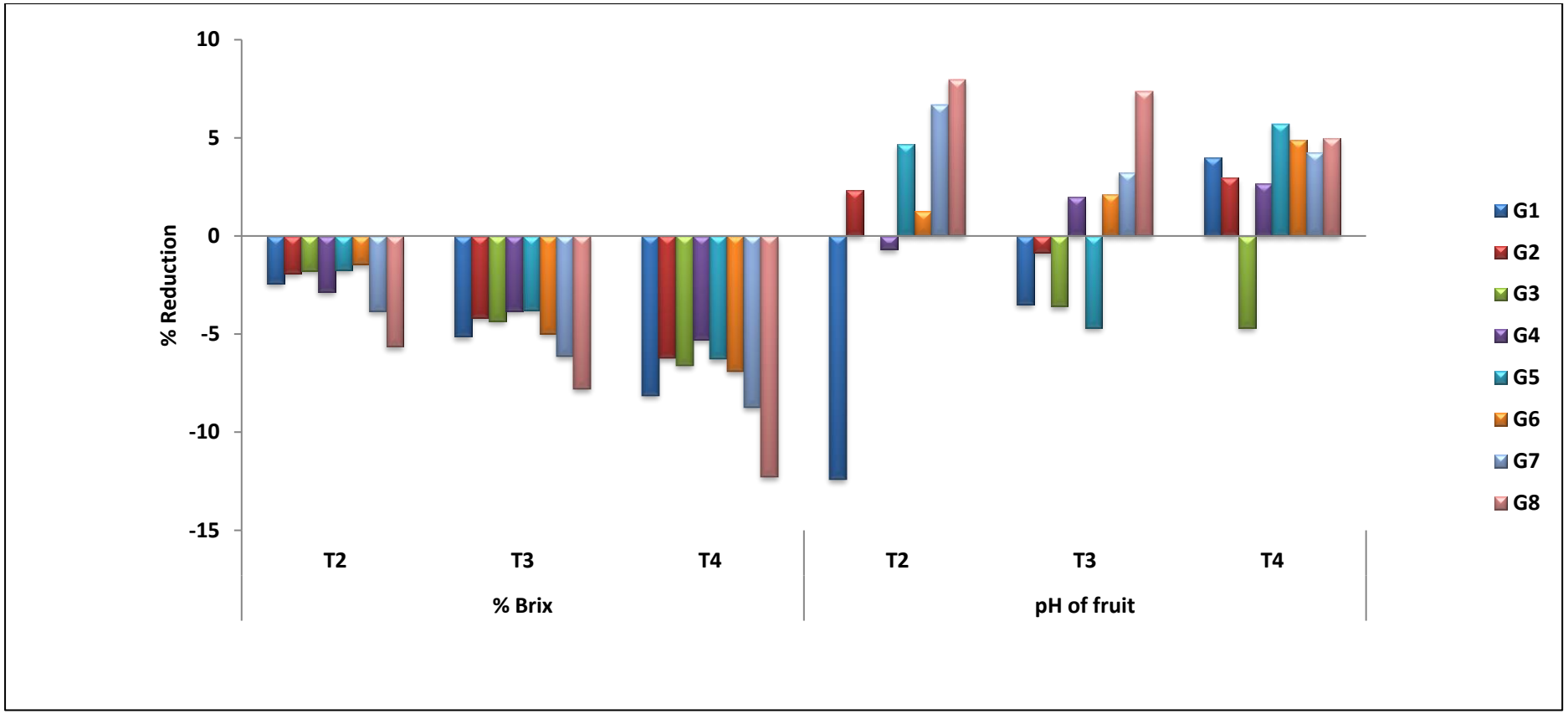

Figure 10. Reduction percentage in % Brix content and pH of fruit under increasing salinity treatments.

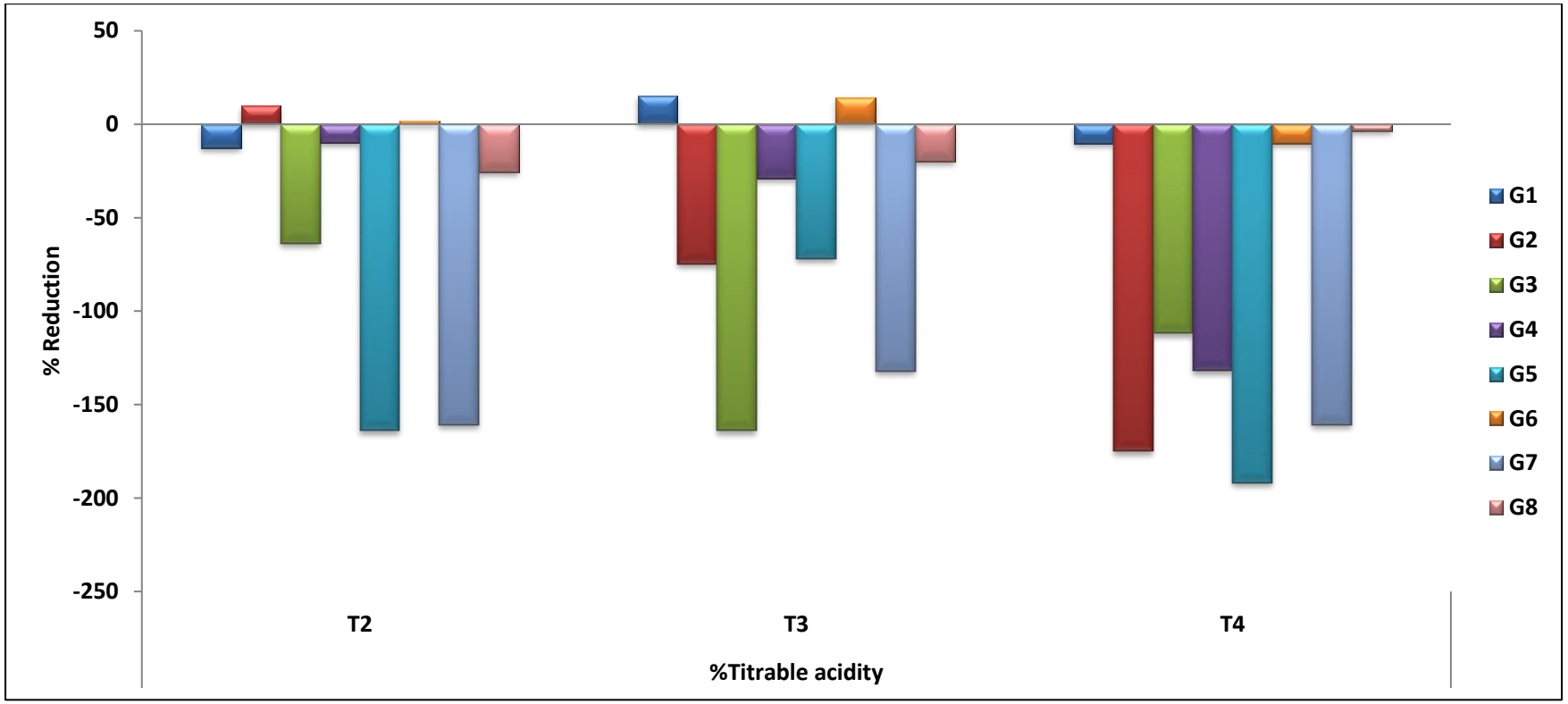

Figure 11. Reduction percentage in titrable acidity under increasing salinity treatments.

4.1.3.4 Vitamin C content (mg/ 100 g)

Eight genotypes of tomato showed statistically showed significant variation in term of vitamin C content (Appendix IV). The highest vitamin C content (15.84 mg/100 g) was found in G_4 which was statistically similar with G_7 (15.5 mg/ 100 g) whereas the lowest content (14.28 mg/ 100 g) was found in G_3 (Table 32).

Vitamin C content showed statistically significant variation among salinity treatments (Appendix IV). The lowest vitamin C content (14.52 mg/ 100 g) was found in T_1 whereas the highest vitamin C content (15.69 mg/ 100 g) was found in T_4 (Table 33). With the increase of salinity level, vitamin C content also increased. Similar result was also found by Begum (201).Fruit quality was increased with the increase of salinity concentration in nutrient solution by increasing the sugar content, organic acid and antioxidants like vitamin C (Flores *et al*., 2003).

Vitamin C showed statistically significant variation among the interaction of tomato genotypes and salinity treatments (Appendix IV). The highest vitamin C content (16.26 mg/ 100 g) was found in G_4T_4 which was statistically similar with G_4T_3 (16.06 mg/ 100 g) whereas the lowest vitamin C content (13.66 mg/ 100 g) in G_3T_1 which was statistically similar with G_3T_2 (14.03 mg/ 100 g) (Table 34).

Vitamin C content increased among the genotypes of tomato under different salinity level (Appendix V and Figure 12). The highest increase in vitamin C content (highest reduction percentage) (-11.73 %) was found in G_7 under T_4 treatments whereas the lowest increase (the lowest reduction percentage) (-1.81 %) was found in G_6 genotypes under T_2 treatment.

4.1.3.5 Lycopene content (mg/ 100 g)

Eight genotypes of tomato showed statistically significant variation in case of lycopene content for both 472 nm and 502 nm (Appendix IV). In case of 472nm, the highest lycopene content (20.70 mg/100 g) was found in G_1 whereas the lowest lycopene content (18 mg/100 g) was found in G_8 (Table 32). In case of 502 nm , the

Table 32. Performance of tomato genotypes on Vitamin C and Lycopene content[Y]

Genotype [X]	Vitamin C (mg/100 g)	Lycopene (mg/100 g) (472 nm)	Lycopene (mg/100 g) (502 nm)
G_1	15.10 cd	20.70 a	15.62 c
G_2	14.86 de	20.13 b	14.87 d
G_3	14.28 f	19.62 c	16.31 b
G_4	15.84 a	19.20 d	15.50 c
G_5	15.29 bc	20.05 b	17.15 a
G_6	15.30 bc	18.54 e	15.74 c
G_7	15.50 ab	20.24 b	16.35 b
G_8	14.71 e	18.00 f	15.28 cd
CV%	2.88	2.36	3.74
LSD 0.05	0.36	0.38	0.48

[X]Eight tomato genotypes coded from G_1 to G_8.
[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

Table 33: Performance of salinity treatments on Vitamin C and Lycopene content[Y]

Salinity treatments[X]	Vitamin C (mg/100 g)	Lycopene (mg/100 g) (472 nm)	Lycopene (mg/100 g) (502 nm)
T_1	14.52 d	24.31 a	18.95 a
T_2	14.91 c	19.96 b	16.36 b
T_3	15.32 b	16.51 d	13.40 d
T_4	15.69 a	17.46 c	14.70 c
CV%	2.88	2.36	3.74
LSD0.05	0.25	0.267	0.34

[X]Four salinity treatments viz. T_1, Control; T_2 4 dS/m; T_3, 8dS/m; T_4 12dS/m.
[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

Table 34. Interaction effect of tomato genotypes and salinity treatments on Vitamin C and Lycopene content[Y]

Interaction[X]	Vitamin C (mg/100 g)	Lycopene (mg/100 g) (472 nm)	Lycopene (mg/100 g) (502 nm)
G_1T_1	14.42 klmn	25.07 b	19.45 ab
G_1T_2	14.8 ghijklm	21.60 de	16.15 fgh
G_1T_3	15.4 bcdefg	17.55 jk	12.49 n
G_1T_4	15.78 abcd	18.57 hi	14.41 kl
G_2T_1	14.17 lmno	24.04 c	17.00 efg
G_2T_2	14.52 ijklmn	19.60 fg	15.04 ijk
G_2T_3	15.13 defghij	18.03 ij	13.04 mn
G_2T_4	15.6 abcdef	18.85 gh	14.41 kl
G_3T_1	13.66 o	24.31 c	20.37 a
G_3T_2	14.03 no	19.64 f	17.04 ef
G_3T_3	14.46 jklmn	16.64 lmn	13.41 mn
G_3T_4	14.99 efghijk	17.89 ijk	14.41 kl
G_4T_1	15.33 cdefgh	23.66 c	18.41 cd
G_4T_2	15.70 abcd	19.60 fg	15.78 hi
G_4T_3	16.06 ab	16.19 n	13.41 mn
G_4T_4	16.26 a	17.37 jkl	14.40 kl
G_5T_1	14.63 hijklmn	25.11 b	20.37 a
G_5T_2	15.2 defghi	21.48 e	17.41 e
G_5T_3	15.48 bcdefg	15.99 no	14.74 jk
G_5T_4	15.83 abcd	17.63 jk	16.07 gh
G_6T_1	14.88 ghijkl	24.00 c	18.62 bc
G_6T_2	15.15 defghij	18.63 hi	16.41 fgh
G_6T_3	15.38 bcdefgh	15.30 op	13.40 mn
G_6T_4	15.78 abcd	16.25 n	14.50 k
G_7T_1	14.91 fghijk	25.95 a	19.64 a
G_7T_2	15.39 bcdefg	21.22 e	17.48 de
G_7T_3	15.66 abce	17.19 klm	13.49 lm
G_7T_4	16.04 abc	16.59 mn	14.81 jk
G_8T_1	14.15 mno	22.34 d	17.75 cde
G_8T_2	14.52 ijklmn	17.90 ijk	15.59 hij
G_8T_3	14.96 efghijk	15.19 p	13.22 mn
G_8T_4	15.22 defghi	16.56 mn	14.55 k
CV%	2.88	2.36	3.74
LSD O.05	0.71	0.75	0.97

[X]fifteen genotypes coded from G_1 to G_8 and four salinity treatments viz. T_1, Control; T_2, 4dS/m; T_3 , 8dS/m; T_4, 12 dS/m.

[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

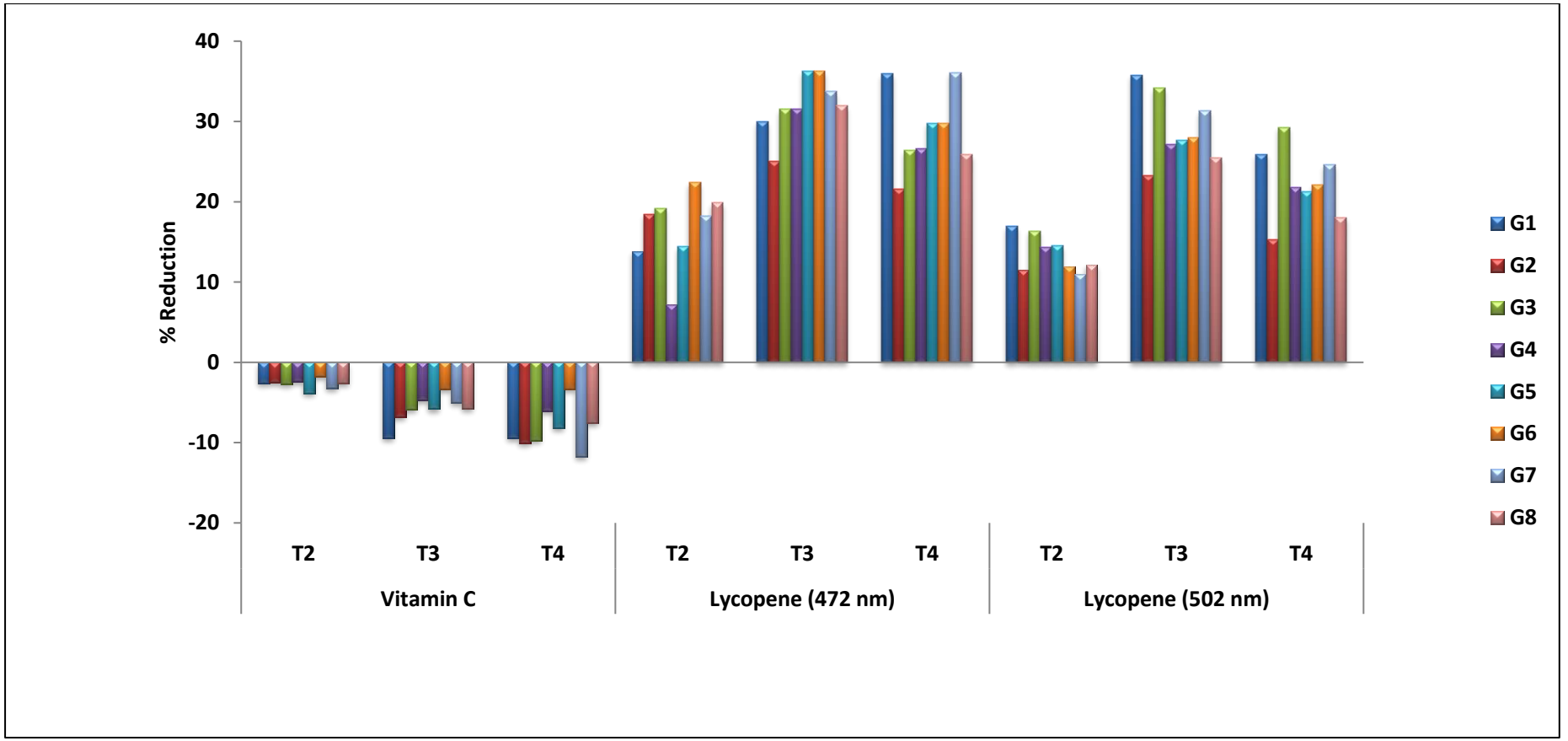

Figure 12. Reduction percentage in Vitamin C, lycopene under increasing salinity treatment.

Highest lycopene content (17.15 mg/100 g) was found in G_5 whereas the lowest lycopene content (14.87 mg/ 100 g) was found in G_2 genotypes (Table 32).

Lycopene content showed statistically significant variation among the salinity treatment (Appendix IV). In case of 472 nm wavelength, the highest lycopen content (24.31 mg/ 100 g) was found in T_1 while the lowest lycopene content (16.51 mg/ 100 g) was found in T_3 salinity treatment (Table 33). In case of 502 nm wavelength, the highest lycopene content (18.95 mg/100 g) was found in T_1 while the lowest lycopene content (13.4 mg/ 100 g) was found in T_3 treatment (Table 33). With the increase of salinity reduce the lycopen content and similar result was observed by Begum (2016).

Lycopene content showed statistically significant variation among the interaction of tomato genotypes and salinity treatments (Appendix IV).In case of 472 nm wavelength, the highest lycopene content (25.95 mg/ 100 g) was found in G_7T_1 whereas the lowest lycopene content (15.19 mg/100 g) was found in G_8T_3 which was statistically identical with G_6T_3 (15.30 mg/ 100 g) (Table 34). In case of 502 nm wavelength, the highest lycopene content (20.37 mg/ 100 g) was found in G_3T_1 which was statistically identical with G_1T_1 (19.45 mg/ 100 g) whereas the lowest lycopene content (12.49 mg/ 100 g) was found in G_1T_3 which was statistically similar with G_2T_3 (13.04 mg/ 100 g), G_3T_3 (13.41 mg/ 100 g), G_4T_3 (13.41 mg/ 100 g), G_6T_3 (13.40 mg/ 100 g) (Table 34).

Lycopene content showed reduction under different salinity treatments (AppendixV and Figure 12). In case of 472 nm wavelength, the highest reduction percentage (37.32 %) was observed in G_5 under T_3 treatment whereas the lowest reduction percentage (7.16 %) was found in G_4 under T_2 treatment. In case of 502 nm wavelength, the highest reduction percentage (35.78 %) was observed in G_1 under T_2 treatment whereas the lowest reduction percentage (11.53 %) was found in G_2 under T_2 treatment.

4.2 Experiment 2: Genotype × stress interaction under drought condition in tomato (*Solanum lycopersicum* L.)

This part discusses the genotypes stress interaction under drought condition in eight genotypes of tomato based on their agromorphogenic, physiological and nutritional traits. Four salinity treatments like T_1; control, T_2; 10 days withhold of water, T_3; 20 days withhold of water and T_4; 30 days withhold of water were applied. CRD was followed with three replications. Genotype performance, drought treatment performance and genotype stress interaction are presented in different tables and figures for better understanding. The observed results are presented here under the following headlines.

4.2.1 Agromorphogenic traits

Agromorphogenic traits such as plant height, no. of leaves, leaf area, no. of branches per plant, days to first flowering, days to first fruit setting , days to maturity, no,. of cluster per plant, no. of flowers per cluster, no. of fruits per clusters, no. of fruits per plant, fruit length, fruit diameter, average fruit weight, yield per plant, skin diameter of fruit, root length, shoot root ratio have been discussed. ANOVA and reduction percentage are presented in Appendix VI and VII respectively. Data are presented in table, figures for better understanding.

4.2.1.1 Plant height (cm)

Eight genotypes of tomato showed statistically significant variation in term of plant height (Appendix VI). The tallest plant (70.83 cm) was found from G_1 which was statistically similar with G_2 and G_8 genotypes whereas the shortest plant (52.00 cm) was found in G_7 genotype (Table 35).

Plant height showed statistically significant variation among the drought treatments (Appendix VI). The tallest plant (70.83 cm) was found in T_1 treatment whereas the shortest plant (51.12 cm) was found in T_4 treatment (Table 36). The plant height showed decrease with the increase of drought treatment. Begum (2016) found similar result of decrease of plant height with the increase of drought treatment. When plant faces severe drought stress, all physiological process become restricted in different level and thus reduces the height of plant. Higher water stress gradually decreases plant height. Similar results reported by Wahb-Allah *et al*. (2001).

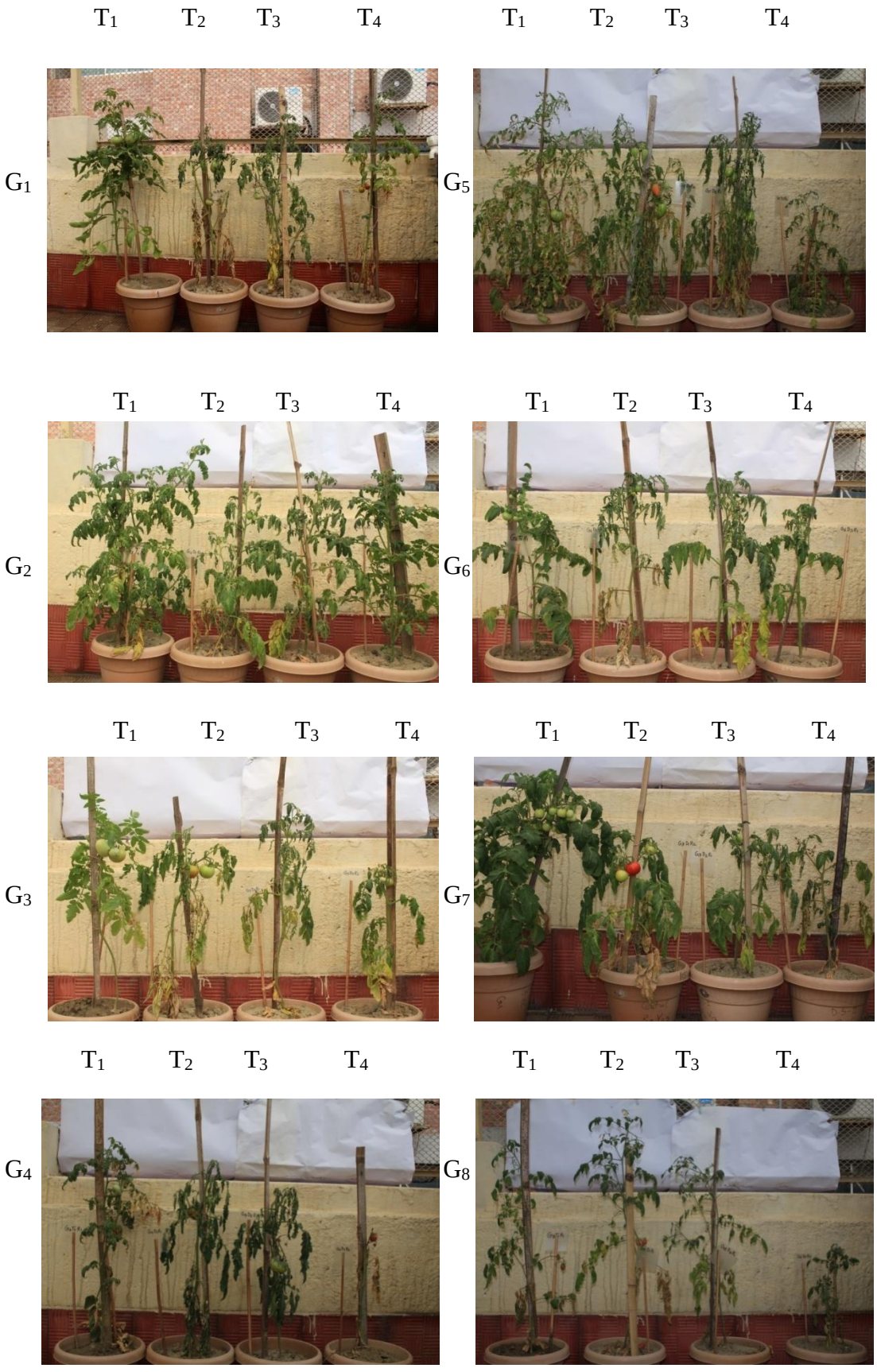

Plate 8. Morphological variation in eight genotypes of tomato under four drought treatments.

Plant height showed statistically significant variation among the interaction of genotypes and drought treatments (Appendix VI). The tallest plant (80.33 cm) was found in G_8T_1 which was statistically similar with G_1T_1 (79.33 cm) , G_2T_1 (79.67 cm), G_8T_2 (74.33 cm) whereas the shortest plant (44.00 cm) was obtained from G_7T_4 which was statistically similar with G_8T_4 (47 cm), G_5T_4 (47.33cm) (Table 37).

Plant height showed significant reduction in eight genotypes under drought treatments (Appendix VII and Figure 13). The highest reduction percentage (41.5 %) was found in G_8 under T_4 treatment whereas the lowest reduction (7.47 %) was found in G_8 under T_2 treatment.

4.2.1.2 Number of leaves per plant

Eight genotypes of tomato showed statistically significant variation in term of number of leaves per plant (Appendix VI). The highest number of leaves per plant (62.17) was found in G_5 whereas the lowest number of leaves per plant (16.75) was found in G_8 genotypes which were statistically similar with G_3 (Table 35).

Number of leaves per plant showed statistically significant variation among drought treatments (Appendix VI). The maximum number of leaves (39.83) was found in T_1 treatment whereas the minimum number of leaves (20.92) was found in T_4 treatment. With the increase in drought level, number of leaf per plant are shown reduced.

Number of leaf per plant showed statistically significant among the interaction of tomato genotypes and drought treatments (Appendix VI). The highest number of leaf per plant (74.00) was found in G_5T_1 whereas the lowest number of leaves per plant (11.00) was found in G_8T_4 and G_6T_4 (11.33) which were statistically similar with G_3T_3 (13.33) (Table 37). The number of leaf per plant showed reduction percentage under drought treatment (Appendix VI and Figure 13). The highest reduction percentage (60.01 %) was found in G_6 under T_4 whereas the minimum reduction percentage (12.16 %) was found in G_5 under T_2 treatment.

4.2.1.3 Leaf area (cm^2)

Eight genotypes of tomato showed statistically significant variation in term of leaf area (Appendix VI). The maximum leaf area (463.83 cm^2) was found in G_5 while the minimum leaf area (250.92 cm^2) was found in G_8 genotypes (Table 35).

Table 35. Performance of tomato genotypes on plant height, number of leaves and leaf area[Y]

Genotype [X]	Plant height (cm)	Number of leaves per plant	Leaf area (cm^2)
G_1	70.83 a	29.92 c	355.50 d
G_2	66.50 a	37.75 b	118.92 h
G_3	58.17 b	16.00 f	448.83 b
G_4	59.25 b	23.33 d	169.83 g
G_5	58.17 b	62.17 a	463.83 a
G_6	57.50 b	18.17 e	427.50 c
G_7	52.00 c	22.67 d	312.83 e
G_8	66.58 a	16.75 f	250.92 f
CV%	9.77	5.98	1.57
LSD 0.05	4.87	1.38	4.10

[X]Eight tomato genotypes coded from G_1 to G_8
[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Table 36: Performance of drought treatments on plant height, number of leaves per plant and leaf area[Y]

Drought treatments[X]	Plant height (cm)	Number of leaves/ plant	Leaf area (cm^2)
T_1	70.83 a	39.83 a	338.04 a
T_2	63.49 b	27.79 b	322.17 b
T_3	59.08 c	24.83 c	312.62 c
T_4	51.12 d	20.92 d	301.25 d
CV%	9.77	5.98	1.57
LSD0.05	3.44	0.98	2.90

[X]Four drought treatments viz. T_1, Control; T_2 ,10 days withhold of water; T_3, 20 days withhold of water; T_4, 30 days withhold of water.
[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Table 37. Interaction effect of tomato genotypes and drought treatments on plant Height, Number of leaves per plant and Leaf area[Y]

Interaction[X]	Plant height (cm)	Number of leaves/plant	Leaf area (cm^2)
G_1T_1	79.33 a	41.00 e	370.00 k
G_1T_2	72.67 abc	34.00 f	361.33 l
G_1T_3	68.67 bcd	23.67 i	349.33 m
G_1T_4	62.67 defg	21.00 ijk	341.33 m
G_2T_1	79.67 a	64.33 bc	126.00 u
G_2T_2	66.67 bcde	31.00 g	121.00 u
G_2T_3	63.00 cdefg	29.00 gh	118.00 uv
G_2T_4	56.67 fghijkl	26.67 h	110.67 v
G_3T_1	62.67 defg	20.67 jk	479.00 b
G_3T_2	58.67 efghij	15.67 lmn	455.33 de
G_3T_3	60.00 defghi	13.33 no	443.33 fg
G_3T_4	51.33 ijklm	14.33 n	417.67 i
G_4T_1	67.00 bcde	31.00 g	182.00 s
G_4T_2	61.67 defgh	20.67 jk	175.33 s
G_4T_3	57.33 efghijk	21.33 ij	164.33 t
G_4T_4	51.00 ijklm	20.33 jk	157.67 t
G_5T_1	68.67 bcd	74.00 a	500.67 a
G_5T_2	61.67 defgh	65.00 b	466.67 c
G_5T_3	55.00 ghijkl	61.67 c	449.33 ef
G_5T_4	47.33 lm	48.00 d	438.67 gh
G_6T_1	65.67 bcdef	28.33 gh	460.00 cd
G_6T_2	59.33 defghi	17.33 lm	432.00 h
G_6T_3	56.00 fghijkl	15.67 lmn	420.00 i
G_6T_4	49.00 jklm	11.33 o	398.00 j
G_7T_1	63.33 cdefg	36.33 f	321.33 n
G_7T_2	52.67 hijklm	21.33 ij	314.00 no
G_7T_3	48.00 klm	18.33 kl	310.00 o
G_7T_4	44.00 m	14.67 mn	306.00 o
G_8T_1	80.33 a	23.00 ij	265.33 p
G_8T_2	74.33 ab	17.33 lm	251.67 q
G_8T_3	64.67 bcdefg	15.67 lmn	246.67 qr
G_8T_4	47.00 lm	11.00 o	240.00 r
CV%	9.77	5.98	1.57
LSD O.05	9.74	2.76	8.19

[X]Eight genotypes coded from G_1 to G_8 and four drought treatments viz. T_1, Control; T_2, 10 days withhold of water; T_3 20 days withhold of water; T_4, 30 days withhold of water.

[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

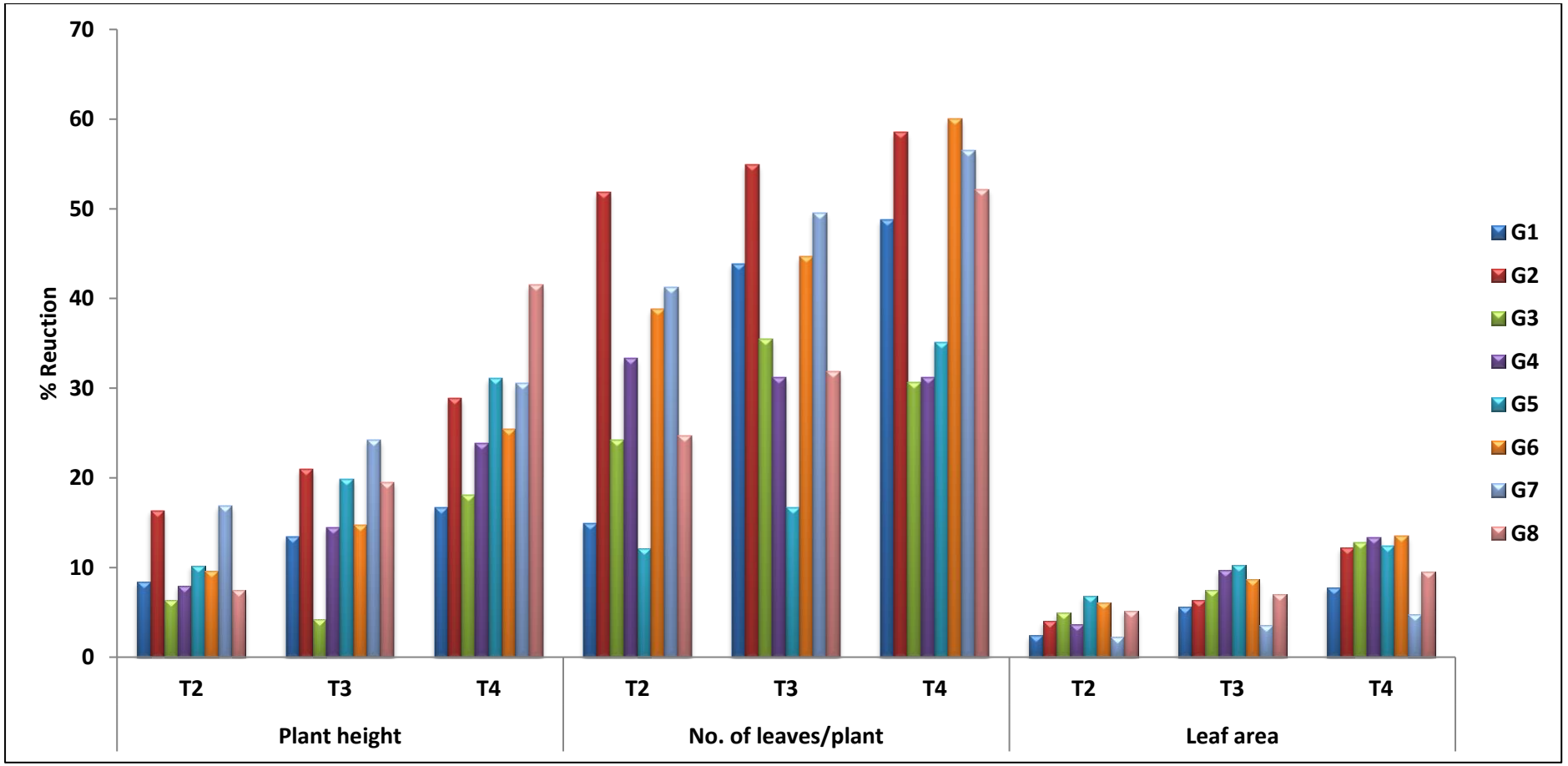

Figure 13: Reduction percentage in plant height, No. of leaves/plant and Leaf area under increasing drought treatments.

Leaf area showed statistically significant variation among the drought treatments (Appendix VI). The maximum leaf area (338.04 cm^2) was obtained from T_1 whereas the minimum leaf area (301.25 cm^2) was obtained from T_4 treatment (Table 36).With the increase of drought treatment, leaf area decreased.

Leaf area showed statistically significant variation among the interaction of genotypes and drought treatments (Appendix VI). The highest leaf area (500.67 cm^2) was obtained from G_5T_1 whereas the minimum leaf area (240.00 cm^2) was obtained from G_8T_4 combination (Table 37).

Leaf area showed significant reduction among the genotypes under drought treatments (Appendix VII and Figure 13). The maximum reduction percentage (13.48 %) was found in G_6 under T_4 whereas the minimum reduction percentage (2.29 %) as found in G_7 under T_2 drought treatment.

4.2.1.4 Number of branches per plant

Eight genotypes showed statistically significant in term number of branches per plant (Appendix VI). The maximum number of branch (6.50) was found in G_2 genotypes whereas the minimum number of branch (4.33) was found in G_6 and G_7 (Table 38).

Number of branches per plant showed statistically significant among drought treatment (Appendix VI). The highest number of branches per plant (7.17) was found in T_1 whereas the lowest number of branches per plant (3.80) was found in T_4 treatments (Table 39). The number of branches per plant decrease with the increase of drought treatments.

Number of branches per plant showed statistically significant among the interaction of tomato genotypes and drought treatments (Appendix VI). The maximum number of branches per plant (10.67) was found in G_2T_1 whereas the minimum number of branches per plant (2.67) was found in G_8T_4 (Table 40).

Number of branches per plant showed reduction among eight genotypes under drought treatments (Appendix VII and Figure 14). The highest reduction percentage (62.51 %) was found in G_2 under T_4 drought treatment whereas the minimum reduction percentage (12.38 %) was found in G_6 under T_2 treatment.

4.2.1.5 Days to first flowering

Eight tomato genotypes showed statistically significant variation in term of days to first flowering (Appendix VI. The longest time for first flowering (34.50 days) was found in G_6 whereas the shortest time for first flowering was found G_4 (17.92) which was statistically similar with G_1(18.33 days) and G_3 (19.08d days) (Table 38).

Days to first flowering showed statistically significant among the treatments (Appendix VI). The longest time for first flowering (26.29 days) was found in T_1 treatment which was statistically similar with T_2 (24.87 days) whereas the shortest time for first flowering (22.75 days) was found in T_4 treatment which was statistically similar with T_3 (22.87 days) (Table 39). With the increase of drought level, plant showed early flowering than control.

Days to first flowering showed statistically significant variation among the interaction of genotypes and drought treatment (Appendix VI). Longest time taken for first flowering was found in G_6T_1 (36.00 days), G_6T_2 (35.33 days), G_6T_4 (36.00 days) which were statistically similar with G_7T_1 (32.33 days) , G_8T_2 (32.33 days) whereas the shortest time taken for first flowering was found in G_4T_4 (17.33 days), G_4T_3 (17.33 days), G_1T_4 (17.33 days), G_1T_3 (17.67 days) which were statistically similar with G_4T_2 (18 days).

Eight genotypes showed significant variation in days to first flowering (Appendix VII and Figure 14). Early flowering ((maximum reduction) was found in G_7 (31.95 days) under T_4 treatment whereas late flowering (minimum reduction) was found in G_8 (-5.41 %) under T_2 treatment (Figure 14).

4.2.1.6 Days to first fruit setting

Eight genotypes of tomato showed statistically significant variation in term of days to first flowering (Appendix VI). Longest time for first fruit setting (53.50 days) was found in G_6 whereas the shortest time for first fruit setting was found in G_4 (36.92 days), G_3 (38.08 days) and G_1 (37.33 days).

Table 38. Performance of tomato genotypes on No. of branches per plant, Days to first flowering, days to first fruit setting[Y]

Genotype [X]	No. of branches /plant	Days to first flowering	Days to first fruit setting
G_1	5.75 b	18.33 e	37.33 e
G_2	6.50 a	28.33 b	47.33 b
G_3	5.08 c	19.08 e	38.08 e
G_4	4.33 d	17.92 e	36.92 e
G_5	5.75 b	22.00 d	41.00 d
G_6	4.33 d	34.50 a	53.50 a
G_7	4.33 d	25.50 c	44.50 c
G_8	4.50 d	27.92 b	46.92 b
CV%	13.98	10.50	5.88
LSD 0.05	0.58	2.07	2.07

[X]Eight tomato genotypes coded from G_1 to G_8

[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Table 39. Performance of drought treatments on No. of branches per plant, Days to first flowering, days to first fruit setting[Y]

Drough treatments[X]	No. of branches /plant	Days to first flowering	Days to first fruit setting
T_1	7.17 a	26.29 a	45.29 a
T_2	5.08 b	24.87 a	43.87 a
T_3	4.25 c	22.87 b	41.87 b
T_4	3.80 d	22.75 b	41.75 b
CV%	13.98	10.50	5.88
LSD0.05	0.41	1.47	1.47

[X]Four drought treatments viz. T_1, Control; T_2 10 days withhold of water; T_3, 20 days withhold of water; T_4, 30 days withhold of water.

[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

Table 40. Interaction effect of tomato genotypes and drought treatments on No. of branches per plant, days to first flowering and days to first fruit setting[Y]

Interaction[X]	No. of branches /plant	Days to first flowering	Days to first fruit setting
G_1T_1	8.67 b	20.00 hijkl	39.00 hijk
G_1T_2	4.67 hijk	18.33 jkl	37.33 jkl
G_1T_3	4.67 hijk	17.67 l	36.67 l
G_1T_4	5.00 ghij	17.33 l	36.33 l
G_2T_1	10.67 a	30.67 bc	49.67 bc
G_2T_2	6.67 cde	29.00 bcd	48.00 bcd
G_2T_3	4.67 hijk	28.00 cde	47.00 cde
G_2T_4	4.00 jklm	25.67 def	44.67 def
G_3T_1	7.00 cd	19.33 jkl	38.33 jkl
G_3T_2	5.00 ghij	19.67 ijkl	38.67 ijkl
G_3T_3	4.00 jklm	18.67 jkl	37.67 jkl
G_3T_4	4.33 ijkl	18.67 jkl	37.67 jkl
G_4T_1	6.00 defg	19.00 jkl	38.00 jkl
G_4T_2	4.67 hijk	18.00 kl	37.00 kl
G_4T_3	3.67 klmn	17.33 l	36.33 l
G_4T_4	3.00 mn	17.33 l	36.33 l
G_5T_1	7.33 c	22.33 fghij	41.33 fghij
G_5T_2	5.67 efgh	22.33 fghij	41.33 fghij
G_5T_3	5.00 ghij	22.00 fghijk	41.00 fghijk
G_5T_4	5.00 ghij	21.33 ghijkl	40.33 ghijkl
G_6T_1	5.33 fghi	36.00 a	55.00 a
G_6T_2	4.67 hijk	35.33 a	54.33 a
G_6T_3	4.00 jklm	30.67 bc	49.67 bc
G_6T_4	3.33 lmn	36.00 a	55.00 a
G_7T_1	6.00 defg	32.33 ab	51.33 ab
G_7T_2	4.33 ijkl	24.00 efgh	43.00 efgh
G_7T_3	4.00 jklm	23.67 fghi	42.67 fghi
G_7T_4	3.00 mn	22.00 fghijk	41.00 fghijk
G_8T_1	6.33 cdef	30.67 bc	49.67 bc
G_8T_2	5.00 ghij	32.33 ab	51.33 ab
G_8T_3	4.00 jklm	25.00 defg	44.00 defg
G_8T_4	2.67 n	23.67 fghi	42.67 fghi
CV%	13.98	10.50	5.88
LSD O.05	1.16	4.15	4.15

[X]Eight genotypes coded from G_1 to G_8 and four drought treatments viz. T_1, Control; T_2, 10 days withhold of water; T_3, 20 days withhold of water; T_4, 30 days withhold of water.

[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

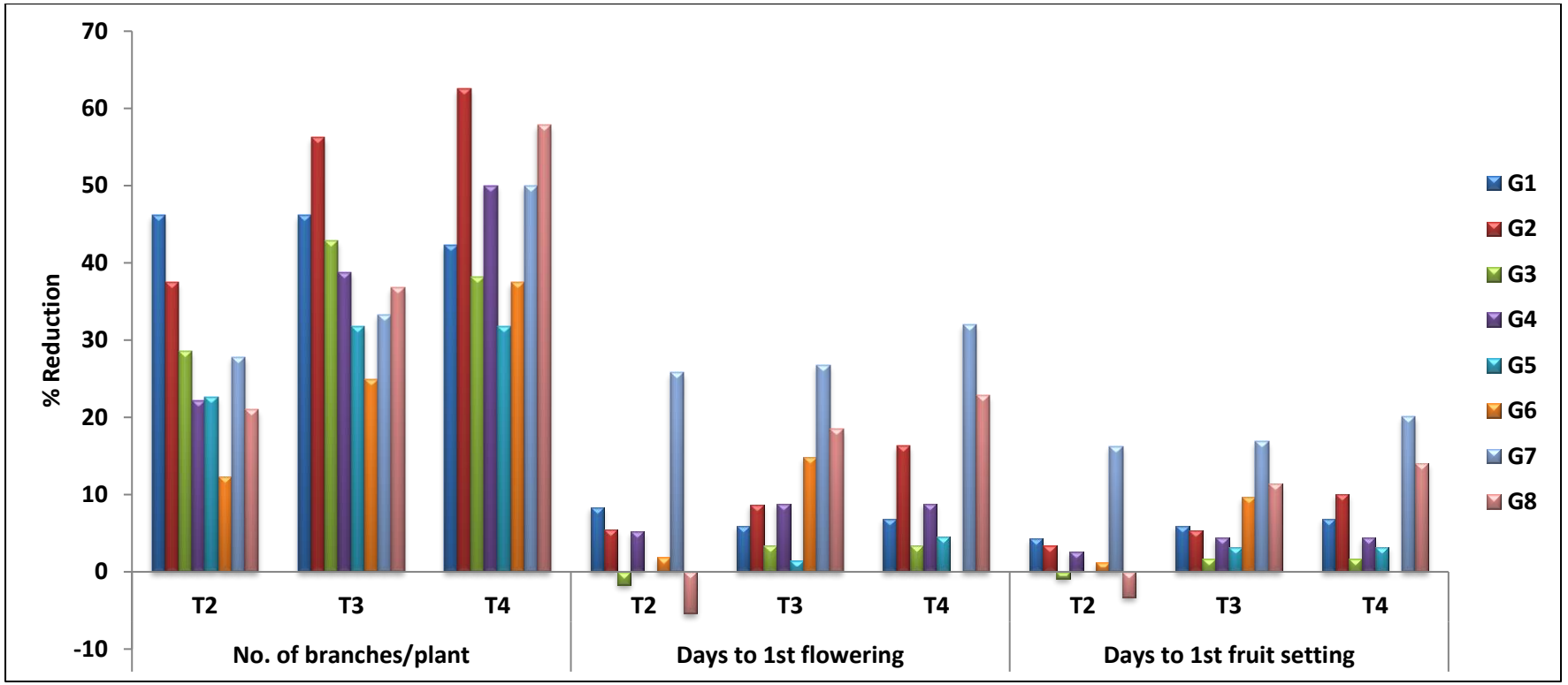

Figure 14. Reduction percentage in No. of branches/plant, days to 1st flowering and days to first fruit setting under increasing drought Treatment.

Days to first fruit setting showed statistically significant variation among the treatments (Appendix VI). The longest time taken for first fruit setting was found in T_1 (45.29 days), T_2 (43.87 days) whereas the shortest time taken for first fruit setting was found in T_3 (41.87 days), T_4 (41.75 days) (Table 39). Days to first fruit setting showed statistically significant variation among the interaction of genotypes and drought treatments (Appendix VI). The longest time for first fruit setting was found in G_6T_1 (55 days), GG_6T_4 (55 days) which were statistically similar with G_7T_1 (51.33 days) and G_8T_2 (51.33 days) whereas the shortest time for first fruit setting was found in G_1T_4 (36.33 days), G_1T_3 (36.67 days), and G_4T_3 (36.33 days) and G_4T_4 (36.3 days) (Table 40). Eight genotypes showed variation in days to first fruit setting (Appendix VII and Figure 14). The maximum reduction (early fruit setting) was found in G_7TT_3 (16.87 %) whereas the minimum reduction percentage (late flowering) as found in G_8 under T_2 treatment.

4.2.1.7 Days to maturity

Eight genotypes of tomato showed statistically significant variation in term of days to maturity (Appendix VI). The longest time taken for maturity was found in G_2 (80 days), G_6 (79.42 days) whereas the shortest time taken for maturity (67.67 days) was found in G_5 (Table 41).

Days to maturity showed statistically significant variation among drought treatments (Appendix VI). The longest time taken for maturity (78.71 days) was found in T_1 whereas the shortest time taken for maturity (69.92 days) was found in T_4 drought treatment (Table 42). Plant takes less time for maturity under drought treatment than control. Similar result was also found by Begum (2016). Days to maturity showed statistically variation among interaction of genotypes and drought treatment (Appendix VI). The longest time taken for days to maturity was found in G_2T_1 (84.33 days), G_6T_1 (84.33 days) which were statistically similar with G_2T_2 (81.00 days) whereas the shortest time taken for maturity (65.33 days) was found in G_5T_4 (65.33 days) which was statistically similar with G_8T_4 (66.00 days) (Table 43).

Tomato genotypes showed variation in days to maturity (Appendix VII and Figure 15). The early maturity (maximum reduction percentage) was found in G_8T_4 (16.80%) whereas the late maturity (minimum reduction percentage) was found in G_2 (3.95 %) under T_2 treatment.

4.2.1.8 Number of clusters per plant

Eight genotypes of tomato showed statistically significant variation in term of number of clusters per plant (Appendix VI). The maximum cluster was found in G_8 (6.08) which was statistically similar with G_7 (5.75) and G_5 (5.75) whereas the minimum cluster number was found in G_1 (4.75), G_2 (5.00), G_3 (4.83) and G_4 (4.92) (Table 41).

Number of clusters per plant showed statistically variation among the drought treatments (Appendix VI). The maximum cluster number (7.17) was found in T_1 whereas the minimum cluster (3.96) was found in T_4 treatment (Table 42). With the increase of drought treatment, number of cluster per plant becomes reduced. Wahb-Allah *et al.* (2011) found similar result.

Number of clusters per plant showed statistically significant variation among the interaction of genotypes and drought treatments (Appendix VI). The highest cluster was found in G_2T_1 (7.67), G_6T_1 (7.67) which were statistically similar with G_5T_1 (7.00) and G_8T_1 (7.33) whereas the lowest cluster number was found in G_2T_4 (3.00) which was statistically similar with G_3T_4 (3.33) (Table 43).

Tomato genotypes showed reduction under drought treatments in case of number of clusters per plant (Appendix VII and Figure 15). The highest reduction percentage (60.88 %) was found in G_2 under T_4 treatment whereas the lowest reduction percentage (9.00 %) was obtained from G_8 under T_2 drought treatment.

4.2.1.9 Number of flowers per cluster

Tomato genotypes showed statistically significant variation in case of number of flowers per cluster (Appendix VI). The highest flowers per cluster was found in G_8 (5.85) whereas the lowest flowers per cluster was found in G_4 (4.08) (Table 41). Number of flowers per cluster showed statistically variation among the drought treatment (Appendix VI). The highest flower per cluster (6.08) was found in T_1 whereas the lowest (3.04) was found in T_4 drought treatment. Flowers per cluster are shown 9reduced with the increase of drought treatment. Flower dropping is a common morphological pattern in plant under moisture stress. Reduction in flower number per cluster due to the increase of drought levels was found by Sibomana and Aguyoh (2013).

Table 41. Performance of tomato genotypes on Days to maturity, No. of clusters per plant and No. of flowers per cluster[Y]

Genotype [X]	Days to maturity	Number of clusters per plant	Number of flowers per cluster
G_1	73.00 bc	4.75 c	4.50 c
G_2	80.00 a	5.00 c	5.00 b
G_3	71.17 c	4.83 c	4.25 cd
G_4	73.25 bc	4.92 c	4.08 d
G_5	67.67 d	5.75 ab	4.58 c
G_6	79.42 a	5.50 b	4.42 cd
G_7	74.08 b	5.75 ab	4.25 cd
G_8	72.17 bc	6.08 a	5.75 a
CV%	4.61	11.16	10.28
LSD 0.05	2.78	0.49	0.39

[X]Eight tomato genotypes coded from G_1 to G_8

[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Table 42: Performance of drought treatments on Days to maturity, No. of cluster per plant and No. of flowers per cluster[Y]

Drought treatments[X]	Days to maturity	Number of clusters per plant	Number of flowers per cluster
T_1	78.71 a	7.17 a	6.08 a
T_2	74.67 b	5.63 b	5.17 b
T_3	72.08 c	4.54 c	4.12 c
T_4	69.92 d	3.96 d	3.04 d
CV%	4.61	11.16	10.28
LSD0.05	1.97	0.34	0.27

[X]Four drought treatments viz. T_1, Control; T_2 10 days withhold of water; T_3, 20 days withhold of water; T_4 30 days withhold of water.

[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

Table 43. Interaction effect of tomato genotypes and drought Days tomaturity, No. of cluster per plant and No. of flowers per cluster[Y]

Interaction[X]	Days to maturity	Number of clusters per plant	Number of flowers per cluster
G_1T_1	78.33 bcde	6.67 bc	6.00 c
G_1T_2	74.33 defgh	4.67 fgh	5.00 def
G_1T_3	70.33 ghijk	4.00 hij	4.00 ghi
G_1T_4	69.00 hijk	3.67 ijk	3.00 jk
G_2T_1	84.33 a	7.67 a	6.00 c
G_2T_2	81.00 ab	5.67 de	5.33 cde
G_2T_3	78.67 bcde	3.67 ijk	5.00 def
G_2T_4	76.00 bcdef	3.00 k	3.67 hij
G_3T_1	76.33 bcdef	6.67 bc	5.33 cde
G_3T_2	71.67 fghi	5.00 efg	4.67 efg
G_3T_3	69.67 hijk	4.33 ghi	4.00 ghi
G_3T_4	67.00 ijk	3.33 jk	3.00 jk
G_4T_1	78.00 bcde	6.67 bc	5.67 cd
G_4T_2	74.00 defgh	5.67 de	4.33 fgh
G_4T_3	71.33 fghij	4.00 hij	3.33 ijk
G_4T_4	69.67 hijk	3.33 jk	3.00 jk
G_5T_1	71.00 fghij	7.00 ab	6.00 c
G_5T_2	67.67 ijk	6.00 cd	5.33 cde
G_5T_3	66.67 ijk	5.33 def	4.00 ghi
G_5T_4	65.33 k	4.67 fgh	3.00 jk
G_6T_1	84.33 a	7.67 a	6.00 c
G_6T_2	80.67 abc	5.67 de	4.67 efg
G_6T_3	77.33 bcde	4.00 hij	4.33 fgh
G_6T_4	75.33 cdefg	4.67 fgh	2.67 k
G_7T_1	78.00 bcde	7.67 a	5.33 cde
G_7T_2	74.00 defgh	5.67 de	4.67 efg
G_7T_3	73.33 efgh	5.33 def	4.00 ghi
G_7T_4	71.00 fghij	4.33 ghi	3.00 jk
G_8T_1	79.33 abcd	7.33 ab	8.33 a
G_8T_2	74.00 defgh	6.67 bc	7.33 b
G_8T_3	69.33 hijk	5.67 de	4.33 fgh
G_8T_4	66.00 jk	4.67 fgh	3.00 jk
CV%	4.61	11.16	10.28
LSD O.05	5.56	0.97	0.78

[X]Eight genotypes coded from G_1 to G_8 and four drought treatments viz. T_1, Control; T_2, 10 days withhold of water; T_3 20 days withhold of water; T_4, 30 days withhold of water

[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

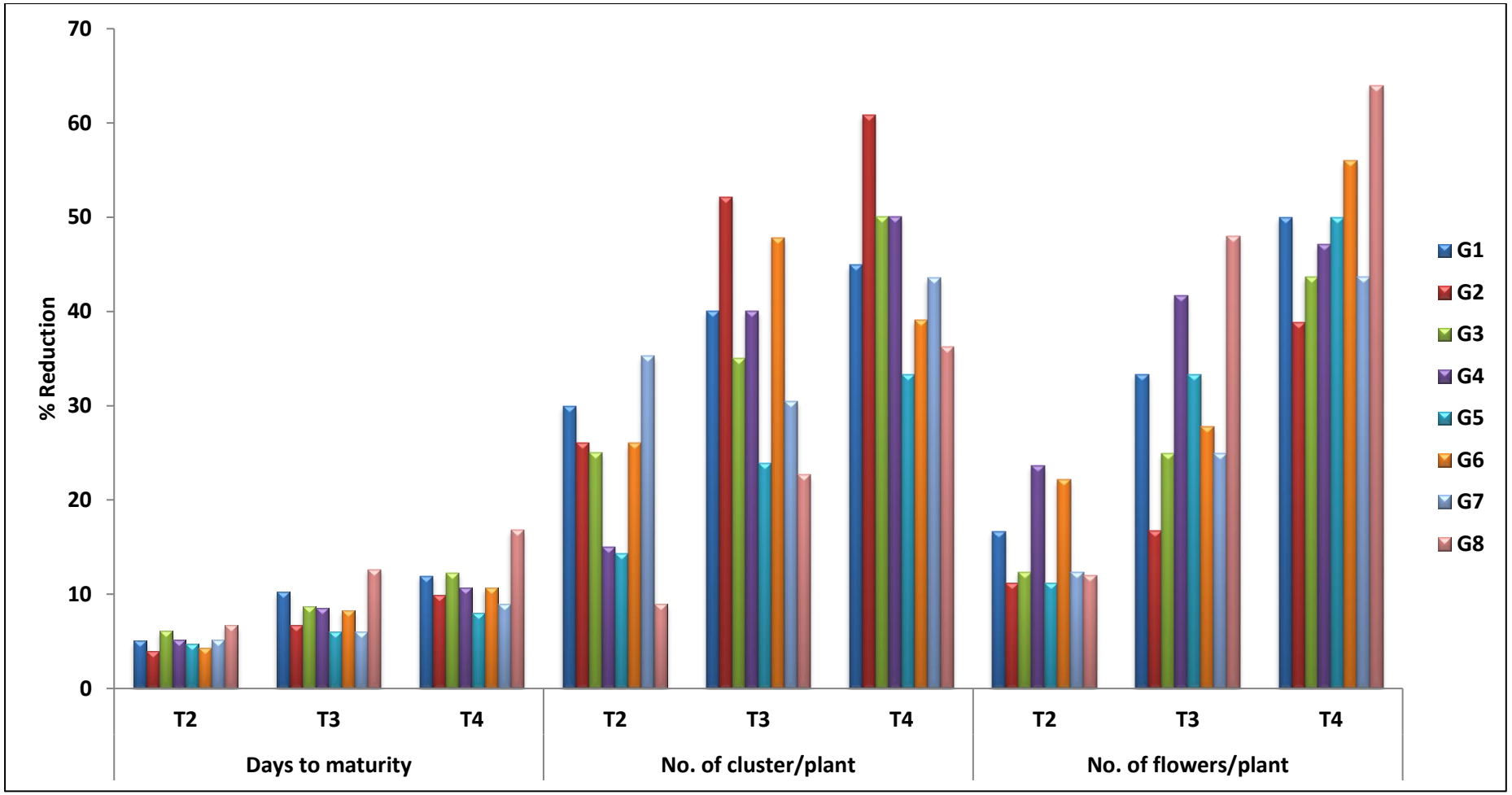

Figure 15: Reduction percentage in Days to maturity, No. of cluster/plant and No. of flowers/plant under increasing drought treatment.

Number of flowers per cluster showed significant variation among the interaction of tomato genotypes and drought treatments (Appendix VI). The maximum flowers per cluster (8.33) was found in G_8T_1 whereas the minimum (2.67) was found in G_6T_4 which was statistically similar with G_7T_4 (2.67), G_5T_4 (3.00), G_3T_4 (3.00), G_1T_4 (3.00) (Table 43).

Eight tomato genotypes showed reduction under drought treatments in case of flowers per cluster (Appendix VII and Figure 15). The highest reduction percentage (63.98 %) was found in G_8 under T_4 drought treatment whereas minimum reduction percentage (11.17 %) was found in G_2 and G_5 under T_2 treatment.

4.2.1.10 Number of fruit per cluster

Eight genotypes of tomato genotypes showed statistically significant variation in term of number of fruit (Appendix VI). The highest number of fruit per cluster (3.50) was found in G_8 and G_5 which were statistically similar with G_4 and G_6 whereas the lowest (2.67) was found in G_7 (Table 44).

Number of fruit per cluster showed statistically significant variation among the drought treatment (Appendix VI). The highest number of fruit per cluster (4.79) was found in T_1 while the lowest number of fruit per cluster (2.13) was found in T_4 drought treatment (Table 45). With the increase of drought treatment, fruit pr cluster reduced. Flowers per cluster become reduced under increasing drought treatment that results in decrease the number of fruit per cluster. Similar result was also found by Begum (2016).

Number of fruit per cluster showed statistically significant among the interaction of tomato genotypes and drought treatments (Appendix VI). The highest fruit per cluster (5.00) was found in G_1T_1, G_2T_1, G_3T_1, G_4T_1, G_5T_1, G_6T_1, G_8T_1 whereas the lowest fruit per cluster (1.67) was found in G_7T_4 (Table 46).

Tomato genotypes showed significant reduction under different drought treatment (Appendix VI and Figure 16). The maximum reduction percentage (61.43 %) was found in G_7 under T_4 treatment whereas the minimum reduction percentage (26.6 %) was found in G_6 under T_2 treatment.

4.2.1.11 Number of fruit per plant

Eight genotypes showed statistically significant variation in term of number of fruit per plant (Appendix VVI). The highest fruit number was found in G_8 (16.25) and G_5 (15.42) whereas the minimum fruit number was found in G_2 (10) (Table 44).

Number of fruit showed statistically significant variation among the drought treatments (Appendix VI). The highest fruit number (19.25) was found in T_1 whereas the lowest (6.04) was found in T_4 drought treatment (Table 45). With the increase of drought treatment, fruit number decreased due to the reduction of cluster per plant, flower per cluster, fruits per cluster.

Number of fruit per plant showed statistically significant variation among the interaction of genotypes and drought treatments (Appendix VI). The maximum fruit number per plant (22.00) was found in G_5T_1 whereas the minimum fruit number was found in G_2T_4 (4.00) which was statistically similar with G_1T_4 (4.67), G_4T_4 (5.00), G_7T_4 (5.00) (Table 46).

Number of fruit per plant showed reduction under drought treatments (Appendix VII and Figure 16). The maximum reduction percentage (76.47 %) was found in G_2 under T_4 drought treatment whereas the minimum reduction (22.56 %) was found G_8 under T_2 treatment. Reduction percentage was higher in higher drought treatment.

4.2.1.12 Length of fruit (mm)

Eight genotypes showed statistically significant variation in term of fruit length (Appendix VI). The highest length was found in G_5 (78.24 mm) whereas the lowest fruit length was found in G_8 (28.56 mm) (Table 44).

Fruit length showed statistically significant variation among the drought treatments (Appendix VI). The highest fruit length (55.02 mm) was found in T_1 whereas the lowest fruit length (44.57 mm) was found in T_4 which was statistically similar with T_3 (47.58 mm).

Fruit length showed statistically significant variation among the interaction of tomato genotypes and drought treatments (Appendix VI). The highest fruit length (83.94 mm) was found in G_5T_1 which was statistically similar with G_5T_2 (80.00 mm) whereas the

Table 44. Performance of tomato genotypes on Number of fruits per cluster, number of fruits per plant and length of fruit[Y]

Genotype [X]	Number of fruit per cluster	Number of fruit per plant	Length of fruit (mm)
G_1	3.00 bc	11.33 b	37.67 e
G_2	3.08 abc	10.00 d	59.25 b
G_3	3.00 bc	10.08 cd	51.47 c
G_4	3.42 ab	11.67 b	51.44 c
G_5	3.50 a	15.42 a	78.24 a
G_6	3.33 ab	11.42 b	42.95 d
G_7	2.67 c	11.08 bc	45.03 d
G_8	3.50 a	16.25 a	28.56 f
CV%	16.34	10.32	12.63
LSD 0.05	0.43	1.03	5.09

[X]Eight tomato genotypes coded from G_1 to G_8

[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Table 45. Performance of drought treatments on Number of fruits per cluster, number of fruits per plant and length of fruit[Y]

Drought treatments[X]	Number of fruit per cluster	Number of fruit per plant	Length of fruit (mm)
T_1	4.79 a	19.25 a	55.02 a
T_2	3.25 b	13.63 b	50.14 b
T_3	2.58 c	9.71 c	47.58 bc
T_4	2.13 d	6.04 d	44.57 c
CV%	16.34	10.32	12.63
LSD0.05	0.30	0.73	3.60

[X]Four drought treatments viz. T_1, Control; T_2 10 days withhold of water; T_3, 20 days withhold of water; T_4 ,30 days withhold of water.

[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

Table 46. Interaction effect of tomato genotypes and droughty treatments Number of fruits per cluster, number of fruits per plant and length of fruit[Y]

Interaction[X]	Number of fruit per cluster		Number of fruit per plant		Length of fruit (mm)	
G_1T_1	5.00	a	19.00	bc	47.04	ghij
G_1T_2	3.00	cde	13.00	ef	38.33	jklm
G_1T_3	2.00	fg	8.67	ij	34.33	klmn
G_1T_4	2.00	fg	4.67	l	31.00	mno
G_2T_1	4.67	a	17.00	cd	65.88	cd
G_2T_2	3.00	cde	11.33	fgh	61.11	de
G_2T_3	2.33	efg	7.67	jk	57.33	def
G_2T_4	2.33	efg	4.00	l	52.67	efgh
G_3T_1	4.67	a	16.67	d	56.55	efg
G_3T_2	3.00	cde	10.67	ghi	52.67	efgh
G_3T_3	2.33	efg	8.00	j	50.00	fghi
G_3T_4	2.00	fg	5.00	l	46.67	ghij
G_4T_1	5.00	a	19.33	b	55.77	defg
G_4T_2	3.67	bc	13.33	ef	52.33	efgh
G_4T_3	3.00	cde	9.00	ij	49.67	fghi
G_4T_4	2.00	fg	5.00	l	48.00	fghij
G_5T_1	4.67	a	22.00	a	83.94	a
G_5T_2	3.33	cd	16.67	d	80.00	ab
G_5T_3	3.00	cde	13.67	e	75.67	abc
G_5T_4	3.00	cde	9.33	hij	73.33	bc
G_6T_1	5.00	a	18.33	bcd	47.48	fghij
G_6T_2	3.67	bc	12.67	efg	42.67	hijkl
G_6T_3	2.67	def	9.00	ij	41.67	ijkl
G_6T_4	2.00	fg	5.67	kl	40.00	ijklm
G_7T_1	4.33	ab	18.00	bcd	49.90	fghi
G_7T_2	2.67	def	13.00	ef	44.00	hijk
G_7T_3	2.00	fg	8.33	j	44.67	hij
G_7T_4	1.67	g	5.00	l	41.55	ijkl
G_8T_1	5.00	a	23.67	a	33.57	lmn
G_8T_2	3.67	bc	18.33	bcd	30.00	mno
G_8T_3	3.33	cd	13.33	ef	27.33	no
G_8T_4	2.00	fg	9.67	hij	23.33	o
CV%	16.34		10.32		12.63	
LSD O.05	0.85		2.05		10.17	

[X]Eight genotypes coded from G_1 to G_8 and four drought treatments viz. T_1, Control; T_2, 10 days withhold of water; T_3 20 days withhold of water; T_4, 30 days withhold of water

[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

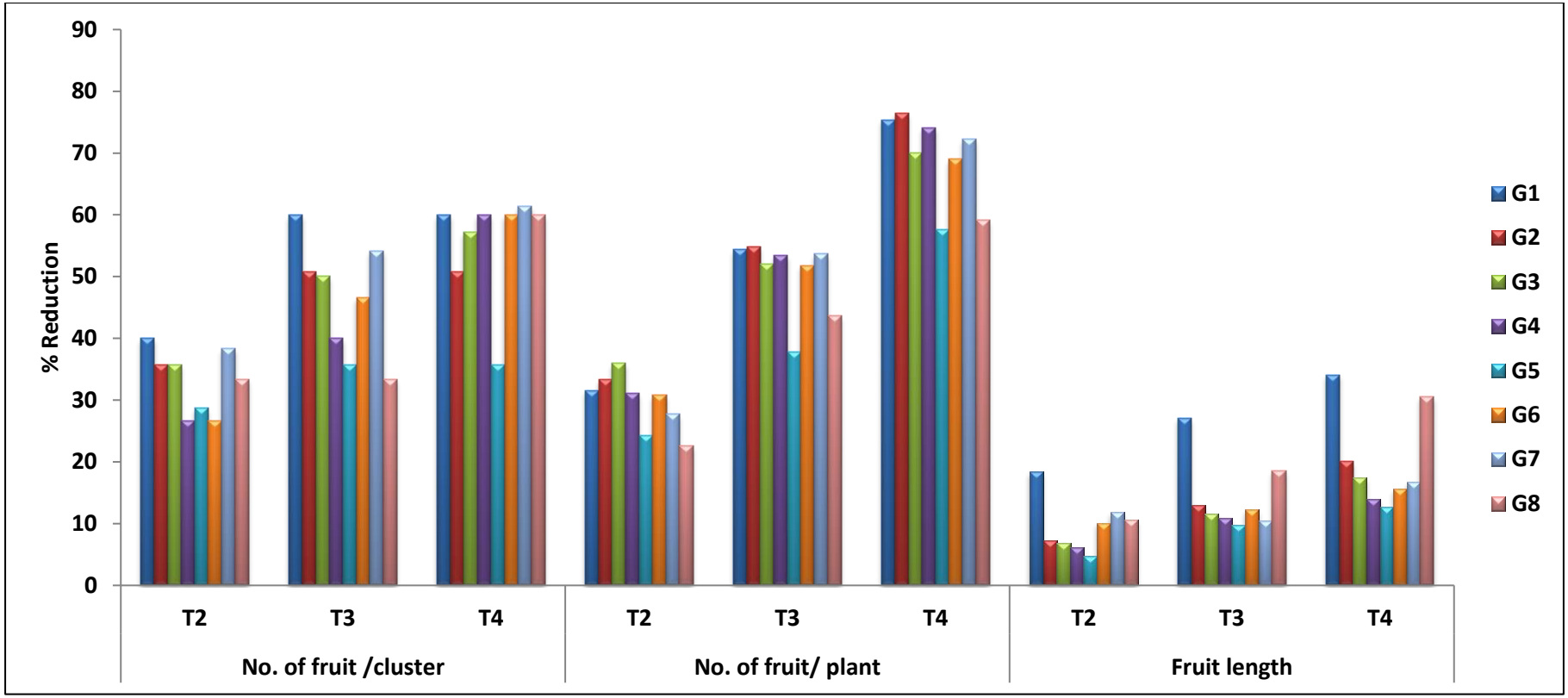

Figure 16. Reduction percentage in No. of fruit/cluster, No. of fruit/plant and fruit length under increasing drought treatment

Lowest fruit length (23.33 mm) was found in G_8T_4 which was statistically similar with G_8T_3 (27.33 mm) (Table 46).

The fruit length showed reduction among the drought treatments (Appendix VII and Figure 16). The highest reduction percentage (34.10 %) was found in G_1 under T_4 drought treatment whereas the minimum reduction percentage (4.69 %) was found in G_5 under T_2 treatments.

4.2.1.13 Fruit diameter (mm)

Eight genotypes showed statistically significant variation in term of fruit diameter (Appendix VI). The maximum fruit diameter (75.05 mm) was found in G_4 whereas the minimum fruit diameter (21.27 mm) was found in G_8 (Table 47).

Fruit diameter showed statistically insignificant variation among the treatments (Appendix VI). The highest fruit diameter (55.58 mm) was found in T_1 treatment whereas the minimum fruit diameter (47.37 mm) was found in T_4 drought treatment (Table 48). With the increase of drought treatment, fruit diameter decreased gradually. Similar result was found by Begum (2016).

Fruit diameter showed statistically significant variation among the interaction of genotypes and drought treatments (Appendix VI). The highest fruit diameter (79.87 mm) was found in G_4T_1 which was statistically similar with G_4T_2 (76.00 mm) whereas the lowest fruit diameter (19.00 mm) was found in G_4T_4 which was statistically similar with G_8T_3 (21.67 mm), G_8T_3 (20.33 mm) and G_8T_1 (24.08 mm) (Table 49).

Fruit diameter showed significant reduction among genotypes under drought treatments (Appendix VII and Figure 17). The highest reduction percentage (26.60 %) was found in G_1 under T_4 drought treatment whereas the lowest reduction percentage (2.62 %) was found in G_5 under T_2 treatment

4.2.1.14 Average fruit weight (g)

Eight genotypes of tomato showed statistically significant variation n term of average fruit weight (Appendix VI). The highest average fruit weight was found in G_4 (43.92

g) which was statistically similar with G_1 (41.33 g) whereas the lowest average fruit weight (9.17 g) was found in G_8) (Table 47).

Average fruit weight showed statistically significant variation among the drought treatments (Appendix VI). The highest average fruit weight (38.49 g) was found in T_1 whereas the lowest average fruit weight (24.37 g) was found in T_4 treatment (Table 48). With the increase of drought treatment, average fruit weight reduced. Less water flow in the fruit cause reduction in fruit size and thus reduces the fruit weight. Tuberosa and Salvi (2006) reported that tomato growth parameters and yield were higher at a high irrigation rate and decreased significantly at drought stress.

Average fruit weight showed statistically significant variation among the interaction of tomato genotypes and drought treatments (Appendix VI). The highest average fruit weight (58.00 g) was found in G_1T_1 which was statistically similar with G_4T_1 (56.33 g) whereas the lowest fruit weight was found in G_8T_4 (7.67 g) which was statistically similar with G_8T_3 (8.67 g), G_8T_2 (9.00 g) and G_8T_1 (11.33 g) (Table 49).

Genotypes showed reduction under different drought treatment in case of average fruit weight (Appendix VII and Figure 17). The maximum reduction percentage (48.28 %) was found in G_1 under T_4 whereas the minimum reduction (4.78 %) was found in G_5 under T_2 treatment.

4.2.1.15 Yield per plant (kg/plant)

Eight genotypes of tomato showed statistically significant variation in term of yield per plant (Appendix VI). The highest yield per plant (0.56 kg) was found in G_4 which was statistically similar with G_1 (0.51 kg) and G_5 (0.51 kg) whereas the lowest yield per plant (0.16 kg) was found in G_8 (Table 47)

Yield per plant showed statistically significant variation among the drought treatments (Appendix VI).the highest yield per plant (0.73 kg) was found in T_1 treatment whereas the lowest yield per plant (0.14 kg) was found in T_4 (Table 48).

Table 47. Performance of tomato genotypes on fruit diameter, average fruit Weight and yield per plant[Y]

Genotype [X]	Fruit diameter (mm)	Average fruit weight (g)	Yield per plant (Kg/plant)
G_1	60.67 bc	41.33 a	0.52 a
G_2	38.89 e	29.33 c	0.32 bc
G_3	63.47 b	30.49 bc	0.34 b
G_4	75.05 a	43.92 a	0.56 a
G_5	46.19 d	32.33 b	0.51 a
G_6	56.88 c	30.08 bc	0.36 b
G_7	42.92 de	24.33 d	0.28 c
G_8	21.27 f	9.17 e	0.16 d
CV%	13.30	12.11	17.57
LSD 0.05	5.50	2.98	0.05

[X]Eight tomato genotypes coded from G_1 to G_8.

[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

Table 48. Performance of drought treatments on fruit diameter, average fruit weight and yield per plant[Y]

Drought treatments[X]	Fruit diameter (mm)	Average fruit weight (g)	Yield per plant (Kg/plant)
T_1	55.58	38.49 a	0.73 a
T_2	50.59	30.34 b	0.40 b
T_3	49.12	27.29 c	0.26 c
T_4	47.37	24.37 d	0.14 d
CV%	13.30	12.11	17.57
LSD0.05	3.89	2.11	0.04

[X]Four drought treatments viz. T_1, Control; T_2 10 days withhold of water; T_3, 20 days withhold of water; T_4 , 30 days withhold of water.

[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

Table 49: Interaction effect of tomato genotypes and drought treatments on fruit diameter, average fruit weight and yield per plant[Y]

Interaction[X]	Fruit diameter (mm)	Average fruit weight (g)	Yield per plant (Kg/plant)
G_1T_1	74.02 abc	58.00 a	1.10 a
G_1T_2	58.00 efg	42.67 b	0.56 de
G_1T_3	56.33 fghi	34.67 def	0.30 hijkl
G_1T_4	54.33 fghij	30.00 fghijk	0.14 pqr
G_2T_1	41.90 kl	38.67 bcd	0.66 bcd
G_2T_2	39.67 kl	29.33 fghijkl	0.33 ghij
G_2T_3	38.00 kl	26.00 ijklmno	0.20l mnopq
G_2T_4	36.00 l	23.33 mno	0.09 qr
G_3T_1	67.87 bcde	43.27 b	0.73 bc
G_3T_2	63.33 cdef	28.70 ghijklm	0.30 hijkl
G_3T_3	62.00 def	26.33 ijklmno	0.21 klmnop
G_3T_4	60.67 def	23.67 lmno	0.12 pqr
G_4T_1	79.87 a	56.33 a	1.10 a
G_4T_2	76.00 ab	44.33 b	0.59 de
G_4T_3	73.67 abc	40.67 bc	0.36 ghi
G_4T_4	70.67 abcd	34.33 defg	0.17 mnopqr
G_5T_1	48.01 ghijk	35.00 cdef	0.77 b
G_5T_2	46.75 hijkl	33.33 defgh	0.58 de
G_5T_3	45.67 ijkl	31.67 efghi	0.43 fg
G_5T_4	44.33 jkl	29.33 fghijkl	0.27 ijklmn
G_6T_1	60.51 def	36.00 cde	0.65 cd
G_6T_2	57.00 efgh	31.00 efghij	0.39 gh
G_6T_3	55.33 fghi	28.00 hijklmn	0.25 jklmno
G_6T_4	54.67 fghij	25.33 ijklmno	0.14 opqr
G_7T_1	48.34 ghijk	29.33 fghijkl	0.53 ef
G_7T_2	42.33 kl	24.33 klmno	0.32 hijk
G_7T_3	41.67 kl	22.33 no	0.19 mnopq
G_7T_4	39.33 kl	21.33 o	0.11 pqr
G_8T_1	24.08 m	11.33 p	0.28 ijklm
G_8T_2	21.67 m	9.00 p	0.16 nopqr
G_8T_3	20.33 m	8.67 p	0.12 pqr
G_8T_4	19.00 m	7.67 p	0.07 r
CV%	13.30	12.11	17.57
LSD O.05	11.00	5.96	0.11

[X]Eight genotypes coded from G_1 to G_8 and four drought treatments viz. T_1, Control; T_2, 10 days withhold of water; T_3 20 days withhold of water; T_4, 30 days withhold of water.

[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

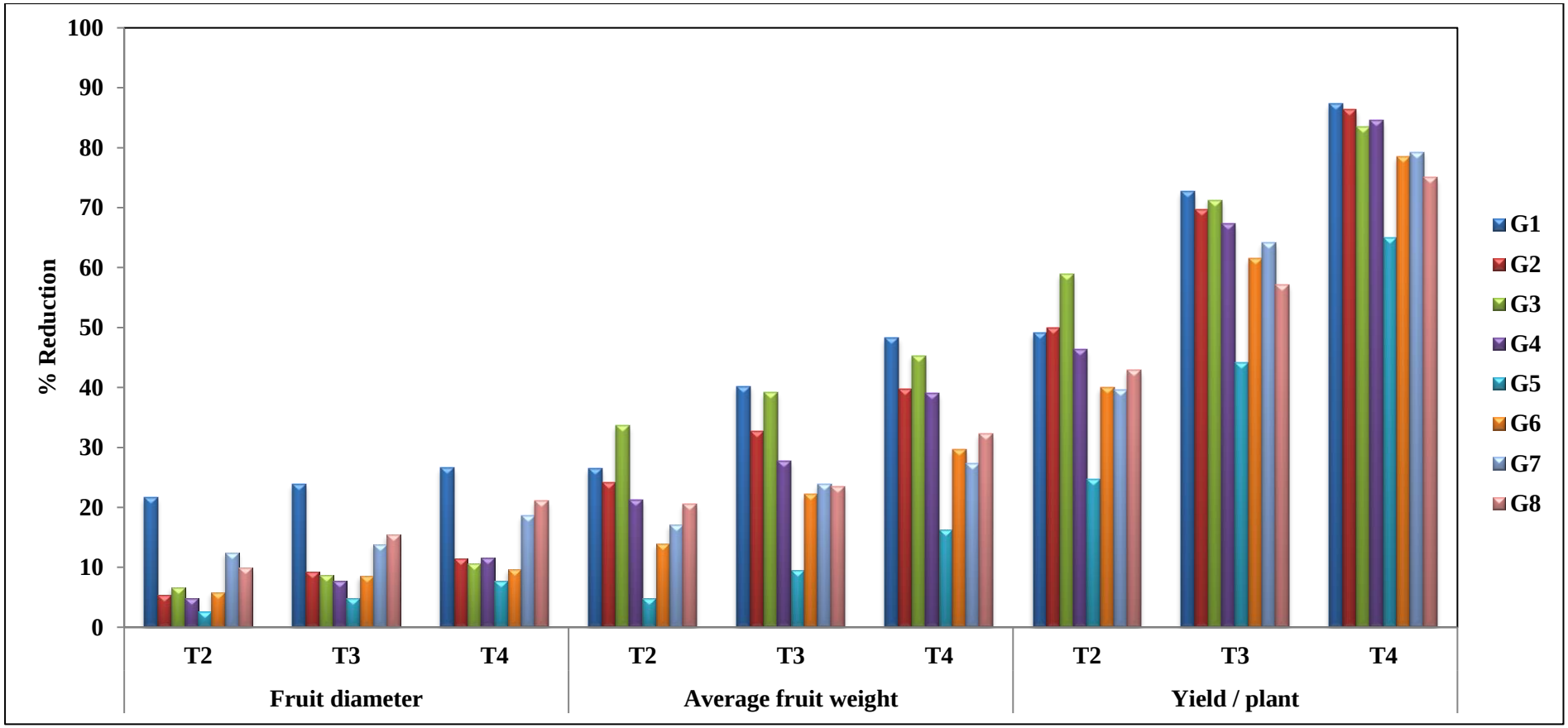

Figure 17. Reduction percentage in Fruit diameter, average fruit weight and yield/plant under increasing drought treatments.

With the increase of drought stress, yield per plant decreased. Due to moisture stress, plant shows reduction in number of flower per cluster, number of fruit setting, number of fruit per plant, fruit length and diameter, single fruit weight and thus results in the reduction of yield per plant. Drought stress reduces the yield per plant Kirnak *et al.* (2001) assessed comparative yield responses of greenhouse-grown tomato to full and deficit irrigation. They reported that marketable tomato yield was lowest under conventional deficit irrigation treatments.

Yield per plant showed significant variation among the interaction of genotypes and drought treatments (Appendix VI). The highest yield per plant (1.10 kg) was found in G_1T_1 and G_4T_1 whereas the minimum yield (0.07 kg) was found in G_8T_4 which was statistically similar with G_2T_4 (0.09 kg) (Table 49).

Genotypes showed reduction in yield per plant under increasing drought treatments (Appendix VII and Figure 17). The maximum reduction percentage was found in (87.28 %) in G_1 under T_4 treatment whereas the minimum reduction percentage was found in G_5T_2 (24.68 %).

4.2.1.16 Root length (cm)

Eight genotypes of tomato showed statistically significant variation in term of root length (Appendix VI). The maximum root length (13.17 cm) was found in G_3 whereas the minimum root length (9.86 cm) was found in G_8 (Table 50).

The root length showed statistically significant variation among the drought treatments (Appendix VI). The maximum root length was found in T_4 (12.38 cm) which was statistically similar with T_1 (12.33 cm) whereas the minimum root length (10.91 cm) was found in T_3 drought treatment (Table 51). Tuberosa and Salvi (2006) reported that tomato growth parameters and yield were higher at a high irrigation rate and decreased significantly at drought stress.

The root length showed statistically significant variation among the interaction of genotypes and drought treatments (Appendix VI). The maximum root length was found in G_1T_1 (14.83 cm) which was statistically similar with G_3T_1 (14.27 cm) whereas the minimum root length was found in G_8T_1 ((8.97 cm) (table 52).

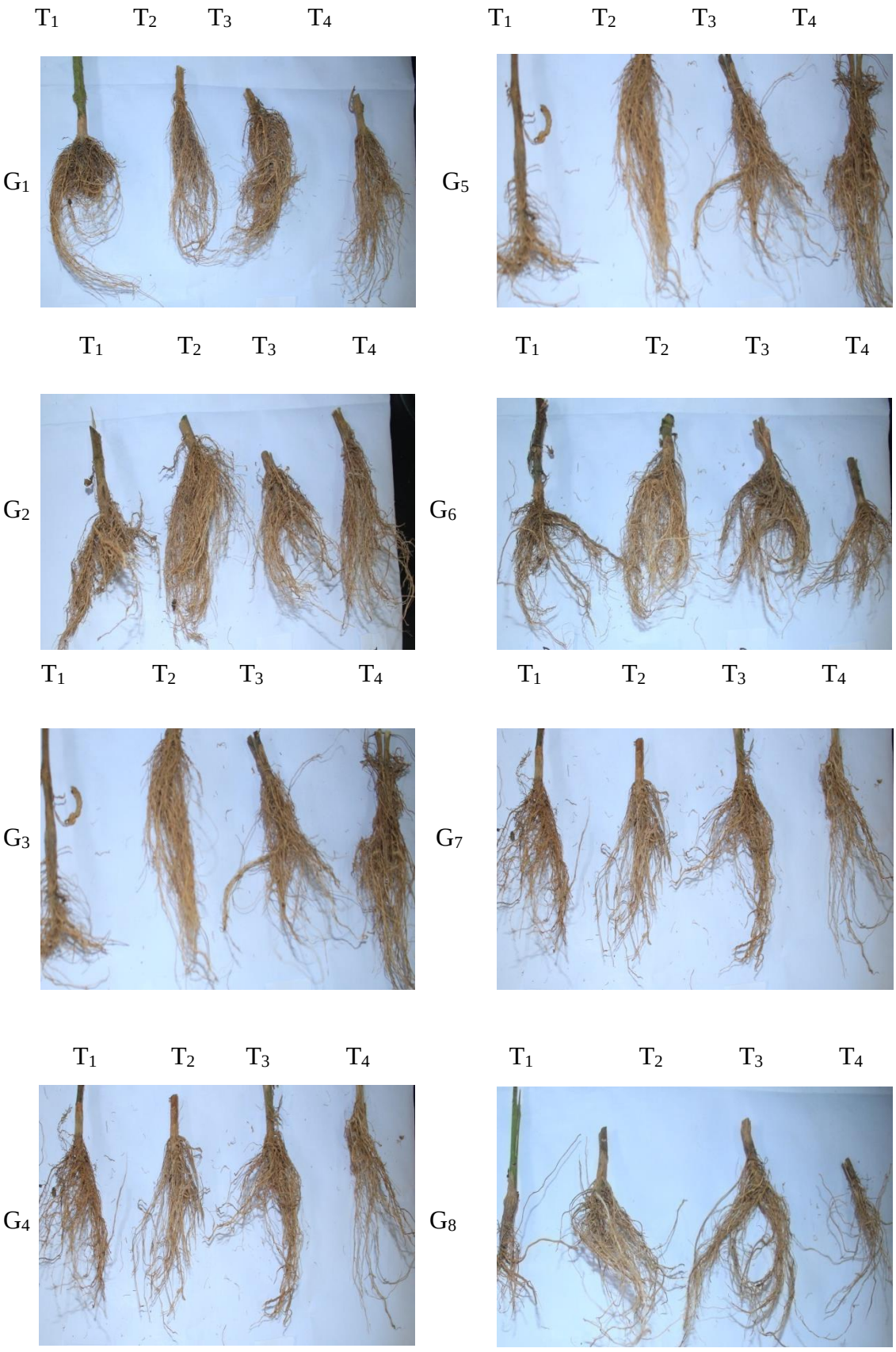

Plate 9. Morphological variation in root of eight tomato genotypes under four Drought treatments.

Genotypes showed reduction/increase in term of root length under drought treatments (Appendix VII and Figure 18). The highest reduction percentage (30.07 %) was found in G_1 under T_3 treatment whereas the lowest reduction percentage (-16.54 %)) was found in G_8 under T_1 treatment.

4.2.1.17 Shoot root ratio

Eight tomato genotypes showed statistically significant variation in term of shoot root ratio (Appendix VII). The maximum shoot root ratio was found in G_8 (6.79) whereas the minimum shoot root ration was found in G_3 (4.45) (table 50).

Shoot root ratio showed statistically significant variation among the drought treatments (Appendix VI). The maximum shoot root ratio was found in T_1 (5.91) which was statistically similar with T_2 (5.63) whereas the minimum shoot root ratio was found in T_4 (4.17) (Table 51).

Shoot root ratio showed statistically significant variation among the interaction of genotypes and drought treatments (Appendix VI). The highest shoot root ratio was found in G_8 (8.96) whereas the lowest shoot root ratio was found in G_5T_4 (3.43) (Table 52).

Tomato genotypes showed reduction /increase in term of shoot root ratio under drought treatments (Appendix VII and Figure 18). The highest reduction percentage was found in G_8 (45.20 %) under T_4 treatment whereas the minimum reduction percentage was found in G_1 (-23.55 %) under T_3 treatment.

4.2.1.18 Skin diameter of fruit (mm)

Eight genotypes of tomato showed statistically significant variation in term of skin diameter of fruit (Appendix VI). The maximum fruit skin diameter (8.03mm) was found in G_2 and G_5 whereas the minimum skin diameter of fruit (3.63 mm) was found in G_6 genotype (Table 50).

Table 50. Performance of tomato genotypes root length, shoot root ratio and skin diameter of fruit[Y]

Genotype [X]	Root length (cm)	Shoot root ratio	Skin diameter of fruit (mm)
G_1	12.29 b	5.81 b	2.87 e
G_2	11.79 c	5.71 b	8.03 a
G_3	13.17 a	4.45 d	4.33 c
G_4	12.39 b	4.80 cd	2.82 e
G_5	12.21 b	4.81 cd	8.03 a
G_6	11.44 c	5.02 c	3.63 d
G_7	10.85 d	4.89 c	5.60 b
G_8	9.86 e	6.79 a	2.83 e
CV%	3.97	9.22	6.11
LSD 0.05	0.39	0.40	0.24

[X]Eight tomato genotypes coded from G_1 to G_8

[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Table 51: Performance of drought treatments on root length, shoot root ratio and skin diameter of fruit[Y]

Drought treatments[X]	Root length (cm)	Shoot root ratio	Skin diameter of fruit (mm)
T_1	12.33 a	5.91 a	5.07
T_2	11.38 b	5.63 ab	4.75
T_3	10.91 c	5.43 b	4.67
T_4	12.38 a	4.17 c	4.59
CV%	3.97	9.22	6.11
LSD0.05	0.27	0.28	0.17

[X]Four drought treatments viz. T_1, Control; T_2 10 days withhold of water; T_3, 20 days withhold of water; T_4 ,30 days withhold of water.

[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

Table 52. Interaction effect of tomato genotypes and drought treatments on root length, shoot root ratio and skin diameter of fruit[Y]

Interaction[X]	Root length (cm)		Shoot root ratio		Skin diameter of fruit (mm)
G_1T_1	14.83	a	5.35	fghi	3.03
G_1T_2	11.80	fg	6.17	cde	2.90
G_1T_3	10.37	i	6.61	bcd	2.80
G_1T_4	12.17	ef	5.12	ghijk	2.77
G_2T_1	11.67	fg	6.83	bc	8.50
G_2T_2	11.30	gh	5.90	defg	8.07
G_2T_3	10.60	hi	5.94	ef	7.87
G_2T_4	13.60	bc	4.18	lmno	7.70
G_3T_1	14.27	ab	4.40	klmn	4.77
G_3T_2	13.18	cd	4.46	jklmn	4.30
G_3T_3	11.57	fg	5.18	fghijk	4.17
G_3T_4	13.67	bc	3.75	no	4.10
G_4T_1	12.83	de	5.22	fghij	3.03
G_4T_2	11.80	fg	5.23	fghij	2.86
G_4T_3	11.80	fg	4.85	hijkl	2.73
G_4T_4	13.13	cd	3.88	mno	2.67
G_5T_1	13.17	cd	5.21	fghij	8.67
G_5T_2	11.50	fg	5.37	fghi	7.83
G_5T_3	10.50	i	5.23	fghij	7.83
G_5T_4	13.67	bc	3.43	o	7.77
G_6T_1	11.50	fg	5.72	efg	3.87
G_6T_2	12.17	ef	4.87	hijkl	3.60
G_6T_3	11.53	fg	4.84	hijkl	3.57
G_6T_4	10.57	hi	4.63	ijklm	3.50
G_7T_1	11.40	g	5.56	efgh	5.77
G_7T_2	8.83	j	5.95	def	5.60
G_7T_3	10.50	i	4.58	ijklm	5.57
G_7T_4	12.67	de	3.48	o	5.48
G_8T_1	8.97	j	8.96	a	2.93
G_8T_2	10.47	i	7.09	b	2.81
G_8T_3	10.43	i	6.18	cde	2.82
G_8T_4	9.57	j	4.91	hijkl	2.77
CV%	3.97		9.22		6.11
LSD O.05	0.76		0.80		0.48

[X]Eight genotypes coded from G_1 to G_8 and four drought treatments viz. T_1, Control; T_2, 10 days withhold of water; T_3 ,20 days withhold of water; T_4, 30 days withhold of water

[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

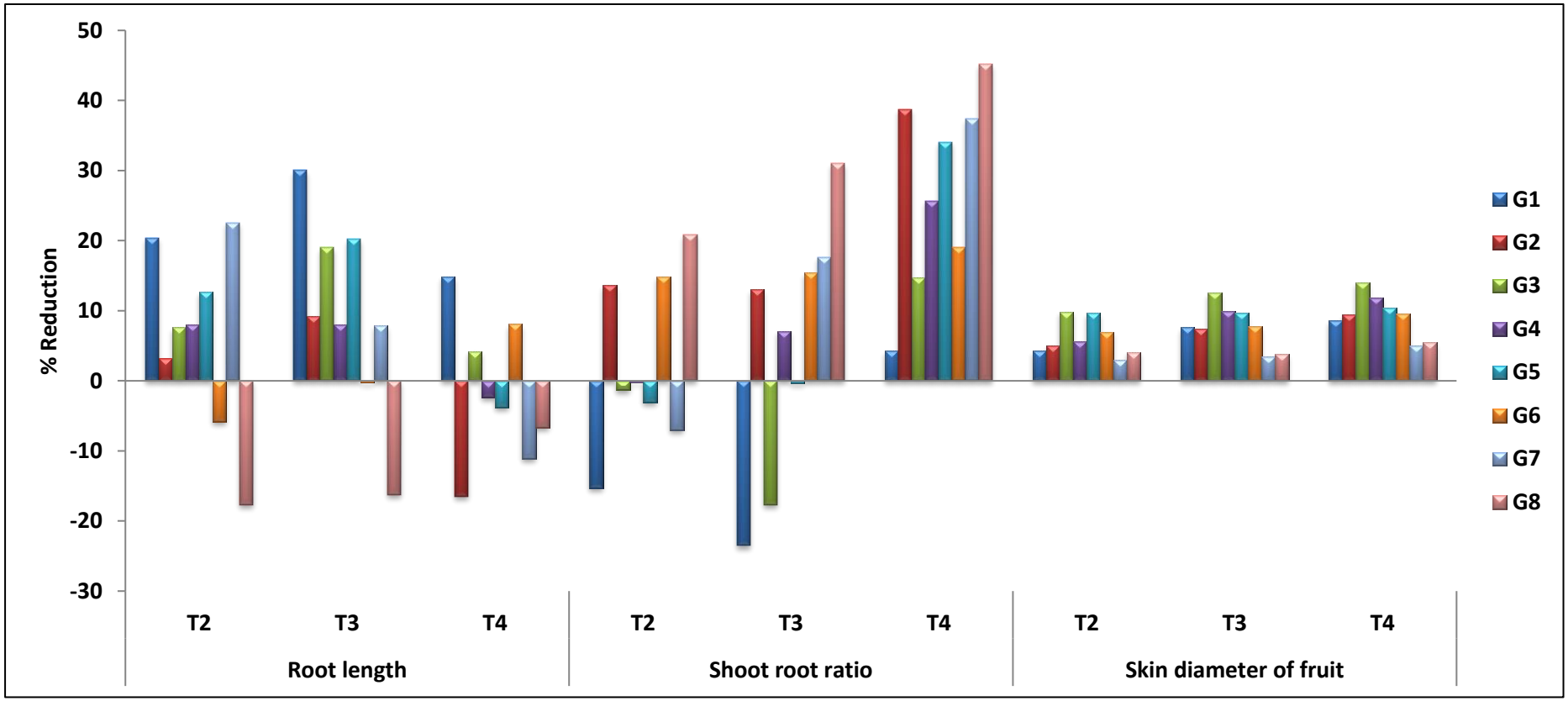

Figure 18. Reduction percentage in root length, shoot root ratio and skin diameter of fruit under increasing drought treatments.

Skin diameter of fruit showed statistically insignificant among the drought treatments (Appendix VI). The highest skin diameter (5.07 mm) was found in T_1 whereas the lowest skin diameter (4.59 mm) was found in T_4 treatment (Table 51). With the increase of drought treatment, fruit skin diameter reduced due to the lower moisture content in fruit.

Fruit skin diameter showed statistically insignificant among the interaction of genotypes and drought treatment (Appendix VI). The maximum skin diameter was found in G_5T_1 (8.67 mm) whereas the minimum skin diameter was found in G_4T_3 (2.73 mm) (Table 52).

Genotypes showed reduction in fruit skin diameter with the increase of drought treatments (Appendix VII and Figure 18). The maximum reduction percentage was found in G_3 (14.04 %) in T_4 whereas the minimum reduction percentage as found in G_7 (2.94 %) under T_2 treatment.

4.2.2 Physiological traits

Physiological traits like Ethylene concentration (ppm), % Membrane Stability Index, chlorophyll content (%), Relative water content, % Moisture content, % dry matter content, Proline content (ug/g) are presented and discussed in this section. ANOVA and reduction percentage are presented in Appendix VI and Appendix VII. Data are arranged in table, graph for better understanding.

4.2.2.1 Ethylene content (ppm)

Eight genotypes of tomato showed statistically insignificant in term of ethylene content (Appendix VI). The highest ethylene content (0.30 ppm) was found in G_1 whereas the lowest (0.16 ppm) was found in G_5 (Table 53).

Ethylene content showed statistically insignificant among the drought treatments (Appendix VI). The highest ethylene content was found in T_4 (0.22 ppm) whereas the lowest ethylene content was found in T_1 (0.15 ppm) (Table 54). With the increase of drought treatment, ethylene content, ethylene content reduced.

Ethylene content showed statistically insignificant among the interaction of tomato genotypes and drought treatments (Appendix VI). The highest ethylene content was found in G_2T_4 (0.25 ppm) whereas the lowest (0.14 ppm) was found in G_1T_1, G_3T_1, G_4T_1, G_6T_1, G_8T_1 (Table 55).

Ethylene content showed increase among the genotypes under drought treatment (Appendix VII and Figure 19). The highest increase percentage (-71.43 %) was found in G_3 under T_4 whereas the lowest increase was found in G_5 (-6.66 %) under T_3 treatment.

4.2.2.2 Membrane Stability Index (%)

Eight genotype of tomato showed statistically significant variation in case of Membrane stability index (Appendix VI)). The highest MSI as found in G_1 (59.58 %) which was statistically similar with G_5 (58.33 %)) whereas the lowest MSI was found in G_4 (36.08 %) which was statistically similar with G_7 (37.75 %) (Table 53).

MSI showed statistically significant variation among the drought treatments (Appendix VI). The highest MSI was found in T_1 (60.21 %) whereas the lowest MSI (39.83 %) was found in T_4 drought treatment (Table 54). With the increase of drought treatment, MSI decreased significantly in all treatments.

MSI showed statistically significant variation among the interaction of tomato genotypes and drought treatments (Appendix VI). The highest MSI was found in G_1T_1 (76.33 %) whereas G_7T_4 showed lowest MSI (27.33 %) (Table 55).

Tomato genotypes showed reduction in MSI in all treatments (Appendix VII and figure 19). The highest reduction was found in G_7 (47.71 %) under T_3 whereas the lowest reduction percentage was found in G_5 (9.00 %) under T_3 drought treatment.

4.2.2.3 Chlorophyll content (%)

Eight genotypes of tomato showed statistically significant variation in term of chlorophyll content (Appendix VI). The highest chlorophyll content was found in G_5 (51.58 %) which was statistically similar with G_1 (50.00 %) whereas the minimum chlorophyll content as found in G_7 (35.83 %) (Table 53).

Chlorophyll content showed statistically significant variation among the drought treatments (Appendix VI). The highest chlorophyll content (49.58 %) was found in T_1 whereas the lowest (40.29 %) was found in T_4 drought treatment (Table 54). With the increase of drought treatment, chlorophyll content reduced.

Chlorophyll content showed statistically significant variation among the interaction of genotypes and treatments (Appendix VI). The highest chlorophyll content was found in G_1T_1 (56.67 %) which was statistically similar with G_6T_1 (56.00 %) whereas the lowest chlorophyll content was found in G_8T_4 (32.00 %) (Table 55).

Genotypes showed significant reduction in chlorophyll content under increasing drought treatments (Appendix VII and Figure 19). The maximum reduction percentage was found in G_8 (26.14 %) under T_4 whereas the minimum reduction was found in G_2 (5.84 %) under T_2 treatment.

4.2.2.4 Relative water content (%)

Eight genotypes of tomato showed statistically significant variation in term of relative water content (Appendix VI). The highest RWC was found in G_2 (56.75 %) which was statistically similar with G_4 (55.92 %), G_7 (56.67 %), G_8 (55.67 5) while th lowest RWC was found in G_6 (36.08 %) (Table 56).

The RWC showed statistically significant variation among the drought treatments (Appendix VI). The maximum RWC was found in T_1 (56.04 %) whereas the lowest RWC was found in T_4 (44.83 %) (Table 57). With the increase of drought condition, RWC reduced significantly.) The higher relative water content indicated better growth and development, which in turn depends on leaf area. Rapid early growth and maintenance of RWC at reasonably higher level during reproductive phase greatly influences the yield. Sivakumar (2014) also reported that relative water content decreased under drought stress than control.

Table 53. Performance of tomato genotypes ethylene concentration, Membrane Stability Index and chlorophyll content [Y]

Genotype [X]	Ethylene concentration (ppm)	% Membrane Stability Index	Chlorophyll content (%)
G_1	0.30	59.58 a	50.00 ab
G_2	0.20	34.75 d	48.25 b
G_3	0.20	53.83 b	38.25 cd
G_4	0.19	36.08 d	39.58 c
G_5	0.16	58.33 a	51.58 a
G_6	0.19	49.92 c	49.17 b
G_7	0.20	37.75 d	35.83 e
G_8	0.18	48.58 c	36.67 de
CV%	7.14	9.06	6.55
LSD 0.05	0.12	3.50	2.33

[X]Eight tomato genotypes coded from G_1 to G_8.
[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

Table 54.Performance of drought treatments on ethylene concentration, Membrane Stability Index and chlorophyll content [Y]

Drought treatments[X]	Ethylene concentration (ppm)	% Membrane Stability Index	Chlorophyll content (%)
T_1	0.15	60.21 a	49.58 a
T_2	0.17	45.92 b	43.21 b
T_3	0.21	43.46 b	41.58 bc
T_4	0.22	39.83 c	40.29 c
CV%	7.14	9.06	6.55
LSD0.05	0.09	2.48	1.65

[X]Four drought treatments viz. T_1, Control; T_2 10 days withhold of water; T_3, 20 days withhold of water; T_4 ,30 days withhold of water.
[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

Table 55. Interaction effect of tomato genotypes and drought treatments, ethylene concentration, Membrane Stability Index and chlorophyll content [Y]

Interaction[X]	Ethylene concentration (ppm)	% Membrane Stability Index	Chlorophyll content (%)
G_1T_1	0.14	76.33 a	56.67 a
G_1T_2	0.15	55.33 cde	49.67 def
G_1T_3	0.20	55.00 de	47.67 efgh
G_1T_4	0.22	51.67 ef	46.00 fgh
G_2T_1	0.15	46.00 fg	54.67 abc
G_2T_2	0.19	32.33 jk	48.00 efgh
G_2T_3	0.22	30.67 jk	46.00 fgh
G_2T_4	0.25	30.00 jk	44.33 ghi
G_3T_1	0.14	64.33 b	44.67 ghi
G_3T_2	0.20	54.67 de	37.33 kl
G_3T_3	0.22	52.67 def	35.67 lmn
G_3T_4	0.24	43.67 g	35.33 lmn
G_4T_1	0.14	52.67 def	46.33 fgh
G_4T_2	0.19	28.67 jk	38.67 jkl
G_4T_3	0.22	34.00 ijk	37.00 klm
G_4T_4	0.22	29.00 jk	36.33 klmn
G_5T_1	0.15	63.00 b	54.33 abcd
G_5T_2	0.17	57.67 bcde	51.33 bcde
G_5T_3	0.16	57.33 bcde	50.67 cdef
G_5T_4	0.17	55.33 cde	50.00 cdef
G_6T_1	0.14	62.33 bc	56.00 ab
G_6T_2	0.20	51.67 ef	48.33 efg
G_6T_3	0.20	44.33 g	46.33 fgh
G_6T_4	0.23	41.33 gh	46.00 fgh
G_7T_1	0.15	58.00 bcde	40.67 ijk
G_7T_2	0.21	35.33 hij	36.00 klmn
G_7T_3	0.22	30.33 jk	34.33 lmn
G_7T_4	0.24	27.33 k	32.33 mn
G_8T_1	0.14	59.00 bcd	43.33 hij
G_8T_2	0.18	51.67 ef	36.33 klmn
G_8T_3	0.20	43.33 g	35.00 lmn
G_8T_4	0.22	40.33 ghi	32.00 n
CV%	7.14	9.06	6.55
LSD O.05	0.24	7.00	4.67

[X]Eight genotypes coded from G_1 to G_8 and four drought treatments viz. T_1, Control; T_2, 10 days withhold of water; T_3 , 20 days withhold of water; T_4, 30 days withhold of water

[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

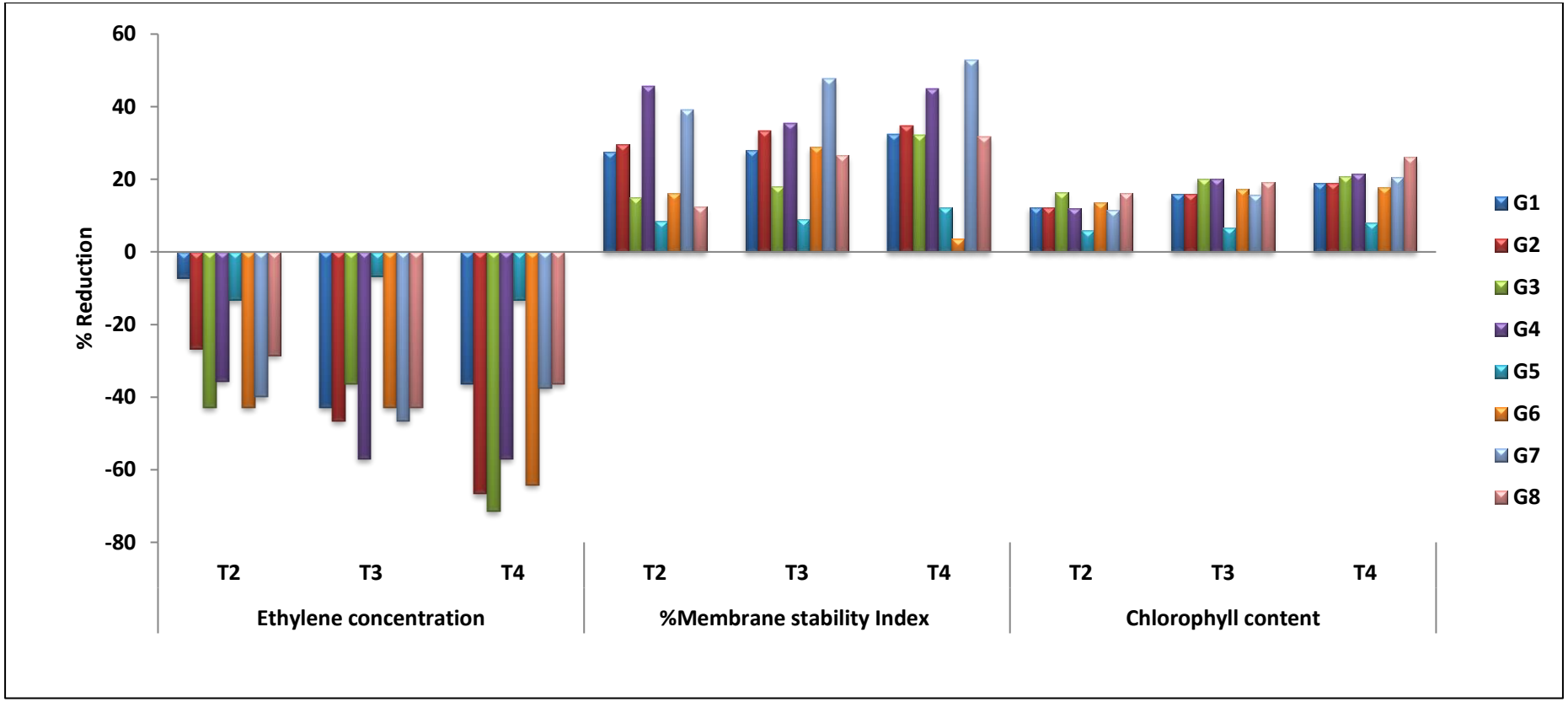

Figure 19. Reduction percentage in Ethylene concentration, % membrane Stability Index and Chlorophyll content under increasing Drought treatments

RWC showed statistically significant variation among the interaction of genotypes and drought treatments (Appendix VI). The highest RWC was found in G_7T_1 (65.67 %) which was statistically similar with G_2T_1 (65.00 %), G_4T_1 (64 %), G_8T_1 (62.67 %) whereas the lowest RWC was found in G_1T_4 (30.67 %) (Table 58).

RWC showed reduction in genotypes under drought treatments (Appendix VII and Figure 20). The maximum reduction percentage (28.55 %) was found in G_6 under T_4 treatment whereas the lowest reduction was found in G_5 (5.34 %) under T_2 treatment.

4.2.2.5 Moisture content in fruit (%)

Eight genotypes of tomato showed statistically significant variation in term of Moisture content in fruit (Appendix VI). The highest moisture content was found in G_3 (90.75 %) which was statistically similar with G_5 (90.58 %) and G_1 (90.58 %) whereas the lowest moisture content (89.50 %) was found in G_2 (Table 56).

Moisture content showed statistically significant variation among the drought treatments (Appendix VI). The highest moisture content (93.29 %) was found in T_1 whereas the lowest moisture content was found in T_4 (88.46 %) (Table 57). Moisture content in fruit reduced with the increase of drought stress. Due to lack moisture deficit, plant cannot uptake water and thus moisture content in fruit reduced.

Moisture content showed statistically significant variation among the interaction of genotypes and drought treatments (Appendix VI). The highest moisture content was found in G_3T_1 (94.00 %) whereas the lowest moisture content (87.67 %) was found in G_2T_4 (table 58).

Moisture content in fruit was reduced under the increasing of drought stress (Appendix VII and figure 20). The maximum reduction percentage was found in G_3 (5.67 %) under T_4 drought treatment whereas the lowest reduction percentage was found in G_1 (3.56 %) under T_2 treatment. From the reduction percentage table, it was clear that T_4 drought treatments showed higher reduction percentage than other treatments.

Table 56. Performance of tomato genotypes on Relative water content of plant, %Moisture content and % dry matter content in fruit[Y]

Genotype [X]	Relative water content	% Moisture in fruit	% dry matter in fruit
G_1	34.75 c	90.58 ab	9.42 bc
G_2	56.75 a	89.50 c	10.5 a
G_3	46.67 b	90.75 a	9.25 c
G_4	55.92 a	89.92 c	10.08 a
G_5	46.75 b	90.58 ab	9.42 bc
G_6	36.08 c	89.92 c	10.08 a
G_7	56.67 a	89.67 c	10.33 a
G_8	55.67 a	90.00 bc	10.00 ab
CV%	5.25	0.83	7.53
LSD 0.05	2.08	0.61	0.61

[X]Eight tomato genotypes coded from G_1 to G_8

[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

Table 57. Performance of drought treatments on Relative water content of plant, %Moisture content and % dry matter content in fruit[Y]

Drought treatments[X]	Relative water content	% Moisture in fruit	% dry matter in fruit
T_1	56.04 a	93.29 a	6.71 d
T_2	47.83 b	89.67 b	10.33 c
T_3	45.92 c	89.04 c	10.96 b
T_4	44.83 c	88.46 d	11.54 a
CV%	5.25	0.83	7.53
LSD0.05	1.47	0.43	0.43

[X]Four drought treatments viz. T_1, Control; T_2 10 days withhold of water; T_3, 20 days withhold of water; T_4 ,30 days withhold of water.

[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Table 58. Interaction effect of tomato genotypes and drought treatments on Relative water content of plant, %Moisture content and % dry matter content in fruit[Y]

Interaction[X]	Relative water content	% Moisture in fruit	% dry matter in fruit
G_1T_1	42.33 g	93.67 ab	6.33 gh
G_1T_2	34.00 hi	90.33 c	9.67 f
G_1T_3	32.00 hi	89.67 cde	10.33 def
G_1T_4	30.67 i	88.67 efgh	11.33 abcd
G_2T_1	65.00 a	92.67 b	7.33 g
G_2T_2	56.00 b	89.00 defg	11.00 bcde
G_2T_3	53.33 bcd	88.67 efgh	11.33 abcd
G_2T_4	52.67 bcd	87.67 h	12.33 a
G_3T_1	54.33 bc	94.00 a	6.00 h
G_3T_2	46.00 efg	90.33 c	9.67 f
G_3T_3	44.00 fg	90.00 cd	10.00 ef
G_3T_4	42.33 g	88.67 efgh	11.33 abcd
G_4T_1	64.00 a	93.33 ab	6.67 gh
G_4T_2	54.67 bc	89.33 cdef	10.67 cdef
G_4T_3	53.33 bcd	88.67 efgh	11.33 abcd
G_4T_4	51.67 cd	88.33 fgh	11.67 abc
G_5T_1	50.00 de	93.67 ab	6.33 gh
G_5T_2	47.33 ef	90.00 cd	10.00 ef
G_5T_3	45.67 fg	90.00 cd	10.00 ef
G_5T_4	44.00 fg	88.67 efgh	11.33 abcd
G_6T_1	44.33 fg	93.00 ab	7.00 gh
G_6T_2	35.00 h	89.33 cdef	10.67 cdef
G_6T_3	33.33 hi	88.33 fgh	11.67 abc
G_6T_4	31.67 hi	89.00 defg	11.00 bcde
G_7T_1	65.67 a	93.00 ab	7.00 gh
G_7T_2	55.00 bc	89.33 cdef	10.67 cdef
G_7T_3	53.33 bcd	88.33 fgh	11.67 abc
G_7T_4	52.67 bcd	88.00 gh	12.00 ab
G_8T_1	62.67 a	93.00 ab	7.00 gh
G_8T_2	54.67 bc	89.67 cde	10.33 def
G_8T_3	52.33 bcd	88.67 efgh	11.33 abcd
G_8T_4	53.00 bcd	88.67 efgh	11.33 abcd
CV%	5.25	0.83	7.53
LSD O.05	4.17	1.22	1.22

[X]Eight genotypes coded from G_1 to G_8 and four drought treatments viz. T_1, Control; T_2, 10 days withhold of water; T_3 ,20 days withhold of water; T_4, 30 days withhold of water

[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

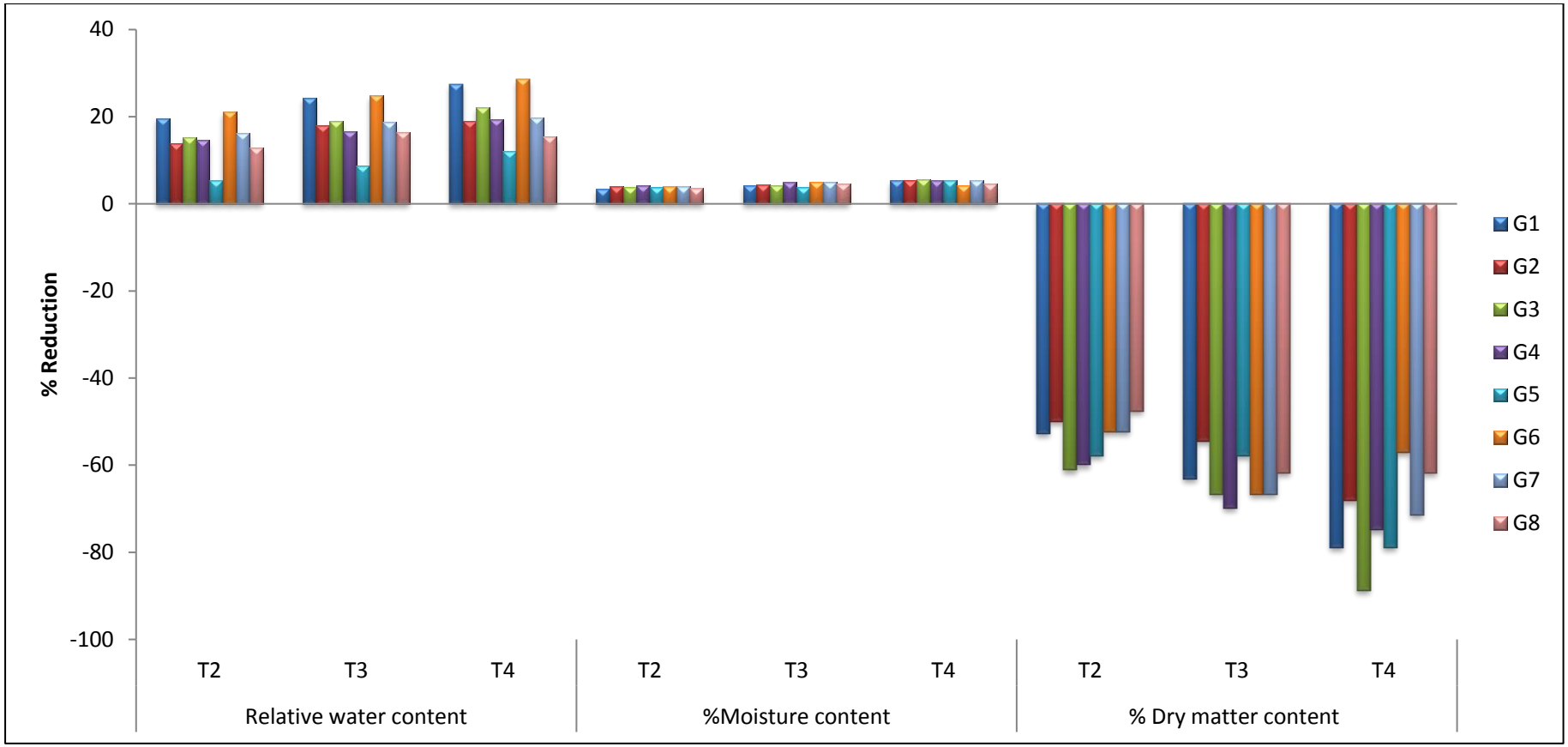

Figure 20. Reduction percentage in Relative water content, % moisture content and % dry matter content under increasing drought treatments.

4.2.2.6 Dry matter content in fruit (%)

Eight genotypes of tomato showed statistically significant variation in term of dry matter content of fruit (Appendix VI). The highest dry matter content was found in G_7 (10.05 %) whereas the lowest dry matter content was found in G_3 (925 %) (Table 56).

Dry matter content showed statistically significant variation among the drought treatments (Appendix VI). The highest dry matter content was found in T_4 (11.54 %) whereas the lowest dry matter content was found in T_1 (6.71 %). With the increase in the moisture stress, dry matter content increased as the moisture content decreased in fruit.

Dry matter content showed statistically significant variation among the interaction of genotypes and drought treatments (Appendix VI). The highest dry matter content was found in G_2T_4 (12.33 %) which was statistically similar with G_7T_4 (12.00 %) whereas the lowest dry matter content was found in G_3T_1 (6.00 %) (Table 58).

Dry matter content increased among the genotypes with the increase of drought treatments (Appendix VII and Figure 20). The highest increase in dry matter was found in G_3 (-88.83 %) under T_4 whereas the lowest increase was found in G_8 (-47.57 %) under T_2.

4.2.2.7 Proline content (ug/g)

Eight genotypes of tomato showed statistically significant in term of proline content (Appendix VI). The highest proline content was found in G_5 (935.67 ug/g) whereas the lowest proline content was found in G_6 (685.51 ug/g) (table 59).

Proline content showed statistically significant among the drought treatments (Appendix VI). The highest proline content was obtained from T_4 (1412.7 ug/g) whereas the lowest proline content was found in T_1 (304.4 ug/g) (Table 60). With the increase of drought stress, proline content was increased. Pan *et al.* (2006) estimated the amount of proline in grown tomatoes under drought stress and showed increased proline concentrations. Begum (2017) found similar pattern of increase of proline under water stress in tomato.

Table 59. Performance of tomato genotypes on proline content in plant part

Genotype [X]	Proline content (ug/ g)
G_1	751.43 b
G_2	712.39 bc
G_3	732.27 b
G_4	726.45 bc
G_5	935.67 a
G_6	685.51 c
G_7	716.16 bc
G_8	721.66 bc
CV%	7.25
LSD 0.05	44.22

[X]Eight tomato genotypes coded from G_1 to G_8

[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Table 60: Performance of drought treatments on proline content in plant parts

Drought treatments[X]	Proline content (ug/g)
T_1	304.4 d
T_2	488.8 c
T_3	784.8 b
T_4	1412.7 a
CV%	7.25
LSD0.05	31.26

[X]Four drought treatments viz. T_1, Control; T_2 10 days withhold of water; T_3, 20 days withhold of water; T_4 ,30 days withhold of water.

[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

Table 61. Interaction effect of tomato genotypes and drought treatments on proline content in plant part

Interaction[X]	Proline content (ug/ g)	
G_1T_1	304.9	k
G_1T_2	460.3	j
G_1T_3	784	f
G_1T_4	1456.6	b
G_2T_1	298.2	k
G_2T_2	447.7	j
G_2T_3	741	fgh
G_2T_4	1362.6	cd
G_3T_1	302.9	k
G_3T_2	492.3	j
G_3T_3	768.3	fg
G_3T_4	1365.6	cd
G_4T_1	307.5	k
G_4T_2	478.3	j
G_4T_3	682.6	ghi
G_4T_4	1437.3	bc
G_5T_1	304.5	k
G_5T_2	627.2	i
G_5T_3	1170	e
G_5T_4	1641	a
G_6T_1	305.9	k
G_6T_2	476.9	j
G_6T_3	674.6	hi
G_6T_4	1284.6	d
G_7T_1	304.7	k
G_7T_2	458.9	j
G_7T_3	724	fgh
G_7T_4	1377	bc
G_8T_1	306.6	k
G_8T_2	468.9	j
G_8T_3	733.9	fgh
G_8T_4	1377.2	bc
CV%	7.25	
LSD O.05	88.43	

[X]Eight genotypes coded from G_1 to G_8 and four drought treatments viz. T_1, Control; T_2, 10 days withhold of water; T_3 ,20 days withhold of water; T_4, 30 days withhold of water

[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

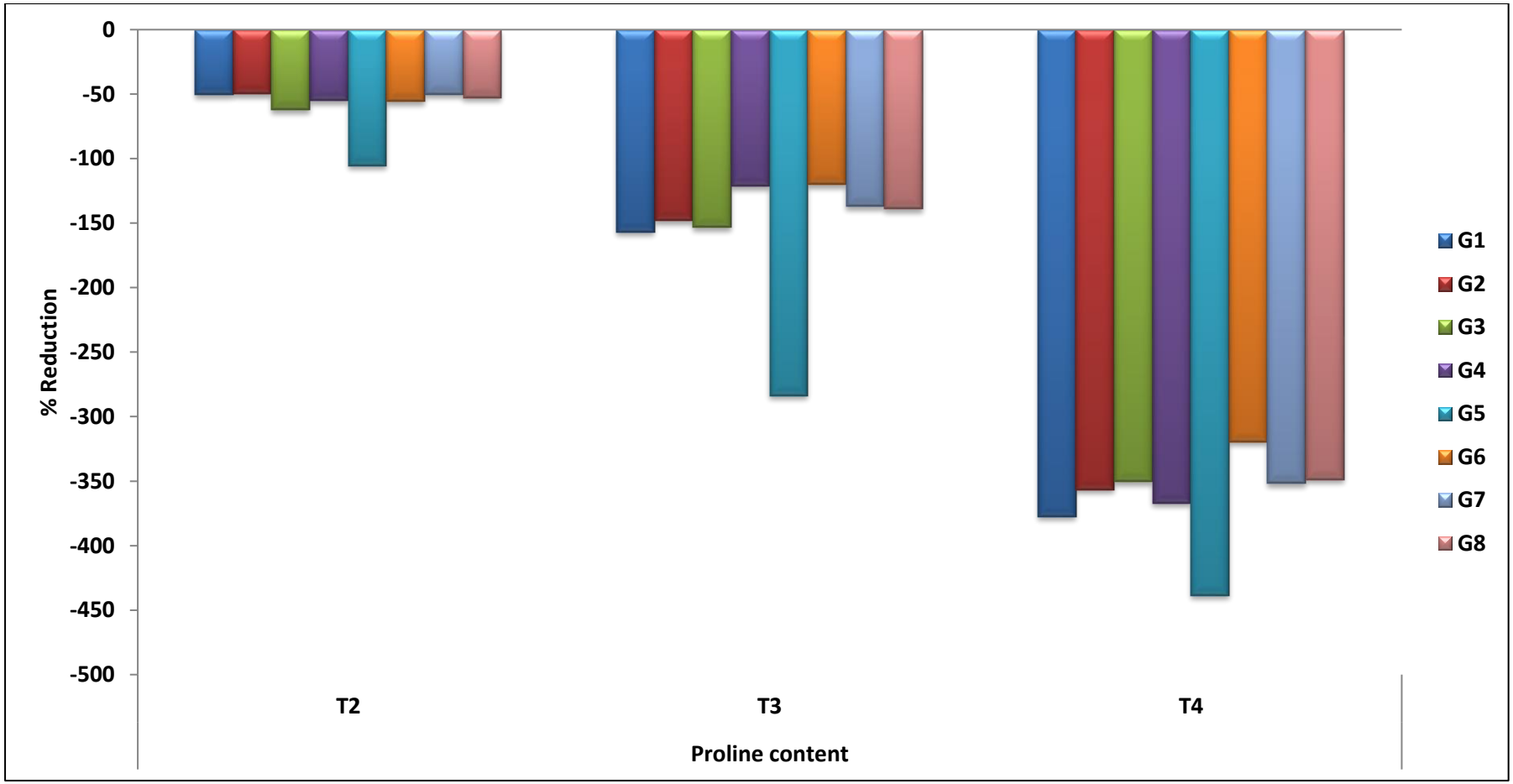

Figure 21. Reduction percentage in proline content under increasing drought treatments

Proline content showed statistically significant among the interaction of genotype and drought treatments (Appendix VI). The highest proline content was found in G_5T_4 (1641 ug/g) whereas the lowest proline content was found in G_5T_1 (304.5 ug/g) (table).

Proline content increased under the increase of drought content among all genotypes (Appendix VII and Figure 21). The highest increase was found in G_5 under T_4 drought treatments whereas the lowest increase was found G_2 under T_2 drought treatment.

4.2.3 Nutritional traits

Nutritional traits viz, %% Brix, ph of fruit, % titrable acidity, vitamin C an lycopene content are presented and discussed in this section. ANOVA and reduction/increase percentage are presented in Appendix VI and Appendix VII respectively. Data are arranged in table and figure for better understanding.

4.2.3.1 Brix content (%)

Eight genotypes showed statistically significant variation in term of % Brix content (Appendix VI). The highest % Brix as found in G_1 (7.98 %) which was statistically significant with G_4 (7.05) whereas the lowest % Brix as found in G_8 (6.01) (Table 62).

%% Brix content showed statistically significant variation among the drought treatments (Appendix VI). The highest %Brix was found in T_4 (7.26 %) whereas the lowest was found in T_1 (6.42 %) (Table 63). With the increase of drought treatments, % brix content was also increased. Under moisture stress condition, soluble sugar is produced more that results in increase in %Brix contet. Helyes *et al.* (2012) also observed that in drought condition Brix % was increased than control.

% Brix content showed statistically significant variation among the interaction of tomato genotypes and drought treatments (Appendix VI). The highest % Brix content as obtained from G_1T_4 (7.59 %) which was statistically similar with G_4T_4 (7.40 %) whereas the lowest % Brix was found in G_8T_1 (5.37 %) (Table 64).

Genotypes showed increase % Brix content with increasing drought treatments (Appendix VII and Figure 22). The maximum increase (highest reduction percentage) was found in G_8 (-24.21 %) under T_4 treatment whereas the minimum increase (lowest reduction percentage) was found in G_5 (-2.53 %) under T_2 treatment.

4.2.3.2 pH of fruit

Eight genotypes showed statistically significant variation in term of pH of fruit (Appendix VI). The highest pH was found in G_8 (4.76) whereas the lowest pH was found in G_1 (4.42) (Table 62).

pH of fruit showed statistically significant variation among the drought treatments (Appendix VI). The highest pH was found in T_1 (4.65) and the lowest pH was found in T_4 (4.50) (Table 63). With the increase of drought treatment, pH of fruit juice was reduced as the titrable acidity is increased.

pH of fruit showed significant variation among the interaction of tomato genotypes and drought treatments (Appendix VI). The highest ph was obtained fromG_8T_1 (5.37) which was statistically similar with GG_5T_3 (4.93) whereas the lowest pH was found in G_1T_4 (4.10) (table 64).

pH of fruit showed reduction among the genotypes under drought treatments (Appendix VII and Figure 22). The percent reduction in pH of fruit with the increase of drought stress was shown in Appendix VII The highest reduction percentage was found in G_1 (-14.28 %) under T_2 whereas the lowest reduction percentage was found in G_8 (7.93 %) under T_2 drought treatments.

4.2.3.3 Titrable Acidity (%)

Eight tomato genotypes showed statistically significant variation in term of titrable acidity (Appendix VI). The highest titrable acidity as found in G_8 (0.61 %) which was statistically similar with G_7 (0.60 %) whereas the lowest titrable acidity was found in G_2 (0.32 %) (Table 62).

Titrable acidity showed statistically significant among the drought treatments (Appendix VI). The highest titrable acidity was found in T_4 (0.59 %) whereas the lowest titrable acidity was found in T_1 (0.34 %) (Table 63).With the increase of drought stress, titrable acidity decreased.

Table 62. Performance of tomato genotypes on %Brix, pH of fruit and %titrable aciity[Y]

Genotype [X]	% Brix	pH of fruit	% Titrable acidity
G_1	7.08 a	4.42 d	0.40 e
G_2	6.97 abc	4.66 ab	0.32 f
G_3	6.98 abc	4.47 cd	0.46 cd
G_4	7.05 ab	4.48 cd	0.44 d
G_5	7.03 abc	4.65 ab	0.52 b
G_6	6.93 bc	4.59 bc	0.49 c
G_7	6.90 c	4.75 a	0.60 a
G_8	6.01 d	4.76 a	0.61 a
CV%	2.60	3.40	7.62
LSD 0.05	0.15	0.13	0.03

[X]Eight tomato genotypes coded from G_1 to G_8

[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Table 63. Performance of drought treatments on %Brix, pH of fruit and %titrable aciity[Y]

Drought treatments[X]	% Brix	pH of fruit	% Titrable acidity
T_1	6.42 d	4.65 a	0.34 c
T_2	6.80 c	4.59 ab	0.50 b
T_3	6.99 b	4.65 a	0.49 b
T_4	7.26 a	4.50 b	0.59 a
CV%	2.60	3.40	7.62
LSD0.05	0.11	0.09	0.02

[X]Four drought treatments viz. T_1, Control; T_2 10 days withhold of water; T_3, 20 days withhold of water; T_4, 30 days withhold of water.

[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

Table 64: Interaction effect of tomato genotypes and drought treatments on %Brix, pH of fruit and %titrable aciity[Y]

Interaction[X]	% Brix		pH of fruit		% Titrable acidity	
G_1T_1	6.30	lm	4.27	lm	0.39	gh
G_1T_2	7.08	cdefg	4.88	abc	0.44	efg
G_1T_3	7.37	abc	4.42	ijkl	0.33	ij
G_1T_4	7.59	a	4.10	m	0.43	g
G_2T_1	6.53	kl	4.71	bcdefg	0.20	lm
G_2T_2	6.94	fghi	4.60	defghijk	0.18	m
G_2T_3	7.13	bcdef	4.75	bcdef	0.35	hi
G_2T_4	7.39	bcd	4.57	defghijk	0.55	c
G_3T_1	6.60	jk	4.38	jkl	0.25	kl
G_3T_2	6.93	fghi	4.38	jkl	0.41	g
G_3T_3	7.03	defg	4.54	defgijkl	0.66	b
G_3T_4	7.36	abc	4.59	defgijkl	0.53	cd
G_4T_1	6.60	jk	4.49	ghijkl	0.31	ij
G_4T_2	7.00	efgh	4.52	efghijkl	0.34	hi
G_4T_3	7.18	bcdef	4.54	defghijk	0.40	gh
G_4T_4	7.40	ab	4.37	kl	0.72	a
G_5T_1	6.73	hjk	4.72	bcdefg	0.25	kl
G_5T_2	6.90	fghi	4.50	fghijkll	0.66	b
G_5T_3	7.13	bcdef	4.94	ab	0.43	fg
G_5T_4	7.37	abc	4.45	hijkl	0.73	a
G_6T_1	6.60	jk	4.69	bcdefgh	0.49	def
G_6T_2	6.90	fghi	4.63	cdefghijk	0.50	cde
G_6T_3	7.03	efg	4.59	defghijkl	0.42	g
G_6T_4	7.12	bcdef	4.46	hijkl	0.54	cd
G_7T_1	6.60	jk	4.93	ab	0.28	jk
G_7T_2	6.83	ghij	4.60	defghijk	0.73	a
G_7T_3	6.90	fghi	4.77	abcd	0.65	b
G_7T_4	7.26	bcde	4.72	bcdefg	0.73	a
G_8T_1	5.37	o	5.01	a	0.55	c
G_8T_2	5.78	n	4.61	defghijk	0.69	ab
G_8T_3	6.21	m	4.64	cdefghi	0.66	b
G_8T_4	6.67	ijk	4.76	abcde	0.53	cd
CV%	2.60		3.40		7.62	
LSD O.05	0.29		0.26		0.06	

[X]Eight genotypes coded from G_1 to G_8 and four drought treatments viz. T_1, Control; T_2, 10 days withhold of water; T_3 ,20 days withhold of water; T_4, 30 days withhold of water

[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

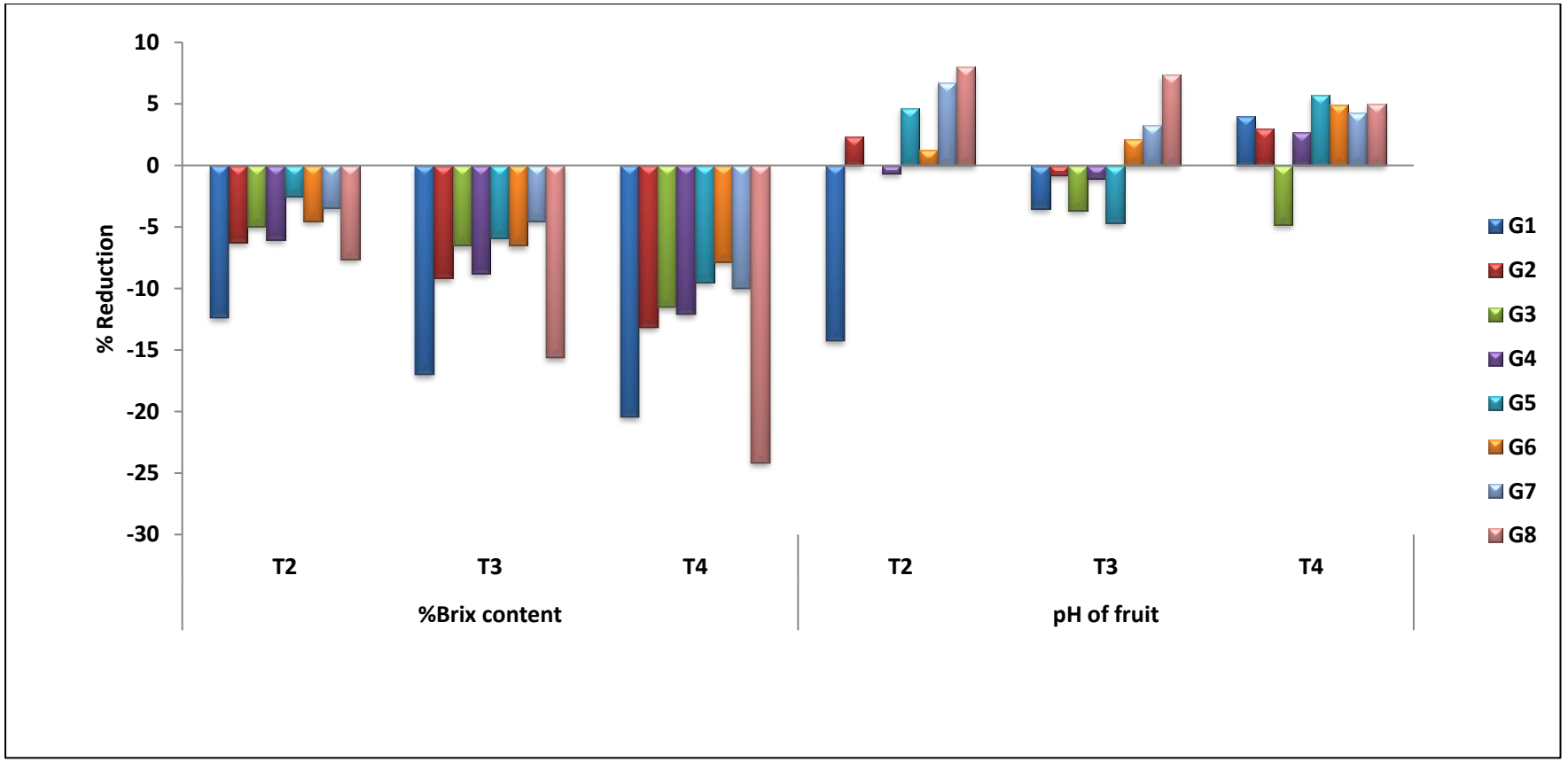

Figure 22: Reduction percentage in Brix content and pH of fruit under increasing drought treatments

Titrable acidity showed statistically significant variation among the interaction of tomato genotypes and drought treatments (Appendix VI). The highest titrable acidity (0.73 %) was obtained from G_7T_2 and G_5T_4 which was statistically similar with G_4T_4 (0.72 %) whereas the lowest titrable acidity was found in G_2T_2 (0.18 %) (Table 64).

Titrable acidity showed increase in all genotypes among the drought treatments (Appendix VII and Figure 23). The highest increase was found in G_5 (-192.00 %) under T_4 drought treatment whereas the lowest increase was found in G_8 (3.64 %) under T_4 treatment.

4.2.3.4 Vitamin C content (mg/ 100 g)

Eight genotypes of tomato showed statistically significant variation in term of vitamin C (Appendix VI). The highest vitamin C content was found in G_5 (15.33 mg/ 100 g) whereas the lowest vitamin C was found in G_8 (11.67 mg/ 100 g) (Table 65).

Vitamin C content showed statistically variation among the drought treatments (Appendix VI). The highest vitamin C content was found in T_1 (16.92 mg/ 100 g) whereas the lowest vitamin C content was found in T_4 (10.75 mg/ 100 g) (Table 66). With the increase of drought treatments, vitamin c content reduced. Under moisture stress condition, stomata remain closed most of the times that restrict the absorption of CO_2 and synthesis of Vitamin C reduced.

Vitamin C content showed statistically significant among the interaction of tomato genotypes and drought treatments (Appendix VI). The highest vitamin C content was found in G_5T_1 (17.67 mg/ 100 g) which was statistically similar with G_1T_1 (17.33 mg/ 100 g), G_4T_1 (17.00 mg/ 100 g), G_6T_1 (17.33 mg/ 100 g), G_7T_1 (17.33 mg/ 100 g) whereas the lowest vitamin C content was found in G_8T_4 (9.67 mg/ 100 g) (Table 67).

Vitamin C content showed reduction in all genotypes under increasing drought treatments (Appendix VII and Figure 24). The highest reduction percentage was found in G_7 (42.30 %) under T_4 treatment whereas the lowest reduction percentage (11.48 %) was found in G_2 and G_3 under T_4 drought treatment.

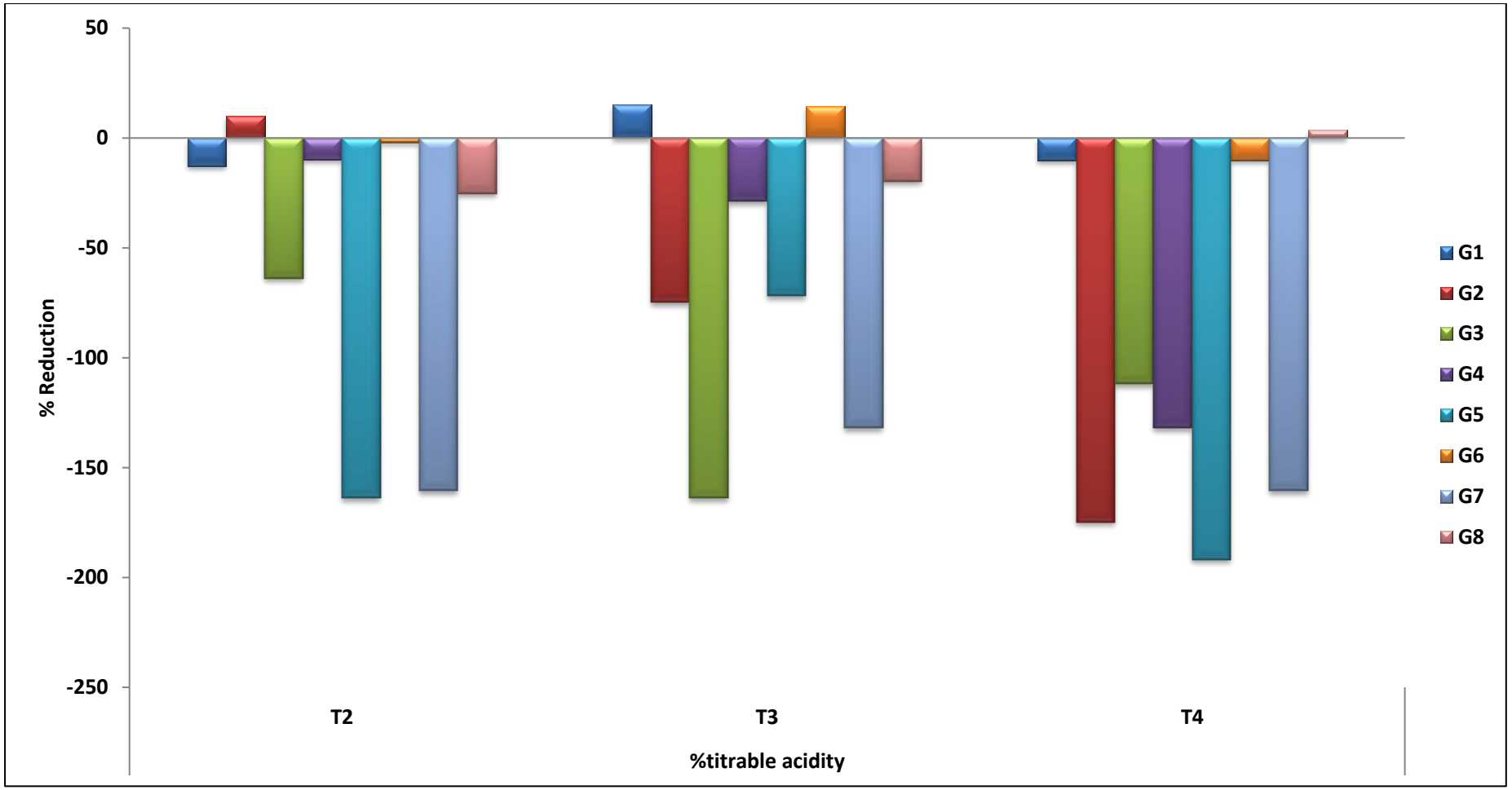

Figure 23. Reduction percentage in titrable acidity under increasing drought treatments

4.2.3.5 Lycopene content (mg/ g)

Eight genotypes of tomato showed statistically showed variation in term of Lycopene content (Appendix VI). The highest lycopene content in case of 472 nm was found in G_5 (9.66 mg/ g)) whereas the lowest lycopene content was found in G_2 (8.14 mg/ g). In case of 502 nm the highest lycopene content was found in G_5 (6.03 mg/ g) whereas the lowest lycopene content was found in G_6 (4.99 mg/ g) (table 65).

Lycopene content showed statistically significant among the drought treatments (Appendix VI). In case of 472 nm wavelength, the highest lycopene content was found in T_1 (11.85 mg/ g) whereas the lowest lycopene content was found in T_4 (6.43 mg/ g). In case of 502 nm wavelength, the highest lycopene content was found in T_1 (7.19 mg/ g) whereas the lowest content was found in T_4 (4.32 mg/ g) (Table 66). In both wavelengths, with the increase of drought stress, the lycopene content decreased. Under moisture stress, the pigment break down and thus lycopene content reduced. Begum (2016) found similar findings.

Lycopene content showed statistically significant among the interaction of tomato genotypes and drought treatments (Appendix VI). Under 472 nm wavelength, the highest lycopene content was found in G_5T_1 (13.18 mg/ g) whereas the lowest lycopene content was found in G_1T_4 (5.40 mg/ g). Under 502 nm , the highest lycopene content was found in G_5T_1 (8.10 mg/ g) whereas G_6T_4 showed lowest lycopene content (3.89 %) (Table 67).

Lycopene content showed reduction among all genotypes under drought treatments (Appendix VII and Figure 24). In caase of 472nm , the highest reduction percentage was found in G_1 (56.49 %) under T_4 treatment whereas the lowest reduction percentage was found in G_3 (11.27 %) under T_2 treatments. In 502 nm, the highest reduction percentage was found in G_1 (44.41 %) under T_4 treatment whereas the lowest reduction percentage was found in G_7 (10.41 %) under T_2 treatment.

Table 65. Performance of tomato genotypes on Vitamin C and Lycopene content[Y]

Genotype [X]	Vitamin C	Lycopene (472 nm)	Lycopene (502 nm)
G_1	13.58 b	8.70 c	5.68 b
G_2	12.17 cd	8.14 d	5.19 c
G_3	12.50 c	8.91 bc	5.71 b
G_4	12.75 c	8.67 c	5.77 b
G_5	15.33 a	9.66 a	6.03 a
G_6	12.67 c	9.06 bc	4.99 d
G_7	12.33 c	8.93 bc	5.80 b
G_8	11.67 d	9.16 c	5.99 a
CV%	6.06	5.57	3.34
LSD 0.05	0.64	0.41	0.15

[X]Eight tomato genotypes coded from G_1 to G_8

[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Table 66. Performance of drought treatments on Vitamin C and Lycopene content[Y]

Drought treatments[X]	Vitamin C	Lycopene (472 nm)	Lycopene (502 nm)
T_1	16.92 a	11.85 a	7.19 a
T_2	12.13 b	9.76 b	6.02 b
T_3	11.71 b	7.58 c	5.05 c
T_4	10.75 c	6.43 d	4.32 d
CV%	6.06	5.57	3.34
LSD0.05	0.45	0.29	0.11

[X]Four drought treatments viz. T_1, Control; T_2 10 days withhold of water; T_3, 20 days withhold of water; T_4, 30 days withhold of water.

[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

Table 67. Interaction effect of tomato genotypes and drought treatments on Vitamin C and Lycopene content[Y]

Interaction[X]	Vitamin C		Lycopene (472 nm)		Lycopene (502 nm)	
G_1T_1	17.33	ab	12.41	ab	7.34	b
G_1T_2	13.33	fg	9.93	ef	6.20	f
G_1T_3	12.33	gh	7.05	ijk	5.08	hi
G_1T_4	11.33	hij	5.40	m	4.08	mn
G_2T_1	15.67	cd	10.49	de	6.71	de
G_2T_2	11.67	hi	8.10	g	5.32	hi
G_2T_3	11.00	ijk	7.16	hijk	4.71	j
G_2T_4	10.33	ijk	6.80	jkl	4.03	mn
G_3T_1	16.67	abc	11.18	cd	7.22	bc
G_3T_2	11.67	hi	9.92	ef	6.07	fg
G_3T_3	11.33	hij	7.82	ghi	5.12	hi
G_3T_4	10.33	jkl	6.68	jkl	4.44	jkl
G_4T_1	17.00	ab	11.22	cd	7.34	b
G_4T_2	12.33	gh	9.77	ef	6.18	f
G_4T_3	11.67	hi	7.63	ghi	5.03	i
G_4T_4	10.00	kl	6.07	lm	4.51	jk
G_5T_1	17.67	a	13.18	a	8.10	a
G_5T_2	15.00	de	10.95	cd	6.27	f
G_5T_3	14.67	de	7.83	ghi	5.12	hi
G_5T_4	14.00	ef	6.69	jkl	4.64	jk
G_6T_1	17.33	ab	12.54	ab	6.70	e
G_6T_2	11.67	hi	9.95	ef	5.20	hi
G_6T_3	11.33	hij	7.35	ghij	4.20	lm
G_6T_4	10.33	jkl	6.40	kl	3.89	n
G_7T_1	17.33	ab	11.73	bc	7.01	cd
G_7T_2	11.00	ijk	9.52	f	6.28	f
G_7T_3	11.00	ijk	7.83	ghi	5.34	h
G_7T_4	10.00	kl	6.64	jkl	4.58	jk
G_8T_1	16.33	bc	12.06	b	7.14	bc
G_8T_2	10.33	jkl	9.90	ef	6.66	e
G_8T_3	10.33	jkl	7.97	gh	5.77	g
G_8T_4	9.67	l	6.72	jkl	4.39	kl
CV%	6.06		5.57		3.34	
LSD O.05	1.27		0.81		0.31	

[X]Eight genotypes coded from G_1 to G_8 and four drought treatments viz. T_1, Control; T_2, 10 days withhold of water; T_3 20 days withhold of water; T_4, 30 days withhold of water.

[Y]In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

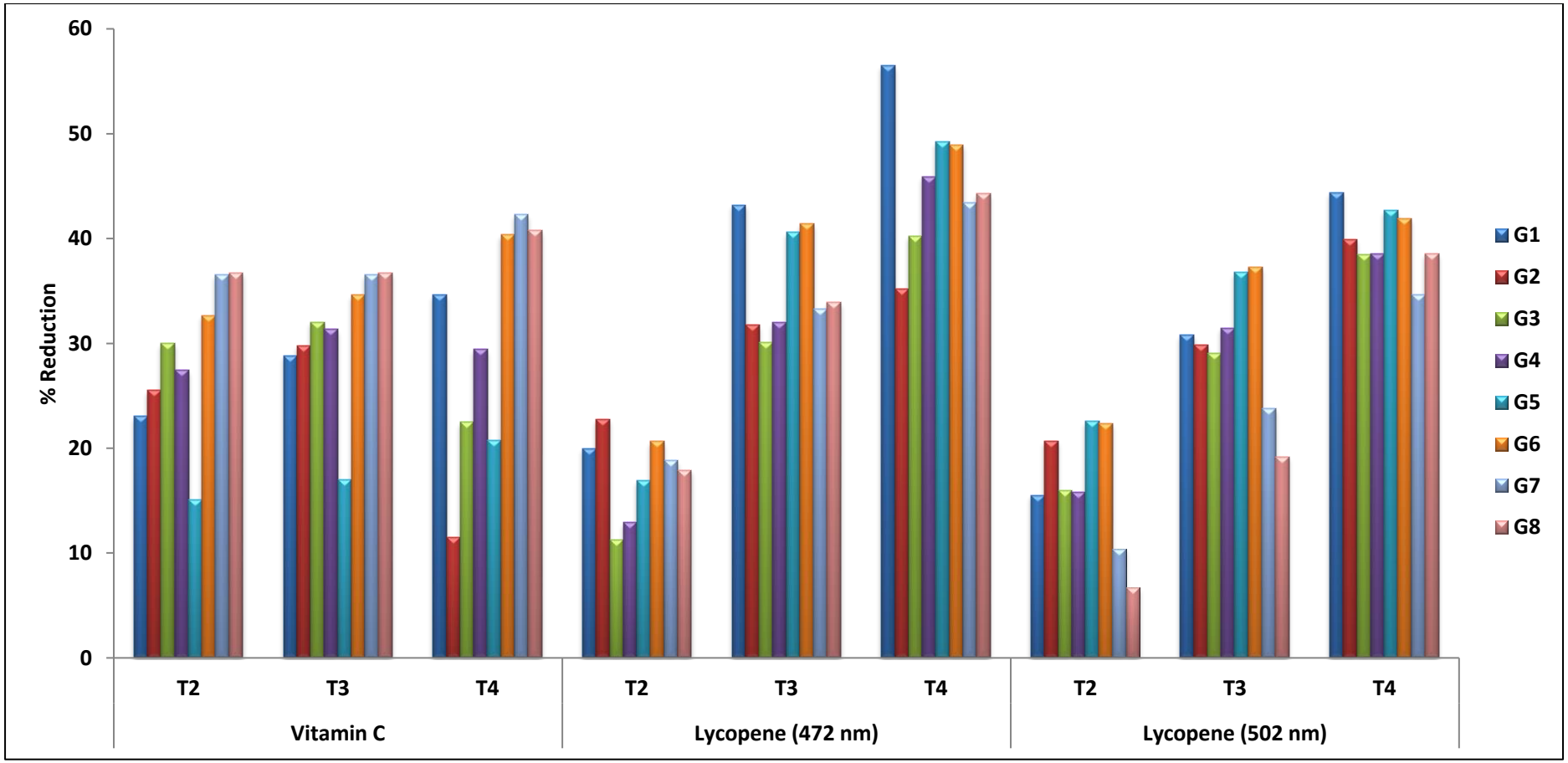

Figure 24. Reduction percentage in Vitamin C and lycopene content under increasing drought treatments.

CHAPTER V

SUMMARY AND CONCLUSION

Two independent pot experiments were conducted for salt and drought in net house, Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University, Dhaka during November 2018 to April 2019. Salt experiment was conducted with eight tomato genotypes under four treatments viz, T_1 (control), T_2 (4 dS/m), T_3 (8 dS/m) and T_4 (12 dS/m) with CRD design with three replication. Drought experiment was conducted with same eight genotypes under four drought treatments viz. T_1 (control), T_2 (10 days withhold of water), T_2 (20 days withhold of water), T_3 (20 days withhold of water) and T_4 (30 days withhold of water) with CRD design with four replication. Genotypes stress interaction was evaluated based on agromorphogenic, physiological and nutritional traits. Data was analyzed with Statistix 10 software. ANOVA, reduction percentage, genotypes performance, genotype stress interaction was arranged in different table and graph.

In interaction of tomato genotypes with salinity treatment, tallest plant was found in G_2T_1 (79.67 cm) which as statistically similar with G_1T_1 (77.33 cm) whereas the shortest plant was found in G_6T_4 (47.00 cm). G_2 under T_3 treatment showed maximum reduction (36.4 %) whereas G_6T_2 showed minimum reduction (4.00 %) in plant height. Maximum number of leaves were found in G_2T_1 (69.33) whereas the minimum number of laves were found in G_3T_4 (13.33) which was statistically similar with G_6T_4 (13.67). The maximum reduction in leaf number was found in G_4T_4 (57.27 %) whereas the minimum reduction was found in G_3T_2 (17.12 %). Leaf area was found highest in G_3T_1 (415 cm2) and lowest in G_2T_4 (124 cm2). The maximum leaf area reduction was found in G_5T_4 (16.80 %) and minimum in G_7T_2 (1.15 %). Number of branches was found highest in G_2T_1 (9.00) which was statistically similar with G_1T_1 (8.33) and lowest in G_6T_4 (3.00). The maximum reduction in branch number was found in G_2T_4 (59.33 %) and minimum in G_6T_2 (6.6 %). The early flowering was found in G_1T_1 (15.67 days) and late flowering was found in G_2T_2 (42 days). The maximum reduction was found in case of first flowering in G_2T_3 (27.38 %) whereas the minimum reduction in G_2T_1 (-32.62 %). The longest time for first fruit setting was found in G_2T_2 (67.67 days) and shortest time (35.67 days) in G_1T_1 and G_5T_1. The maximum reduction in case of first fruit setting was found in G_2T_3 (30.07 %) and

minimum reduction was found in G_5T_3 (-43.09 %). Early maturity was found in G_8T_4 (65.00 days) whereas the late maturity as in G_2T_2 (89.00 days) .The reduction percentage was maximum in G_2T_4 (17.60 %) and minimum in G_2T_2 (-6.80 %). Number of clusters per plant was highest in G_5T_1 (8.33), G_6T_1 (8.33), G_8T_1 (8.33) whereas the lowest in G_2T_4 (3.67). The maximum reduction percentage was found in G_2T_4 (55.94 %) and minimum in G_8T_2 (12.5 %). Number of flowers per cluster was found highest in G_8T_1 (8.33) and lowest in G_6T_4 (2.67). The maximum reduction percentage in case of flower per cluster was found in G_8T_4 (63.98 %) and lowest in G_5T_2 (11.67 %), G_2T_2 (11.67 %). Number of fruits per cluster was highest in G_1T_1 (5.00), G_3T_1 (5.00), G_4T_1 (5.00), G_5T_1 (5.00), G_8T_1 (5.00) whereas the minimum was (1.33) in G_1T_4, G_2T_4, G_5T_4, G_7T_4. The maximum reduction was found in G_3T_4 and G_1T_4 (73.4 %) and minimum in G_4T_2 (26.6 %). Number of fruit per plant was found highest in G_8T_1 (23.67) and lowest in G_2T_4 (4.00), G_5T_4 (4.00). The fruit number reduction was maximum in G_5T_4 (78.18 %) and minimum in G_8T_2 (22.56 %). Length of fruit was highest in G_5T_1 (83.94 mm) which was statistically similar with G_5T_2 (82.49 mm), G_5T_3 (81.78 mm), and G_5T_4 (80.76 mm) and lowest in G_8T_4 (30.08 mm) which was statistically similar with G_8T_1 (32.93 mm), G_8T_2 (32.00 mm) and G_8T_3 (30.08 mm). The maximum reduction was found in G_8T_4 (8.65 %) and lowest in G_6T_2 (1.73 %). Fruit diameter was found highest in G_4T_1 (79.87 mm) which was statistically similar with G_4T_2 (78.00 mm) and lowest in G_8T_4 (20.83 mm) which was statistically similar with G_8T_1 (22.33 mm), G_8T_2 (22.33 mm) and G_8T_3 (21.67 mm). the maximum reduction in fruit diameter was found in G_8T_4 (13.5 %) and minimum in G_4T_2 (2.34 %). Average fruit weight was found highest in G_1T_1 (58.00 g) which was statistically similar with G_4T_1 (56.33 g) and minimum fruit weight in G_8T_4 (2.88 g) which was statistically similar with G_8T_3 (3.67 g), G_8T_2 (4.3 g) and G_8T_1 (6.67 g). The maximum weight reduction was found in G_1T_4 (60.34 %) and minimum in G_6T_2 (13.89 %). Yield per plant was found highest in G_1T_1 (1.10 kg/ plant) which was statistically similar with G_4T_1 (1.09 kg/ plant) whereas the lowest yield per plant was found in G_8T_4 (0.03 kg/plant). The maximum reduction in yield was found in G_1T_4 (90.00 %) and lowest in G_4T_2 (42.20 %). The highest root length was found in G_1T_4 (17.00 cm) and lowest in G_7T_4 (8.33 cm). The maximum reduction in root length was in G_7T_4 (29.58 %) and minimum in G_8T_4 (-34.99 %). The maximum shoot root ratio was found in G_8T_1 (7.51) whereas the lowest was found in G_1T_4 (3.15). The highest skin diameter was found in G_5T_1 (8.67 mm) which was statistically similar with G_2T_1

(8.50 mm) and minimum in G_4T_4 (2.75 mm). The highest skin diameter reduction was found in G_3T_4 (17.19 %) and minimum in G_8T_2 (1.71 %).

In interaction of tomato genotypes and salinity treatments, genotypes showed variation in term of physiological traits. The highest Ethylene content was found in G_2T_4 (0.22 ppm) and lowest in G_8T_1 ((0.13 ppm). The maximum reduction as found in G_8T_4 (-53.85 %) and minimum in G_4T_2 (-6.67 %). The highest MSI (65.67 %) was found in G_1T_1 (65.67 %)) and lowest in G_5T_4 (32.33 %). The maximum reduction was found in G_5T_4 (49.49 %) and minimum in G_6T_2 (14.21%). The highest chlorophyll content was found in G_1T_1 (56.00 %) which was statistically similar with G_6T_1 (54.67 %) and lowest in G_8T_4 (33.67 %). The maximum reduction was found in G_8T_4 (17.21 %) and lowest in G_4T_2 (1.47 %). RWC was highest in G_7T_1 (65 %) and lowest in G_1T_4 (33.33 %). The maximum reduction was found in G_1T_4 (16.67 %) and minimum in G_6T_2 (3.80 %). Moisture content was highest in G_6T_1 (94.12 %) whereas lowest in G_3T_4 (88.98 %). The maximum reduction was found in G_5T_4 (4.15 %) and minimum in G_1T_2 (1.15 %). The highest dry matter content was found in G_3T_4 (11.01) whereas the lowest dry matter content was found in G_6T_1 (5.88 %). The maximum reduction in dry matter content was found in G_6T_4 (-80.07 %) and minimum in G_1T_2 (-16.21 %). The highest Na+ content was found in G_4T_3 (1.40%) which was statistically similar with G_8T_3 (1.37 %) and lowest in G_5T_1 (1.07 %). The maximum reduction was found in G_6T_3 (-25.23 %) and minimum in G_7T_2 (-5.6 %) and G_5T_2 (-5.6 %). The highest K+ content was found in G_4T_1 (1.62 %) which was statistically similar with G_5T_1 (1.60 %) and lowest in G_6T_4 (1.45). The maximum reduction was found in G_4T_4 (9.88 %) and minimum in G_5T_3 (1.87 %).

In interaction of tomato genotypes with salinity stress showed significant variation in nutritional traits. The highest Brix content was found in G_1T_4 (7.58%) whereas the lowest was found in G_8T_1 (5.13 %) which was statistically similar with G_8T_2 (5.42 %). The maximum reduction was found in G_8T_4 (-12.28 %) whereas the minimum reduction was found in G_6T_2 (-1.47 %). The highest pH was found in G_8T_1 (5.01) which was statistically similar with G_7T_1 (4.93) whereas the lowest pH was found in G_1T_4 (4.10). The maximum reduction was found in G_1T_1 (-12.41 %) whereas the minimum reduction was found in G_3T_2 ((0 %). The highest titrable acidity was found in G_5T_4 (0.73 %) whereas the lowest was in G_2T_2 (0.18 %). The maximum reduction was found in G_2T_4 (-175 %) whereas the lowest reduction in G_6T_2 (-2.04 %). Vitamin

c was found highest in G_4T_4 (16.06 mg/ 100 g) whereas the lowest was found in G_3T_1 (13.66 mg/ 100 g). The maximum reduction percentage was found in G_7T_4 (-11.73 %) and minimum reduction percentage in G_6T_2 (-1.81 %). The lycopene content at 472 nm was found highest in G_7T_1 (25.95 mg/ 100 g) whereas the lowest was found in G_8T_3 (15.19 mg/ 100 g). The maximum reduction was found in G_6T_3 (36.25 %) and minimum reduction was found in G_4T_2 (7.16 %). The highest lycopene at 502 nm (20.37 mg/ 100 g) was found in G_3T_1 and G_5T_1 which were statistically similar with G_7T_1 (19.64 mg/ 100 g) and lowest in G_1T_3 (12.49 mg/ 100 g). The maximum reduction was found in G_5T_3 (36.32 %) and minimum was found in G_2T_2 (11.53 %).

In interaction of drought and eight tomato genotypes showed significant variation in agromorphogenic traits. The tallest plant was found in G_8T_1 (80.33 cm) which was statistically similar with G_1T_1 (79.33 cm) and G_2T_1 (79.67 cm) whereas the shortest plant was found in G_7T_4 (44.00 cm). The maximum reduction in plant height was found in G_8T_4 (41.50 %) and minimum reduction was found in G_3T_3 (4.26 %). Number of leaves per plant was found highest in G_5T_1 (75) whereas the lowest leaf number was found in G_8T_4 (11.00) which was statistically similar with G_6T_4. The maximum reduction in leaf number was found in G_6T_4 (60.01 %) whereas the minimum reduction percentage was found in G_5T_2 (12.16 %). Leaf area was found highest in G_5T_1 (500.67 cm2) whereas the lowest leaf area in G_2T_4 (110.67 cm2). The maximum leaf area reduction was found in G_6T_4 (13.48 %) and minimum leaf area reduction in G_7T_2 (2.29 %). Number of branches per plant was found highest in G_2T_1 (10.67) whereas the lowest branch number was found in G_8T_4 (2.67). The maximum reduction was found in G_2T_4 (62.51 %) whereas the minimum reduction was found in G_6T_2 (12.38 %). Early flowering (17.33 days) was found in G_1T_4, G_4T_3, G_4T_4 whereas late flowering (36.00 days) was found in G_6T_4 and G_6T_1. The maximum reduction in fruit was found in G_7T_4 (31.95 %) and minimum reduction in G_8T_2 (-5.41 %). The late fruit setting was found in G_6T_4 (55.00 days) which was statistically similar with G_6T_1 and G_7T_1 whereas the early fruit setting (36.00 days) was found in G_4T_3, G_4T_4 and G_1T_4. The maximum reduction was found in G_7T_4 (20.13 %) and minimum reduction in G_8T_2 (-3.34 %). Longest time for maturity (84.33 days) was found in G_2T_1 and G_6T_1 which was statistically similar with G_2T_2 (81.00 days) whereas the early maturity was found in G_5T_4 (65.33 days). The maximum reduction in maturity was found in G_8T_4 (16.80 days) whereas the lowest reduction was found in G_2T_2 (3.95 %).

The number of clusters per plant (7.67) was found highest in G_2T_1, G_6T_1 and G_7T_1 whereas the lowest cluster number was found in G_2T_4 (3.00). The maximum reduction in number of clusters was found in G_2T_4 (60.88 %) whereas the minimum reduction was found in G_8T_2 (9.00 %). The highest flowers per cluster was found in G_8T_1 (8.33) whereas the lowest was found in G_6T_4 (2.67). The maximum reduction was found in G_8T_4 (63.98 %) and minimum reduction (11.17 %) was found in G_5T_2 and G_2T_2. The highest number of fruit per cluster (5.00) was found in G_1T_1, G_4T_1, G_6T_1, and G_8T_1 whereas the lowest fruit per cluster was found in G_7T7 (1.67). The maximum reduction was found in G_7T_4 (61.43 %) whereas the lowest reduction was found in G_6T_2 (26.6 %). The number of fruit per plant was found G_8T_1 (23.67) whereas the lowest fruit number per plant G_2T_4 (4.00). The maximum reduction was found in G_2T_4 (76.47 %) whereas the minimum reduction percentage was found in G_8T_2 (22.56 %). Fruit length was found highest in G_5T_1 (83.94 mm) whereas the G_8T_4 (23.33 mm). The maximum reduction was found in G_1T_4 (34.10 %) whereas the minimum reduction was found in G_5T_2 (4.69 %). Fruit diameter was found highest in G_4T_1 (79.87 mm) whereas the lowest fruit diameter was found in G_8T_4 (19.00 mm) The maximum reduction was found in G_1T_4 (26.60 %) whereas minimum reduction was found in G_5T_2 (2.62 %). Average fruit weight was found highest in G_1T_1 (58.00 g) which was statistically similar with G_4T_1 (56.33 g) whereas the lowest weight was found in G_8T_4 (7.67 g). The maximum reduction was found in G_1T_4 (48.28 %) and minimum reduction was G_5T_2 (4.78 %). The yield per plant was found highest in G_1T_1 (1.10 kg/plant) and G_4T_1 (1.10 kg/plant) whereas the lowest yield was found in G_8T_4 (0.07 kg/plant). The maximum reduction was found in G_1T_4 (87.28 %) and minimum reduction was found in G_5T_2 (24.68 %). Root length was found highest in G_1T_1 (14.83 cm) and lowest root length was found in G_7T_2 (8.83 cm). The maximum reduction in root length was found in G_1T_3 (30.07) whereas the lowest reduction G_8T_2 (-16.72 %). The highest root length was found in G_8T_1 (8.96 cm) and lowest was found in G_5T_4 (3.43). The highest skin diameter was found in G_2T_1 (8.50 mm) whereas the lowest skin diameter was found in G_4T_4 (2.67 mm).The maximum reduction was found in G_3T_3 (12.57 %) whereas the minimum reduction was found in G_7T_2 (2.94 %).

In interaction of tomato genotypes with drought, there was significant variation in physiological traits. Ethylene concentration was found highest in G_2T_4 (0.25 %) whereas the lowest ethylene concentration (0.14 %) was found in G_1T_1, G_3T_1, G_4T_1,

G_6T_1 and G_8T_1. The maximum reduction was found in G_3T_4 (-71.43 %) whereas the lowest (-7.14 %). The highest MSI was found in G_1T_1 (76.33 %) whereas the lowest MSI was found in G_7T_4 (27.33 %). The maximum reduction was found in G_7T_4 (52.87 %) whereas the lowest MSI was found in G_5T_3 (9.00 %). Highest chlorophyll content was found in G_1T_1 (56.67 %) which was statistically similar with G_6T_1 (56.00 %) whereas the lowest chlorophyll content was found in G_8T_4 (32.00 %). The maximum reduction was found in G_4T_4 (21.58 %) whereas the lowest reduction was found in G_5T_2 (5.84 %). Highest RWC content was found in G_7T_1 (65.67 %) which was statistically similar with G_2T_1 (65.00 %), G_4T_1 (64.00 %), G_8T_1 (62.67 %) whereas the lowest RWC content was found in G_1T_4 (30.67 %). The maximum reduction was found in G_6T_4 (28.55 %) whereas the lowest reduction was found in G_5T_4 (12 %). Moisture content was found highest in G_3T_1 (94.00 %) whereas the lowest in G_2T_4 (87.67 %). The maximum reduction was found in G_3T_4 (5.67 %) whereas the minimum reduction was found in G_1T_2 (3.56 %). Dry matter content was found highest in G_2T_4 (12.33 %) whereas the lowest in G_3T_1 (6 %). The maximum reduction was found in G_3T_4 (-88.83 %) whereas the minimum was found in G_8T_2 (-47.57 %). Highest proline content was found in G_5T_4 (1641 ug/g) whereas the lowest proline content was found in G_3T_1 (302.9 ug/ g). The highest reduction percentage was found in G_5T_4 (-438.92 %) whereas the minimum reduction was found in G_2T_2 (-50.13 %).

In interaction of tomato genotypes with drought, there was significant variation in nutritional traits. Highest Brix content was found in G_1T_4 (7.59 %) whereas the lowest was found in G_8T_1 (5.37 %). The maximum reduction was found in G_8T_4 (-24.21 %) whereas the minimum reduction was found in G_5T_2 (-2.53 %). pH of fruit was found highest in G_8T_1 (5.01) whereas the lowest was found in G_1T_4 (4.10). The maximum reduction in pH was found in G_8T_2 (7.98 %) whereas the minimum reduction was found in G_1T_2 (-14.28 %). Highest titrable acidity (0.73 %) was found in G_5T_4 and G_7T_2 whereas the lowest was found in G_2T_2 (0.18 %). The maximum reduction was found in G_2T_4 (-0.175 %) whereas the minimum reduction was found in G_2T_2 (10 %). Vitamin C content was found in G_5T_1 (17.67 mg/ 100 g) whereas the minimum was found in G_8T_4 (9.67 mg/ 100 g). The maximum reduction was found in G_8T_4 (40.78 %) whereas the minimum reduction was found in G_5T_2 (15.11 mg/ 100 g). The highest lycopene content at 47(2 nm was found in G_5T_1 (13.18 mg/ 100 g) which was statistically similar with G_1T_1 (12.41 mg/ 100 g) whereas the lowest lycopene content

was found in G_1T_4 (5.40 mg/ 100 g). The maximum reduction was found in G_1T_4 (56.49 %) whereas the minimum reduction was found in G_3T_2 (11.27 %). The highest lycopene content at 502 nm was found in G_5T_1 ((8.10 mg/ 100 g) whereas the lowest lycopene content was found in G_6T6 (3.89 mg/ 100 g). The maximum reduction was found in G_1T_4 (44.41 %) whereas the minimum was found in G_8T_2 (6.72 %).

From the research findings of salinity experiment, the following could be recommended

- G_2 could be suggested for for early flowering, early fruit setting, early maturity, higher dry matter and highest lycopene content at mild to moderate saline prone area,
- G_8 could be suggested for early flowering, early fruit setting, early maturity, higher number of clusters per plant and higher number of fruit per plant for moderate salinie area,
- G_4 could be suggested for higher fruit weight, yield per plant and higher soluble solids for mild to moderate saline prone area,
- G_5 could be considered for the cultivation at mild to moderate saline condition for its lower Na^+ uptakement, higher K^+ uptakement and higher vitamin C content.

From the research findings of drought experiment, the following could be suggested

- G_1 could be cultivated at moderate drought condition for early flowering, early fruit fruit setting, early maturity and higher soluble solids,
- G_8 could be suggested for higher cluster per plant, fruit per cluster and higher fruit per plant for moderate drought condition,
- G_4 could be suggested for the cultivation at moderate drought prone area for its higher fruit weight and higher yield,
- G_5 could could be suggested for higher Membrane Stability Index, higher chlorophyll content, higher proline content, higher vitamin C and higher lycopene content at severe drought prone area,

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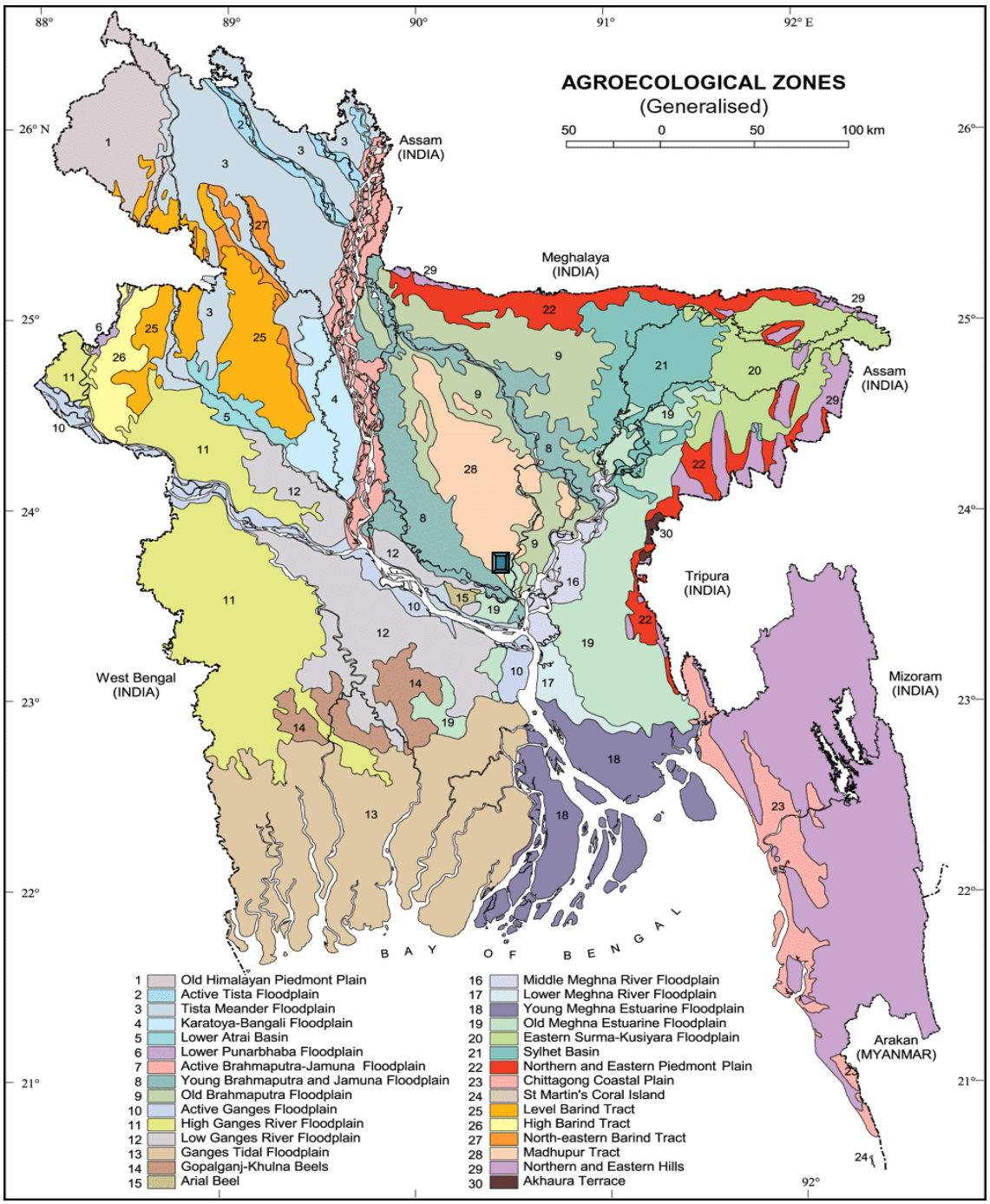
Appendix I. Map showing the experimental site under the study



The experimental site under study

Appendix II. Monthly records of air temperature, relative humidity, rainfall and sunshine hours during the period from November 2018 to March 2019

Month	Year	Monthly average air temperature (ºC)			Average relative humidity (%)	Total rainfall (mm)	Total sunshine (hours)
		Maximum	Minimum	Mean			
Nov	2018	31	18	24	63	Trace	216.4
Dec	2018	27.12	11.56	19.34	61	Trace	212.50
Jan.	2019	28	10	14	65	Trace	212.50
Feb	2019	32	12	22	73.23	4.0	195.00
Mar.	2019	34	16	25	67.23	4.5	225.50

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

Appendix III. 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
Sand	40%
Silt	40%
Clay	20%
Texture	Loamy

Chemical composition:

Soil characters	**Value**
Organic matter	1.44 %
Potassium	0.15 meq/100 g soil
Calcium	3.60 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 soil
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 IV. Analysis of variance of the data on agromorphogenic, physiological and nutritional traits under Salinity treatments.

Source of variation	Degrees of freedom (df)	Mean Sum of Square								
		Plant height	No. of leaves /plant	No. of branches /plant	Leaf area	Days to first flowering	Days to first fruit setting	Days to maturity	No. of cluster /plant	No. of flowers /cluster
Factor A (Genotype)	7	273.90**	1344.33**	4.137**	148882**	462.67**	777.70**	269.429**	2.463**	3.49**
Factor B (Treatment)	3	838.19**	1956.60**	52.958**	3872^{NS}	63.23^{NS}	80.538^{NS}	336.194**	59.70**	41.40**
A x B	21	66.98*	68.22*	2.14**	269^{NS}	123.34*	115.49*	80.23*	0.98*	0.93*
Error	62	24.97	23.89	0.742	1433	24.34	33.773	25.072	0.32	0.22

*Significant at 0.05 level of probability; ** Significant at 0.01level of probality and ^{NS} Non-significant.

Appendix IV. Cont'd

Source of variation	Degrees of freedom (df)	Mean Sum of Square								
		No. of fruit/ cluster	No. of fruit /plant	Length of fruit	Diameter of fruit	Individual fruit weight	Yield per plant	Root length	Shoot root ratio	Skin diameter of fruit
Factor A (Genotype)	7	1.284**	47.05**	2677.12**	4006.8**	1632.1**	0.258**	13.757**	2.483**	59.461**
Factor B (Treatment)	3	43.371**	794.72**	22.6	60.533*	1317.03**	1.618**	1.476^{NS}	1.23^{NS}	0.979**
A x B	21	0.987*	3.58*	46.23*	37.8*	59.60*	0.019*	6.752**	2.12*	0.45*
Error	62	0.261	1.17	15.14	12.21	18.63	0.006	0.571	0.67	0.122

*Significant at 0.05 level of probability; ** Significant at 0.01level of probality and ^{NS} Non-significant.

Appendix IV. Cont'd

Source of variation	Degrees of freedom (df)	Mean Sum of Square								
		Ethylene content	Membrane Stability index	RWC	Chlorophyll Content	% Moisture	% Dry matter	Na^+ content	K^+ content	% Brix
Factor A (Genotype)	7	0.0005**	12.76^{NS}	1119.5**	510.784**	4.02**	4.02**	0.014*	0.006**	4.003**
Factor B (Treatment)	3	0.0151**	3610.86**	139.20**	143.12**	64.0**	64.05**	0.293**	0.723**	1.041**
A x B	21	0.0003*	8.03^{NS}	9.16*	13.95*	0.342*	0.491*	0.002**	0.0009**	0.070**
Error	62	0.0001	7.52	3.05	4.67	0.110	0.16	0.0004	0.0001	0.004

*Significant at 0.05 level of probability; ** Significant at 0.01level of probality and ^{NS} Non-significant.

Appendix IV. Cont'd

Source of variation	Degrees of freedom (df)	Mean Sum of Square				
		Vitamin C	Lycopene (472 nm)	Lycopene (502 nm)	pH of fruit	Titrable Acidity
Factor A (Genotype)	7	2.846**	10.174**	6.196**	0.206**	0.1105**
Factor B (Treatment)	3	6.125**	291.465**	137.75**	0.06^{NS}	0.2653**
A x B	21	0.590*	1.743**	1.35*	0.897**	0.4850**
Error	62	0.189	0.213	0.351	0.024	0.00133

*Significant at 0.05 level of probability; ** Significant at 0.01level of probality and ^{NS} Non-significant.

Appendix V. Reduction percentage in agromorphogenic, physiological and nutritional traits under increasing salinity stress

Genotype	Plant height			No. of leaves/plant			Leaf area			No. of branches/plant			Days to first flowering		
	% T_2	% T_3	% T_4	% T_2	% T_3	% T_4	% T_2	% T_3	% T_4	% T_2	% T_3	% T_4	% T_2	% T_3	% T_4
G_1	7.32	18.53	31.04	23.37	54.47	57.27	3.56	7.13	9.38	36.01	51.98	55.94	-19.15	-29.74	-29.74
G_2	28.04	36.40	29.29	37.50	46.63	53.37	4.2	6.67	8.15	37	41	59.33	-32.62	27.38	26.33
G_3	6.38	11.72	17.55	17.12	31.42	42.86	4.42	6.51	9.08	24.93	30.03	39.04	-9	-9	-13
G_4	6.93	18.09	13.30	25	35.7	41.68	2.67	5.33	9.11	29.88	44.90	44.90	-7.82	-7.82	-11.76
G_5	15.82	12.87	23.26	36.84	44.74	50.53	5.42	15.28	16.80	22.65	36.29	40.93	0	-26.87	-10.48
G_6	4.00	6.90	18.96	23.69	39.48	41.41	3.93	5.08	8.20	6.6	20	40	-16.05	12.26	-15.12
G_7	17.24	2.29	11.5	20.92	36.38	48.19	1.15	3.81	5.13	22.65	44.90	52.61	-4.64	2.34	-5.80
G_8	10.77	12.05	18.06	28.14	47.57	57.27	3.39	4.93	7.39	38.14	42.86	47.57	-31.67	13.72	8.85

Appendix V. Cont'd

Genotype	Days to first fruit setting			Days to maturity			No. of cluster/plant			No. of flowers/ cluster			No. of fruits / cluster		
	% T_2	% T_3	% T_4	% T_2	% T_3	% T_4	% T_2	% T_3	% T_4	% T_2	% T_3	% T_4	% T_2	% T_3	% T_4
G_1	-14.02	-9.33	-9.33	3.83	8.94	11.06	29.12	37.5	54.12	16.67	33.33	50	40	53.4	73.4
G_2	-17.34	30.07	23.71	6.80	13.60	17.60	36.01	48.02	55.94	11.17	16.67	38.83	44.33	46.19	69.28
G_3	-7.06	-7.06	4.43	4	9.77	12	21.77	26.08	39.11	12.38	24.95	43.71	40	60	73.4
G_4	6.08	-3.47	0.87	4.80	9.60	8.72	30.51	39.11	47.85	23.63	41.27	47.09	26.6	40	60
G_5	-14.94	-43.90	-26.15	2.40	0.49	3.35	24.01	31.93	39.98	11.17	33.33	50	35.76	57.17	71..52
G_6	-11.96	-2.39	-19.67	2.36	3.95	1.18	31.93	48.02	43.94	22.16	27.83	55.55	28.69	50.11	64.24
G_7	-4.60	-29.08	2.83	3.83	-0.86	14.04	16.62	29.12	37.5	11.64	24.95	43.71	38.33	53.81	69.28
G_8	4	10	16.67	5.12	12.40	16.67	12.5	31.93	39.98	12	48.01	63.98	33.4	33.4	53.4

Appendix V. Cont'd

Genotype	No. of fruit/plant			Fruit length			Fruit diameter			Average fruit weight			Yield/plant		
	% T_2	% T_3	% T_4	% T_2	% T_3	% T_4	% T_2	% T_3	% T_4	% T_2	% T_3	% T_4	% T_2	% T_3	% T_4
G_1	31.58	54.37	75.42	2.87	6.29	7.42	2.52	3.63	4.71	29.88	45.51	60.34	51.8	74.24	90
G_2	33.35	54.88	76.47	2.93	4.37	6.27	2.15	4.53	7.33	26.74	40.52	50.01	51.51	74.24	88
G_3	35.99	52.01	70	3.18	4.49	6.84	2.75	4.71	6.07	36.14	39.15	50.01	60.27	71.22	83
G_4	31.04	53.44	74.13	2.33	3.62	5.32	2.34	4.01	5.57	18.39	27.21	39.59	42.20	66.06	84.40
G_5	30.87	54.55	78.18	1.73	2.57	3.79	2.62	4.54	6.95	20	33.34	40.48	45.31	70.31	87.5
G_6	30.87	54.55	78.18	1.79	3.29	4.46	2.50	5.80	7.32	13.89	22.22	30.55	40	61.54	78.46
G_7	27.78	53.72	72.22	2.44	3.61	4.65	3.45	5.38	7.00	20.42	29.03	35.48	42.88	67.88	82.14
G_8	22.56	43.68	59.15	2.82	6.29	8.65	7.26	10	13.50	35.08	44.98	56.82	50	68.75	87.5

Appendix V. Cont'd

Genotype	Root length			Shoot root ratio			Skin diameter of fruit			Ethylene concentration			%Membrane stability index		
	% T_2	% T_3	% T_4	% T_2	% T_3	% T_4	% T_2	% T_3	% T_4	% T_2	% T_3	% T_4	% T_2	% T_3	% T_4
G_1	4.47	14.47	-13.33	3.10	4.65	38.95	3.3	5.6	7.6	-14.28	-28.57	-42.86	18.80	32.5	38.07
G_2	-18.18	-2.40	1.60	39.56	38	28.10	4.71	7.18	9.65	-13.33	-26.67	-46.67	15.5	30.48	44.38
G_3	-1.74	-13.00	4.09	8.56	22.04	14.02	7.76	11.95	17.19	-21.43	-28.57	-50.00	15.75	26.62	38.58
G_4	10.37	11.85	9.41	-3.85	7.70	8.45	4.62	6.93	9.24	-6.67	-13.33	-26.66	16.67	31.75	46.87
G_5	16.73	3.53	10.58	-0.42	10.06	14.46	6.57	9.11	11.42	-20	-26.66	-40	19.8	34.37	49.89
G_6	-2.64	4	8	6.67	3.22	12.04	6.98	8.52	9.04	-20	-33.33	-40	14.21	27.87	47.89
G_7	-16.91	-19.78	29.58	28.91	18.94	28.51	1.73	2.60	2.77	-14.28	-35.71	-50	18.46	33.85	47.7
G_8	-13.19	-22.84	-34.99	20.50	33.55	35.55	1.71	2.73	4.43	-30.77	-47.15	-53.85	14.06	30.73	45.83

Appendix V. Cont'd

Genotype	Chlorophyll content			Relative water content			%Moisture content			%Dry matter content			Na^+ content		
	% T_2	% T_3	% T_4	% T_2	% T_3	% T_4	% T_2	% T_3	% T_4	% T_2	% T_3	% T_4	% T_2	% T_3	% T_4
G_1	4.76	7.73	11.91	5	12.5	16.67	1.15	2.75	3.85	-16.21	-39.09	-54.55	-12.03	-25	-23.15
G_2	4.32	9.26	12.09	4.17	7.81	10.42	2.17	2.48	3.2	-25.91	-29.67	-38.21	-12.84	-22.02	-19.27
G_3	3.88	8.53	12.39	5.66	5.03	8	1.55	3.8	4.19	-20.20	-49.50	-54.41	-8.33	-23.15	-19.27
G_4	1.46	2.93	4.38	4.26	4.78	5.85	1.47	3.57	4.51	-21.94	-49.92	-67.25	-8.33	-23.15	-18.51
G_5	4.45	7.69	10.82	4.32	7.90	10.8	1.52	3.04	4.15	-22.59	-45.24	-61.93	-5.60	-14.95	-12.15
G_6	7.32	10.37	14.03	3.8	6.07	10.61	1.83	3.35	4.38	-29.42	-53.74	-70.07	-15.89	-25.23	-19.63
G_7	5.08	9.30	11.85	7.70	10.76	12.31	1.69	2.96	3.98	-25.20	-44.18	-59.49	-5.6	-23.36	-16.82
G_8	9.02	14.75	17.21	5.43	7.6	10.32	1.34	2	4.02	-20.33	-30.57	-61.30	-12.03	-26.85	-19.44

Appendix V. Cont'd

Genotype	K^+ content			K^+ content			% Brix			pH of fruit			%Titrable acidity		
	% T_2	% T_3	% T_4	% T_2	% T_3	% T_4	% T_2	% T_3	% T_4	% T_2	% T_3	% T_4	% T_2	% T_3	% T_4
G_1	3.75	8.13	8.75	3.75	8.12	8.75	-2.42	-5.13	-8.13	-12.41	-3.51	3.98	-12.82	15.38	-10.26
G_2	4.4	7.55	8.18	4.4	7.55	8.18	-1.93	-4.16	-6.24	2.33	-0.85	2.97	10	-75	-175
G_3	2.52	5.67	7.54	2.52	5.67	7.54	-1.80	-4.34	-6.60	0	-3.6	-4.7	-64	-164	-112
G_4	4.32	7.41	9.88	4.32	7.41	9.88	-2.85	-3.85	-5.27	-0.69	2	2.67	-9.67	-29.03	-132
G_5	6.25	1.87	2.5	6.25	1.87	2.5	-1.76	-3.80	-6.29	4.67	-4.67	5.72	-164	-72	-192
G_6	2.5	6.29	8.8	2.5	6.29	8.8	-1.47	-5	-6.92	1.27	2.13	4.9	2.04	14.28	-10.21
G_7	3.77	6.29	8.8	3.77	6.29	8.8	-3.83	-6.13	-8.74	6.7	3.24	4.26	-160.7	-132.1	-160.7
G_8	2.5	6.29	8.17	2.5	6.29	8.17	-5.65	-7.8	-12.28	7.98	7.38	4.99	-25.45	-20	-3.6

Appendix V: Cont'd

Genotype	Vitamin C			Lycopene (472 nm)			Lycopene (502 nm)		
	% T_2	% T_3	% T_4	% T_2	% T_3	% T_4	% T_2	% T_3	% T_4
G_1	-2.63	-9.43	-9.43	13.84	29.99	35.93	16.97	35.78	25.91
G_2	-2.47	-6.77	-10.09	18.47	25	21.59	11.53	23.3	15.23
G_3	-2.7	-5.85	-9.74	19.21	31.55	26.41	16.35	34.17	29.26
G_4	-2.41	-4.76	-6.07	7.16	31.57	26.58	14.28	27.16	21.78
G_5	-3.90	-5.81	-8.20	14.45	36.25	29.79	14.53	27.64	21.2
G_6	-1.81	-3.36	-3.36	22.38	36.25	29.79	11.86	28.03	22.13
G_7	-3.22	-5.03	-11.73	18.23	33.75	36.07	11	31.31	24.59
G_8	-2.62	-5.73	-7.56	19.87	32	25.87	12.16	25.52	18.03

Appendix VI. Analysis of variance of the data on agromorphogenic, physiological and nutritional traits under drought treatments.

Source of variation	Degrees of freedom (df)	Mean Sum of Square								
		Plant height	No. of leaves /plant	No. of branches /plant	Leaf area	Days to first flowering	Days to first fruit setting	Days to maturity	No. of cluster /plant	No. of flowers /cluster
Factor A (Genotype)	7	463.48**	2884.51**	8.44**	202103**	417.59**	417.59**	202.653**	3.106**	3.494**
Factor B (Treatment)	3	1630.92**	1598.40**	52.62**	5819**	69.51**	69.51**	342.899**	47.71**	41.40**
A x B	21	312.16**	81.85**	1.867*	255**	12.741*	19.741*	34.53*	0.742*	0.935*
Error	62	35.64	2.87	0.503	25	3.45	6.451	11.606	0.353	0.224

*Significant at 0.05 level of probability; ** Significant at 0.01 level of probality and ^{NS} Non-significant.

Appendix VI. Cont'd

Source of variation	Degrees of freedom (df)	Mean Sum of Square								
		No. of fruit/ cluster	No. of fruit /plant	Length of fruit	Diameter of fruit	Individual fruit weight	Yield per plant	Root length	Shoot root ratio	Skin diameter of fruit
Factor A (Genotype)	7	1.065*	66.77**	2690.36**	3394.32**	1361.61**	0.229**	12.70**	7.05**	414.78**
Factor B (Treatment)	3	32.57**	766.87**	469.77**	60.67^{NS}	889.09**	1.55**	12.562**	14.07**	3.175^{NS}
A x B	21	1.670*	5.23*	17.55*	123.23*	44.31*	0.038**	3.631**	1.266*	1.32^{NS}
Error	62	0.271	1.58	4.78	40.39	13.32	0.004	0.2176	0.238	5.27

*Significant at 0.05 level of probability; ** Significant at 0.01level of probality and ^{NS} Non-significant.

Appendix VI. Cont'd

Source of variation	Degrees of freedom (df)	Mean Sum of Square								
		Ethylene content	Membrane Stability index	RWC	Chlorophyll content	% Moisture	% Dry matter	Proline	% Brix	Vitamin C
Factor A (Genotype)	7	0.021^{NS}	1197.07**	1012.44**	532.143**	2.594*	2.594*	73412**	1.50**	15.429**
Factor B (Treatment)	3	0.046^{NS}	1912.29**	618.73**	407.583**	113.51**	113.51**	5657525**	3.06**	182.19**
A x B	21	0.021^{NS}	57.03*	13.62*	24.472*	2.304*	2.304*	15676**	0.094*	1.939*
Error	62	0.021	18.40	3.53	8.179	0.554	0.554	2935	0.031	0.608

*Significant at 0.05 level of probability; ** Significant at 0.01level of probality and ^{NS} Non-significant.

Appendix VI. Cont'd

Source of variation	Degrees of freedom (df)	Mean Sum of Square			
		Lycopene (472 nm)	Lycopene (502 nm)	pH of fruit	Titrable Acidity
Factor A (Genotype)	7	2.315**	1.620*	0.206**	0.111**
Factor B (Treatment)	3	138.54**	37.22**	0.117**	0.265**
A x B	21	0.953*	0.200**	0.090*	0.048**
Error	62	0.246	0.035	0.024	0.001

*Significant at 0.05 level of probability; ** Significant at 0.01level of probality and ^{NS} Non-significant.

Appendix VII. Reduction percentage in agromorphogenic, physiological and nutritional traits under increasing drought Stress

Genotype	Plant height			No. of leaves/plant			Leaf area			No. of branches/plant			Days to 1st flowering		
	% T_2	% T_3	% T_4	% T_2	% T_3	% T_4	% T_2	% T_3	% T_4	% T_2	% T_3	% T_4	% T_2	% T_3	% T_4
G_1	8.39	13.44	16.66	14.9	43.9	48.78	2.43	5.58	7.75	46.14	46.14	42.33	8.35	5.97	6.85
G_2	16.32	20.92	28.87	51.81	54.91	58.54	3.99	6.34	12.17	37.49	56.23	62.51	5.45	8.70	16.3
G_3	6.38	4.26	18.09	24.19	35.51	30.67	4.94	7.45	12.81	28.57	42.85	38.15	-1.70	3.41	3.41
G_4	7.95	14.43	23.88	33.32	31.19	31.19	3.67	9.70	13.37	22.17	38.83	50	5.26	8.79	8.79
G_5	10.19	19.90	31.08	12.16	16.67	35.14	6.8	10.25	12.38	22.65	31.79	31.79	0	1.48	4.48
G_6	9.65	14.72	25.39	38.82	44.69	60.01	6.09	8.69	13.48	12.38	24.95	37.52	1.86	14.8	0
G_7	16.83	24.20	30.52	41.29	49.55	56.5	2.29	3.53	4.77	27.83	33.33	50	25.76	26.78	31.95
G_8	7.47	19.50	41.50	24.65	31.87	52.17	5.15	7.03	9.55	21.01	36.81	57.82	-5.41	18.49	22.82

Appendix VII. Cont'd

Genotype	Days to 1st fruit setting			Days to maturity			No. of cluster/plant			No. of flowers/plant			No. of fruit /cluster		
	% T_2	% T_3	% T_4	% T_2	% T_3	% T_4	% T_2	% T_3	% T_4	% T_2	% T_3	% T_4	% T_2	% T_3	% T_4
G_1	4.28	5.97	6.85	5.10	10.21	11.91	29.98	40.03	44.98	16.67	33.33	50	40	60	60
G_2	3.36	5.37	10.07	3.95	6.71	9.88	26.08	52.15	60.88	11.17	16.77	38.83	35.76	50.74	50.74
G_3	-0.88	1.72	1.72	6.10	8.72	12.22	25.04	35.05	50.07	12.38	24.95	43.71	35.76	50.11	57.17
G_4	2.63	4.39	4.39	5.12	8.55	10.68	14.99	40.03	50.07	23.63	41.7	47.08	26.6	40	60
G_5	0	3.21	3.21	4.69	6.01	7.98	14.28	23.86	33.29	11.17	33.33	50	28.69	35.76	35.76
G_6	1.22	9.67	0	4.34	8.30	10.67	26.08	47.84	39.11	22.17	27.83	56	26.6	46.6	60
G_7	16.23	16.87	20.13	5.12	5.98	8.97	35.27	30.51	43.54	12.38	24.95	43.72	38.33	54.19	61.43
G_8	-3.34	11.43	14.09	6.71	12.61	16.80	9	22.65	36.29	12	48.02	63.98	33.4	33.4	60

Appendix VII. Cont'd

Genotype	No. of fruit/ plant			Fruit length			Fruit diameter			Average fruit weight			Yield / plant		
	% T_2	% T_3	% T_4	% T_2	% T_3	% T_4	% T_2	% T_3	% T_4	% T_2	% T_3	% T_4	% T_2	% T_3	% T_4
G_1	31.58	54.37	75.42	18.38	27.02	34.10	21.64	23.90	26.60	26.43	40.22	48.28	49.09	72.72	87.28
G_2	33.35	54.89	76.47	7.24	12.98	20.05	5.32	9.30	11.41	24.15	32.76	39.67	50	69.69	86.36
G_3	35.99	52.01	70	6.86	11.58	17.47	6.69	8.64	10.60	33.67	39.15	45.30	58.90	71.23	83.56
G_4	31.04	53.44	74.13	6.17	10.94	13.95	4.84	7.76	11.52	21.30	27.80	39.06	46.36	67.27	84.55
G_5	24.23	37.86	57.6	4.69	9.85	12.64	2.62	4.87	7.67	4.78	9.51	16.2	24.68	44.16	64.94
G_6	30.88	51.83	69.07	10.13	12.24	15.6	5.80	8.56	9.65	13.89	22.22	29.64	40	61.54	78.46
G_7	27.78	53.72	72.22	11.82	10.48	16.73	12.43	13.80	18.64	17.04	23.86	27.27	39.62	64.15	79.24
G_8	22.56	43.68	59.15	10.63	18.58	30.50	10.01	15.40	21.10	20.56	23.47	32.30	42.85	57.14	75

Appendix VII. Cont'd

Genotype	Root length			Shoot root ratio			Skin diameter of fruit			Ethylene concentration			%Membrane stability Index		
	% T_2	% T_3	% T_4	% T_2	% T_3	% T_4	% T_2	% T_3	% T_4	% T_2	% T_3	% T_4	% T_2	% T_3	% T_4
G_1	20.43	30.07	14.91	-15.33	-23.55	4.29	4.29	7.59	8.58	-7.14	-42.85	-36.36	27.51	27.94	32.30
G_2	3.17	9.16	-16.54	13.62	13.03	38.79	5.05	7.41	9.41	-26.66	-46.66	-66.66	29.72	33.33	34.78
G_3	7.64	18.99	4.20	-1.36	-17.73	14.77	9.85	12.57	14.04	-42.85	-36.36	-71.43	15.02	18.13	32.12
G_4	8.03	8.03	-2.34	-0.19	7.08	25.67	5.61	9.90	11.88	-35.71	-57.14	-57.14	45.56	35.45	44.94
G_5	12.68	20.27	-3.79	-3.07	-0.38	34.1	9.68	9.68	10.38	-13.33	-6.66	-13.33	8.46	9	12.17
G_6	-5.83	-0.26	8.08	14.86	15.38	19.05	6.97	7.75	9.56	-42.85	-42.85	-64.28	16.10	28.87	3.69
G_7	22.54	7.89	-11.14	-7.01	17.63	37.41	2.94	3.46	5.03	-40	-46.66	-37.5	39.08	47.71	52.87
G_8	-17.72	-16.27	-6.68	20.87	31.03	45.20	4.09	3.75	5.46	-28.57	-42.85	-36.36	12.42	26.55	31.64

Appendix VII: Cont'd

Genotype	Chlorophyll content			Relative water content			%Moisture content			% Dry matter content			Proline content		
	% T_2	% T_3	% T_4	% T_2	% T_3	% T_4	% T_2	% T_3	% T_4	% T_2	% T_3	% T_4	% T_2	% T_3	% T_4
G_1	12.35	15.88	18.83	19.67	24.40	27.54	3.36	4.27	5.33	-52.76	-63.19	-78.98	-50.96	-157.1	-377.7
G_2	12.20	15.85	18.91	13.84	17.95	18.96	3.96	4.32	5.39	-50.06	-54.57	-68.21	-50.13	-148.5	-356.9
G_3	16.43	20.14	20.90	15.33	19.01	22.08	3.9	4.25	5.67	-61.16	-66.66	-88.83	-62.53	-153.6	-350.8
G_4	11.90	20.13	21.58	14.57	16.67	19.26	4.28	4.99	5.35	-59.97	-69.86	-74.96	-55.54	-121.9	-367.4
G_5	5.84	6.73	7.96	5.34	8.66	12	3.91	3.91	5.33	-57.97	-57.97	-78.98	-105.9	-284.2	-438.9
G_6	13.69	17.26	17.85	21.04	24.81	28.55	3.94	5.02	4.30	-52.43	-66.71	-57.14	-55.90	-120.5	-319.9
G_7	11.48	15.58	20.51	16.24	18.79	19.79	3.94	5.02	5.37	-52.43	-66.71	-71.43	-50.50	-137.6	-351.9
G_8	16.15	19.22	26.14	12.76	16.49	15.43	3.58	4.65	4.65	-47.57	-61.85	-61.85	-52.93	-139.3	-349.1

Appendix VII: Cont'd

Genotype	%Brix content			pH of fruit			%titrable acidity			Vitamin C			Lycopene (472 nm)		
	% T_2	% T_3	% T_4	% T_2	% T_3	% T_4	% T_2	% T_3	% T_4	% T_2	% T_3	% T_4	% T_2	% T_3	% T_4
G_1	-12.38	-16.98	-20.47	-14.28	-3.51	3.98	-12.82	15.38	-10.26	23.08	28.85	34.62	19.98	43.19	56.49
G_2	-6.28	-9.19	-13.17	2.33	-0.85	2.97	10	-75	-175	25.52	29.8	11.48	22.78	31.74	35.17
G_3	-5	-6.52	-11.52	0	-3.65	-4.8	-64	-164	-112	29.99	32.03	22.48	11.27	30.05	40.25
G_4	-6.06	-8.79	-12.12	-0.67	-1.11	2.67	-9.67	-29.03	-132.2	27.47	31.35	29.41	12.92	32	45.9
G_5	-2.53	-5.94	-9.51	4.66	-4.66	5.72	-164	-72	-192	15.11	16.98	20.77	16.92	40.59	49.24
G_6	-4.55	-6.52	-7.88	1.28	2.13	4.9	-2.04	14.28	-10.20	32.66	34.62	40.39	20.65	41.39	48.96
G_7	-3.49	-4.55	-10	6.69	3.24	4.25	-160.7	-132.1	-160.7	36.52	36.52	42.3	18.84	33.24	43.39
G_8	-7.64	-15.64	-24.21	7.98	7.38	4.99	-25.45	-20	3.64	36.74	36.74	40.78	17.91	33.91	44.28

Appendix VII: cont'd

Genotype	Lycopene (502 nm)		
	% T_2	% T_3	% T_4
G_1	15.53	30.8	44.41
G_2	20.71	29.81	39.94
G_3	15.93	29.08	38.5
G_4	15.8	31.47	38.55
G_5	22.59	36.79	42.72
G_6	22.38	37.31	41.94
G_7	10.41	23.82	34.66
G_8	6.72	19.18	38.52