GENOTYPIC DIFFERENCES IN SOME PHYSIOLOGICAL PARAMETERS UNDER MODERATE DROUGHT STRESS IN TOMATO

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GENOTYPIC DIFFERENCES IN SOME PHYSIOLOGICAL PARAMETERS UNDER MODERATE DROUGHT STRESS IN TOMATO

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CERTIFICATE

This is to certify that thesis entitled, ***"Genotypic differences in some physiological parameters under moderate drought stress in tomato"*** *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* ***Biplob Kumar Roy****, Registration No.:* ***18-09156*** *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 by his.

Dated: December, 2020
Place: Dhaka, Bangladesh

_____
Prof .Dr. Md.Sarowar Hossain
Supervisor

DADICATED TO MY BELOVED PARENTS

Some commonly used abrreviations

Full word	Abbreviations
Agricultural	Agril.
Agriculture	Agric.
And others	et al.
Applied	App.
Bangladesh Agricultural Research Council	BARC
Bangladesh Agricultural Research Institute	BARI
Bangladesh Bureau of Statistics	BBS
Biology	Biol.
Biotechnology	Biotechnol.
Perchloric Acid	HClO4
Calcium ion	Ca2+
Percentage	%
Centimeter	cm
Chlorine ion	Cl-
Chlorophyll	Chl
Completely	CRD
Days After transplanting	DAT
Degree Celsius	°C
Environment	Environ.
Etcetera	etc.
Food and Agriculture Organization	FAO
Gram	G
Gram per liter	g/L
Horticulture	Hort.
International	Intl.
Journal	J.
Kilogram	Kg
Least Significant Difference	LSD
Liter	L
Milligram per liter	mg/L

Some commonly used abrreviations (Cont'd)

Full word	Abbreviations
Milligram(s)	mg
Milliliter	mL
Microgram per gram Number	µg/g
Nanometer	nm
Negative logarithm of hydrogen ion concentration (-log[H+])	pH
Nitric acid	HNO3
Nutrition	Nutr.
Particular pages	pp.
Plant Genetic Resource Centre	PGRC
Potassium Chloride	KCl
Parts per million	ppm
Physiology	Physiol.
Review	Rev.
Relative water content	RWC
Research and Resource Serial	Res.Sl.
Soil Resource Development Institute	Sci.SRDI
Technology	Technol.
That is	i.e.
Ton per hectare	t/ha
Total soluble solid	TSS
Ultra Violet	UV

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GENOTYPIC DIFFERENCES IN SOME PHYSIOLOGICAL PARAMETERS UNDER MODERATE DROUGHT STRESS IN TOMATO

ABSTRACT

A pot experiment was conducted in the net house of the Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University, Dhaka- 1207, during the months of November 2018 to March 2019 observed the Genotypic differences of ten tomato genotypes under three different drought treatments. Two factorial experiment including ten tomato genotypes viz. G_1 (local variety), G_2 (BARI Tomato 16), G_3 (BARI Tomato 3), G_4 (BARI Tomato 15), G_5 (BARI Tomato 2),G_6 (BARI Tomato 18), G_7 (BARI Tomato 19), G_8 (BARI Tomato 14), G_9 (BARI Tomato 11), G_{10} (ROMA VF), and three drought treatments, T_1 (Control), T_2 (15 days withholding of water) and T_3 (35 days withholding of water) were outlined in completely randomized design (CRD) with three replications. The results showed that both the tomato genotypes and drought treatments had significant influence independently and dependently on agromorphogenic, physiological, antioxidant and nutritional traits of tomato plant. Almost all traits responded negatively as the drought level increased except days to first flowering, maturity, proline and brix (%). Regarding yield performance G_8 showed tolerance at moderate drought stress and G_9 at severe drought stress. Regarding antioxidant and nutritional traits, G_5 for brix (%), G_2, G_3 ,G_6 ,G_8 ,G_9 ,G_{10} for Vitamin-C content and G_3 for lycopene content showed tolerance at moderate drought stress period and G_{10} for prolonged and severe drought stress. These genotypes could be recommended to the farmers for cultivation in the drought prone areas of Bangladesh and also could be used in future hybridization or other gene transfer programmes.

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CHAPTER I

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is a diploid (2n=2x=24) and self-pollinated annual crop 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). It is used as a model plant for genetics and genomic studies (Knapp, 2002).Tomato is the only domesticated species (Bilkish, 2016). The fruit of tomato is edible, red in color which is called berry. Fruits of wild plants is 1-2 cm diameter and larger than cultivated forms. Tomato is nutritionally categorized as a vegetable. It has much more influence on nutritional traits but the environment plays major role on its growth where it is grown (Purseglove *et al.,* 1981).

In Bangladesh tomato is the most popular vegetable cultivated with a larger area due to its adaptability (Brown *et al*., 2013; Ahamed, 1995). It is cultivated on 4.5 million hectares in 144 countries and total production is 141 million tons (FAOSTAT, 2013).Tomato contents heigher amount of vitamins A, B and C including calcium and carotene. In our country more than 7 % of vitamin C comes from 100 g edible ripen 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 .(BARI, 2010). From 1990 to 2004 every year consumption of tomatos has been increased ~ 4.5% (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 means the soil moisture scarcity. The northern region of Bangladesh has huge amounts of uncultivable land due to high level of drought and drought affected area is still increasing very rapidly due to climate change. Tomato is commonly cultivated in the Rabi season when scarcity of water rises at its peak point. Drought is considered one of

the major reasons that minimize the upland crop production in Bangladesh (Islam *et al.*, 1982).

Drought is the single most devastating environmental stress, which decreases the crop productivity more than any other environmental stress. Due to continuous short fall in precipitation (meteorological drought) combined with higher evapotranspiration demand leads to agricultural drought (Farooq *et al.*, 2012). Drought means the lack of sufficient moisture required for normal plant growth and development to complete the life cycle of plant. Drought severely affects plant growth and development with substantial reductions in crop growth rate and biomass accumulation. A crop growth models help to predict that this issue will be more severe in future. Drought gives inhinder in the normal growth, disturbs water relations and reduces water use efficiency in plants. Due to drought, the rate of photosynthesis is reduced by closing stomata, membrane damage, and disturbed activity of various enzymes, especially those involved in ATP synthesis (Yuan *et al*., 2015). A wide range of mechanisms using plant where they can withstand in drought such as reduced water loss by increased diffusive resistance, increased water uptake with prolific and deep root systems, and smaller and succulent leaves which reduce transpirational loss of water. Besides Low-molecular-weight osmolytes, including glycinebetaine, and other amino acids, and polyols also play important roles in sustaining cellular functions under drought. Plant growth substances like as salicylic acid, auxins, gibberellins, cytokinins, and abscisic acid modulate plant responses toward drought. By adopting strategies Plant drought stress can be managed stratiges such as mass screening and breeding, marker- assisted selection, and exogenous application of hormones and osmoprotectants to grow plants, as well as engineering for drought resistance.

Tomato (*S. lycopersicum*) has been studied more for its high economic value in the market as a popular vegetable, and high content in health-promoting antioxidant compounds. Tomato is also considered as an excellent plant for both basic and applied plant research due to many reasons, including easiness of culture under a wide range of environments, short life circle photoperiod sensivity high self-fertility and homozygocity great reproductive potential, ease of controlled hybridization etc. (Foolad 2007). In terms of genetics, genomics and breeding the cultivated tomato is a well-studied crop species (Meena and Bahadur 2015). It is popular for its taste, nutritional status and various uses. It is extensively used in salad as well as for culinary purposes and a unique crop which provides a variety of processed products, namely, juice, pickles, paste, puree, sauces,

soup, ketchup etc. Food value of tomato is very rich because of higher contents of vitamins A, B and C including calcium and carotene (Bose and Som 1990). At present leading tomato producing countries of the world are China, United States of America, Turkey, India, Egypt, Italy, Iran, Spain, Brazil Mexico, and Russia (FAO 2010). In Bangladesh it is cultivated as winter vegetable, which occupies an area of 58,854 acres in 2009-10 (BBS 2010).

The total production of tomato was 339 lac tons in China, 137 lac tons in USA, 109 lac tons in Turkey, 103 lac tons in India and 92 lac tons in Egypt in 2008 (FAO, 2010). In Bangladesh 2009-2010 the total production of tomato was 190 thousand metric tons (BBS 2010). The average tomato production in Bangladesh is 50-90 tons/ha (BARI 2010). Now a day, tomatoes are grown round the year. Due to increasing consumption of tomato products, the crop is becoming promising day by day. The best tomato growing areas in Bangladesh are Dinajpur, Rajshahi, Dhaka, Comilla and Chittagong. The yield of tomato is not enough satisfactory in Bangladesh in comparison to the other tomato growing countries of the World. The low yield of tomato in Bangladesh is not an indication of low yielding potentially of this crop. The low yield reason may be, viz. unavailability of quality seeds of high yielding varieties, land for production based on light availability, fertilizer management, pest infestation and improper irrigation facilities as well as production in abiotic stress conditions especially drought (Aditya 1997).

The cultivation of tomato needs proper supply of water and this requirement can meet by applying irrigation. In spite of its broad adaptation, production is concentrated in a few area and rather dry area (Cuortero and Fernandez 1999). The screening of drought tolerant lines and to identify a tolerant genotype is quiet necessary which hopefully may be sustaining a reasonable yield on drought affected soils. Screening may be an easier method to determine drought tolerant genotypes. From the above scheme in mind, the present research work has been undertaken in order to fulfill the following objectives:

- To determine genotype × treatment interaction based on different yield and yield contributing characters as indicators of tolerance ,
- To determine the best drought tolerant genotypes based on agromorphogenic, physiological, antioxidant and nutritional traits and
- To compare the tolerance of genotype, treatment and genotype-treatment interaction for as the membrane stability indices indicator of drought tolerance.

CHAPTER II

REVIEW OF LITERATURE

Tomato is one of the popular and most important vegetable crops in Bangladesh as well as many countries of the world. It is a well-studied crop species for breeding, genetics and genomics in plants. Now a days various resources are available for its research, which can leads to uprising in evaluation of tomato biology (Barone *et al*., 2008). By using different genes many studies have been done to examine its genetic diversity (Asamizu and Ezura, 2009; Benor *et al*. 2008; Carelli *et al*. 2006; Martinez *et al*. 2006).

The researchers are given on much attention on various aspects of its production under different adverse condition especially drought. Many studies on the genetic variability have been done in many countries of the world as well as in Bangladesh also but it is not adequate and conclusive. Nevertheless, some of the important and informative works and research findings so far been done at home and abroad on this aspect. Drought related reviewed are discussed in this chapter under the followings:

2. 1 Tomato

At present the accepted scientific name of the tomato by most of the scientific community is *Solanum lycopersicum* L. The old scientific name is *Lycopersicon esculentum* Mill. and was widely used from 1768 to 2005. In the 2005 Spooner and his associates proposed a change in the original nomenclature which is used by Linnaeus in 1753 (Anonymous 2015).

According to "International Plant Name Index" in 1753, Linnaeus placed the tomato in the genus *Solanum* as *Solanum lycopersicum* and in 1768 Philip Miller moved it to its own genus, naming it *Lycopersicon esculentum* (Anonymous, 2015).

Solanum lycopersicum the correct name of tomato was given by Peralta and Spoonar (2001). This name came into wide use, but it was in violating of the plant naming rules. Genetic evidence has now shown from the "Natural History Museum" that Linnaeus was correct to put the tomato in the genus *Solanum*. However, both names will probably be found in the literature for some time.

Filippone (2014) told the synonymous of tomato is *"wolf peach"* -- peach because it was round and luscious and wolf because it was erroneously considered poisonous. The English word "tomato" comes from the Spanish word, *tomate*, which in turn comes from the Nahuatl (Aztec language) word *tomato*. It was first appeared in print in 1595. A member of the deadly nightshade family, tomatoes were erroneously thought to be poisonous (although the leaves are poisonous) by Europeans who were suspicious of their bright, shiny fruit. Native versions were small, like cherry tomatoes, and most likely yellow rather than red.

Filippone (2014) also told the native of tomato is western South America and Central America. Tomato is a tropical plant which grown in almost every corner of the world from tropical to within a few degrees of the Arctic Circle. Mexico has been considered the most likely center of domestication of tomato.

The secondary centers of diversification are both Italy and Spain (Gentilcore 2010 and Smith 1994).

Vavilov (1951) told the cultivated tomato originated from Peru-Ecuador- Bolivia area of the South American.

Anonymous (2010) told that major tomato producing countries are Spain, Brazil, Iran, Mexico, Greece, Russia, China, USA, India, Turkey, Egypt and Italy. It is believed that the tomato was introduced in subcontinent during the British regime. It is adapted to a wide range of climates.

Peralta *et al*. (2006) told that in tomato (*S. lycopersicum*.) one cultivated species and 12 wild relatives have been reported.

Chen *et al*. (2009) told that genetic variation in modern cultivars or hybrids is limited.

Miller and Tanksley (1990) also told that it is estimated that cultivated tomato genome contains less than 5% of the genetic variation of the wild relatives.

Yi *et al*. (2008) suggested that by domestication and inbreeding dramatically reduced the genetic variation.

2.2 Drought

Drought means as the absence of sufficient amount of moisture necessary for a plant to grow normally and complete its life cycle (Zhu, 2004). Drought is the serious environmental factor which affecting plant growth, development, yield and quality of fruit. It induces various physiological and biochemical adaptations in plants.

Bot *et al*. (2000) has projected that up to 45% of the world agricultural lands are subjected to drought.

Boutraa (2010) stated that Water deficit leads to the anxiety of the most of the physiological and biochemical processes and consequently reduces plant growth and yield.

Cornic (2000) also stated that many authors described that water deficit reduces the rate of photosynthesis in plants.

Turner (1982) stated that leaf water potential (LWP) has been recommended as selection criteria for improving drought tolerance. LWP is known as an index for whole plant water status and conservation of high LWP.

Levitt (1980) also stated that LWP is considered to be associated with dehydration prevention mechanisms .The production of the crop may be related to physiological attributes like transpiration rate, photosynthetic rate, and relative water content (RWC) and LWP.

Haloi and Baldev (1986) also founded that higher RWC indicates better growth and development, which depends on leaf area. Rapid early growth and preservation of RWC at higher level during reproductive phase greatly influences the yield.

Tardieu and Davies (1996) told that the adaptive potential of some plant species decreasing water losses by closing of stomata and reducing the transpiration rate. Hence, quantity of the transpiration rate is an excellent instrument to measure drought tolerant capacity of crop plants. By decreasing of transpiration rate under drought condition raise leaf temperature which is harmful for plants.

Wien *et al*. (1989) also founded that abscission of reproductive organs like flower buds and flowers is a main yield limiting factor in vegetable crops.

Aloni *et al*. (1996) told that the abscission of floral organs during stresses has been related with the changes in physiological processes.

Bhatt *et al*. (2009) told that in tomato, susceptible cultivar's abscission of flowers, flower buds and the reduction in photosynthesis is more than tolerant cultivars. Tomato (*S. lycopersicum*) is one of the most common and widely grown vegetables in the world. By considering the potentiality of this crop, there is abundantly of scope for its improvement, especially under the drought situation. The concept of drought tolerance has been noticed differently by molecular biologist, biochemist, physiologists and agronomists, the major concern is to increase the biomass and yield under limited input of water, which is a characteristic feature of rainfed agriculture. There are several physiological and biochemical traits contributing to the drought tolerance in crops. However, large number of tomato genotypes have not been separated for drought tolerance or exploited for their cultivation under drought situation. To raise drought tolerant genotypes, it is necessary to identify physiological traits of plants, which gives to drought tolerance. Therefore, the present analysis was carried out to study the physiological traits to facilitate the screening and selection of tomato genotypes for drought tolerance. Therefore, the present investigation was carried out to study the physiological traits to facilitate the screening and selection of tomato genotypes for drought tolerance. Drought stress is the major 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 Effect of drought on different traits in tomato

Environmental conditions regulate the agromorphogenic traits, physiological and nutritional traits of plant. Water is an essential element for the existence of plants and without water, every morphological, biochemical and physiological process of plants are stopped at different level. Genotype stress interaction and variability among different genotypes for different characters are important for the selection of drought tolerance genotypes. The characters are agromorphogenics, physiological and nutritional. Agromorphogenic characters 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

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

2.3.1 Genotypic variation

Genotypic variation is the difference in genotypes either between individuals of the same species or between different species as a result of genetic mutation, gene flow, or something that happened during meiosis. Genotypic variability is a degree of the tendency of individual genotypes in a population to vary from one another. The variability of a trait defines how much that trait tends to differ in response to environmental and genetic influences. In population the genotypic variability is due to genotypic modifications among individuals for a particular character (Gupta *et al*. 2004).

2.3.1.1 Effect of drought on agromorphogenic traits in tomato

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) stated 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 in drought stress.

Paul *et al.* (2014) showed an experiment to estimate the variability among twenty eight tomato genotypes under different drought stress and he showed his experiment with three replications. The study showed the genetic variability among the yield contributing traits. The direct and indirect contribution of these parameters towards the yield and identify better combinations as selection criteria for developing high yielding tomato genotypes.

Significant differences among genotypes were found in all characters except height of first leaf appearance at seedling stage.

Kaushik *et al.* (2011) also showed an experiment to evaluate 10 tomato genotypes in randomized block design with three replications. The genotypic variation was maximum (424 to 825 qtl/ha) for fruit yield and minimum for fruit width (4.1 to 5.6 cm).

Shamim *et al*. (2014) studied 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 in-between in total number of fruits. They described that the tomato genotypes had considerable genetic variation in drought tolerance.

Kozlowski (1972) showed an experiment and they estimated the number of fruit reduction in tomato under drought stress. He estimates 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 stated that the reduction of fruit number due to the dropping of flower and fruit at immature stage.

Wien *et al*. (1989) showed an experiment in tomato under drought and stated that drought stress can rise leaf temperature that is harmful for plants. Under drought stress, leaf, flower and fruit abscission occurs that makes 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) conducted a two-factor experiment to determine effects of drought stress on growth and yield of tomato. They stated 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) conducted 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. Diverse 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 decided that irrigation interval with ten days may be used for maximum yield.

Srivastava *et al*. (2015) conducted an 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 increases flower and fruit dropping at immature stage.

Kamrun *et al.* (2011) conducted an experiment with tomato genotypes under drought stress and stated that no significant difference in case of plant was observed under different water stress condition.

Mingo *et al*. (2004) stated 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) conducted 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 stopped.

Mahendran and Bandara (2000) stated severe flower and fruit dropping during flowering stage under water stress. He also stated the high reduction of fruit numbers that resulted in reduction in yield. He stated that plants that were in the moisture stress showed yield reduction as a result of reduction of leaves development, twig and brances.

Turner *et al.* (2010) stated 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 conditions. They measured vegetative growth, flowering and yield traits. They reported that with the increase of shortage 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 becomes arrested. Relative water content is the measurement of plant status in drought stress.

Siva Kumar (2014) conducted an experiment by using the 18 genotypes viz, LE 1, LE 3, LE 5, LE 13, LE 14, LE 18, LE 20, LE 23, LE 27, LE 57, LE 100, LE 114, LE 118, LE 125, CO3, PKM 1, TNAU THCO 3 and COTH 2. 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 stated that vegetative growth and relative water content decreases with the increase of drought stress.

Haloi and Baldev (1986) mentioned that the plants that contain more water that is considered more drought tolerance as it helps for better growth and development.

Srivastava *et al.* (2012) stated water content and transpiration rate is the most important indicators for drought tolerance. They stated that control plants showed higher transpiration rate than plants under drought stress.

Jureková *et al*. (2011) conducted another experiment to determine the relative water content after 10, 17 and 23 days after treatment. They stated that relative water content was declined during the slow dryness. With the decline in relative water content leaf area was reduced.

Siva Kumar (2014) conducted 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) stated that drought stress has significant impact on different physiological traits of tomato plants. He stated that due to the absence of water the plants contain less water than the control plants.

Sibomana *et al*. (2013) find out the effects of water stress on the growth and yield of tomato under water stress. Leaf water content and leaf chlorophyll content was measured 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 physiological parameters proline content is one of the most physiological indicators for drought tolerance.

Kavikishor and Sreenivasulu (2014) showed that Proline protects molecular denaturation during the drought stress and scavenges reactive oxygen species and interacts with phospholipids. Proline acts as osmolyte that protects sub cellular structures under stress condition.

Sankar *et al*. (2007) found that there were significant differences in proline accumulation among the five varieties of bhendi (*Abelmoschus esculentus*) under drought stress treatment.

Seven different traditional rice varieties of Assam were evaluated for their response to osmolyte production under physiological drought condition through reproduction at three levels of osmotic stress of 0.15 bar, 0.25 bar and 0.56 bar of physiological drought initiated by polyethylene glycol (PEG 6000). The proline content for genotypic variation of the seven rice varieties was verified. The results indicated that the varieties like *Laodubi*, *Leserihali*, *Beriabhanga* and *Borah* were the best drought sustaining variety as

they have high proline content under stress condition.

Rhodes and Samaras (1994) showed that to maintain turgor pressure plants accumulate compatible solutes like proline, betaine and polyols in the cytosol.

George *et al*. (2015) showed 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 of 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) conducted 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 calculated 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) showed in 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 stated that plant that was in 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) conducted 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 stated 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 antecedent of beta-carotene with powerful antioxidant activity and powerful health properties. There are some researches going on 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 μg lycopene per fresh fruit of commercial cultivars.

Liu *et al.* (2011) showed an experiment and stated 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 T_1 treatment (control), T_2 treatment (for 15days), T_3 treatment (for 30 days) and T_4(for 45 days). They found higher lycopene content under T_2 treatment and lower under T_4 drought treatment.

Riggi *et al*. (2008) conducted an experimenct 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 stated that lycopene concentration was higher in moderate drought stress than well irrigate plants and lower in severe drought stress.

According to Helyes *et al*. (2012) drought stress indirectly affected lycopene concentration by inducing more and larger fruits. As a dilution effect fall on ingredients. By the higher lycopene production per unit area the higher yield could account for the concentration loss of individual fruits.

Among all nutrients of tomato fruit, Vitamin C is a principle component. Vitamin C amount only very small percentage 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 altered due to moisture stress. He showed 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 compulsory 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 stated that vitamin C was reduced when drought stress was enforced during ripening stage.

According to the Counsel and Horning, (1999) Vitamin C is formed from D-Glucose. Under drought stress, stomata remain closed most of the time CO_2 cannot enter into the cell and thus D-glucose synthesis is failed. 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) described that the concentration of vitamin C increased with increasing water stresses. A wide range of variations 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) described 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 altered as it is very sensitive.

Mahendran and Bandara (2000) also told that Vitamin C gets oxidized due to high leaf temperature and concentration of vitamin C is reduced.

Vijitha and Mahendran (2010) conducted 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 in vegetative, flowering and early maturity stage.

III CHAPTER

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. The experiments for drought stress conducted as independent experiment. The different steps of drought experiment are stated here.

3.1 Genotype × stress interaction under drought condition in tomato *(Solanum lycopersicum* L.*)*

3.1.1 Experimental Site:

The experiment was conducted 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 ten genotypes were used in this experiment (Table 1). Eight genotypes were collected from Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University, Dhaka and one genotype was collected from Plant Genetic Resource Centre (PGRC) at Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh and rest was collected from the Horticulture department of SAU.

3.1.3 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 ten tomato genotypes were used. Factor B was drought treatments. Three drought treatments were used named T_1 (0 days witholding of water /control), T_2 (15 days witholding water, moderate drought) and T_3 (35 days witholding of water, severe drought).

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

Sl. No.	Genotypes No.	Accession No./ Variety Name	Source of collection
01	G_1	RAJA	Department of Genetics and Plant Breeding, SAU.
02	G_2	BARI Tomato-16	Department of Genetics and Plant Breeding, SAU.
03	G_3	BARI Tomato-3	Department of Genetics and Plant Breeding, SAU.
04	G_4	BARI Tomato-15	Department of Genetics and Plant Breeding, SAU.
05	G_5	BARI Tomato-2	Department of Genetics and Plant Breeding, SAU.
06	G_6	BARI Tomato-18	Department of Genetics and Plant Breeding, SAU.
07	G_7	BARI Tomato-19	Department of Genetics and Plant Breeding, SAU.
08	G_8	BARI Tomato-14	Plant Genetic Resource Centre, BARI
09	G_9	BARI Tomato-11	Department of Horticulture ,SAU
10	G_{10}	ROMA VF	Department of Genetics and Plant Breeding, SAU.

SAU= Sher-e-Bangla Agricultural University.

PGRC= Plant Genetic Resource Research Centre, Gazipur.

3.1.4 Design and layout of the experiment

The experiment was carried out and evaluated during Rabi season in Completely Randomized Design (CRD) using two factors. Factor A included ten genotypes and Factor B included 3 different drought treatments. The experiment was conducted in 3 replications and total 90 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 ten 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 cow dung, Urea, Muriate of Potash and Triple super phosphate with a lower dose. Watering of Seedling was done carefully. Rising of seedling showed in the 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 1C.

Plate 1. Different activity during pot experiment in net house A. Rising of seedlings B. Pot preparation C. Transplanting of seedlings D.Tagging and labeling E. Data recording F. Disease identification in fruit ripping stage.

3.1.9 Intercultural operations

Essential watering and intercultural operations were provided as and when needed. Weeding was performed in all pots as and when needed to keep plants free from weeds. Disease and pests is a limiting factor in tomato production. In this experiment when plants were well established, stalking was done by bamboo stick between 25-30 DAT to keep the plants straight. Proper tagging and labeling were done for each plant. Besides this during ripping stage fruit rote below portion of tomato was founded which was shown in the plate no. 1and it was identified by Prof. Dr. Bellal Hossain sir from pathology department and told that it caused by alternaria and he also told that it was due to lack of water and lack of calcium (Ca) nutrient. Recommended dose was applied according to him.

3.1.10 Harvesting and processing

Harvesting of fruits was done after maturity stage. Mature fruits were harvested when fruits turned into red 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.

3.1.11 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 the Plate 1.

3.1.12 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 (cm^2)

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 noted at the time of harvesting.

3.1.12.1.9 Number of fruits per cluster

All fruits per cluster were verified 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 noted 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 fruits per plant

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

3.1.12.1.12 Average fruits weight (g)

Five fruits from each plants were measured and their average weight 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 their 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. Different physiological experiments are illustrated in Plate 2.

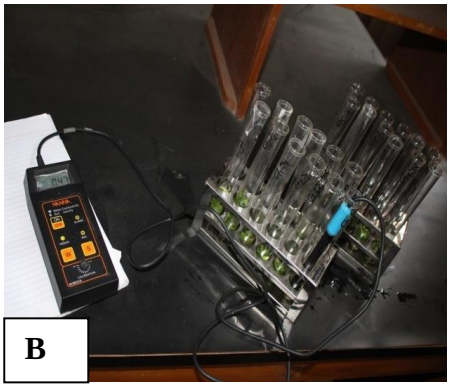
3.1.12.2.1 Determination of Ethylene concentration (ppm)

Ethylene concentration was measured by GAS Indicator 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 Indicator 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 next four weeks of nursery transplantation. After plucking the third leaf from five plants within each treatment, leaves were washed using distilled water and dehydrated 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);

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



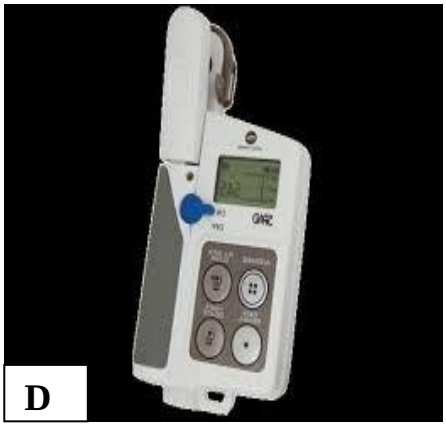


Plate 2. Different types of physiological analysis and data recording A. Leaf sample preparation for %MSI determination, B. Estimation of % MSI by using EC meter, C. Estimation of ethylene concentration by using ethylene box and ethylene detector meter, D. Determination of chlorophyll content SPAD-502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

3.1.12.2.3 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)

Barrs and Weatherly (1962) estimated the relative water content (RWC). The fresh weight of the whole plant was recorded. The plant was floated in water under light until the weight remained 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,

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

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;

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

Dry Matter content was determined by following formula;

% Dry Matter Content= 100-%Moisture content

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 3.

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)

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

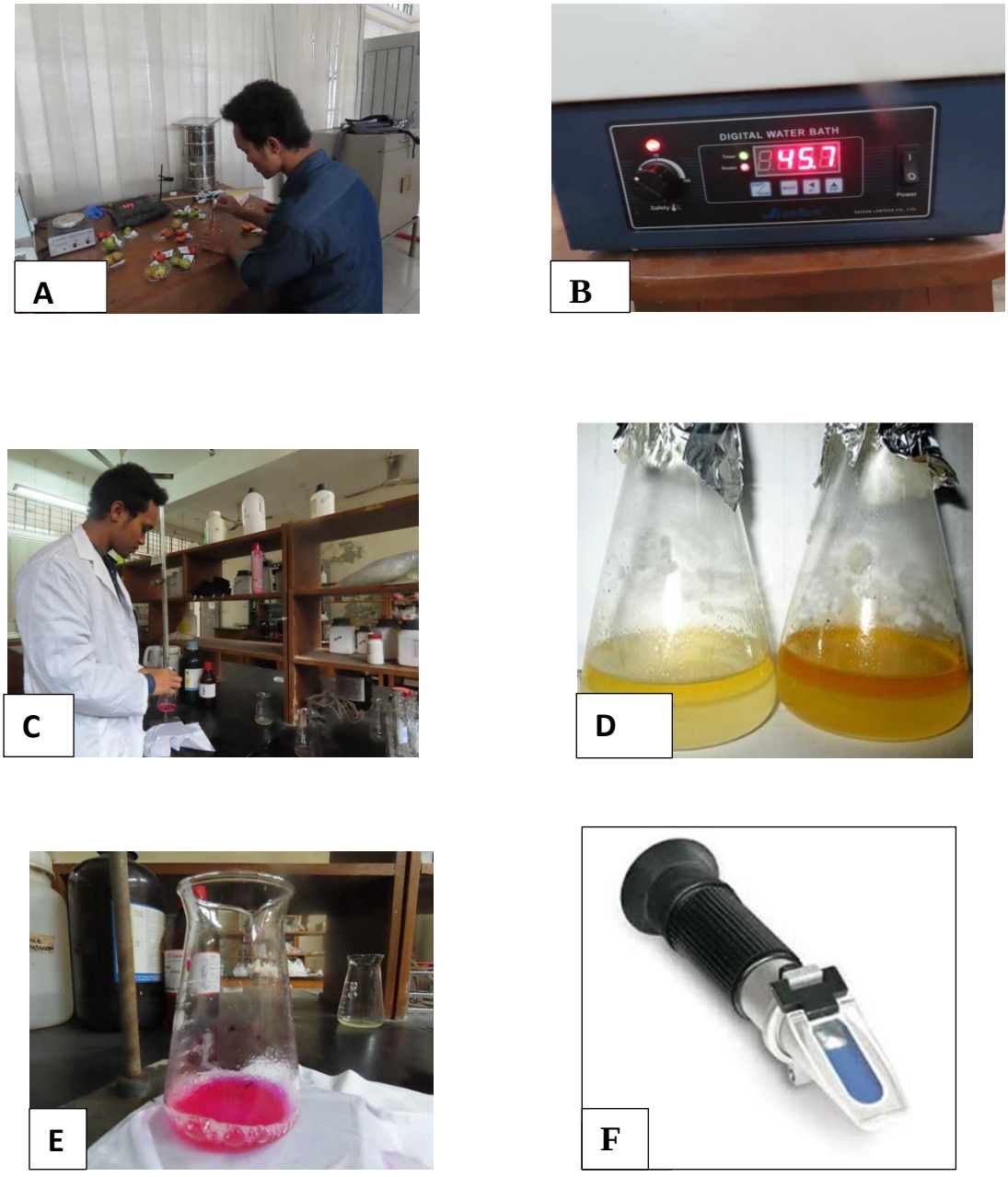


Plate 3. Nutritional analysis in lab A. Determination of pH B .Ethylene determination in hot water bath. C. Titration of tomato juice with dye for vitamin C determination D. development of proline layer. E. Vitamin C determination final point, F. Brix detetrming Refractometer

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;

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

3.1.12.3.2.5 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

3.1.12.3.2.6 Determination of fruits 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.

3.1.12.3.7 Determination of Titrable acidity

Firstly 0.1 N NaOH solutions were prepared by taking 4 gm NaOH pellet into 1000 ml distilled water. It was used in burette. Single fruit was weighted and 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;

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

3.1.12.2.8 Study of variability parameters:

Estimation of the variability among the ten genotypes for traits related to yield per plant in tomato were narrated below:

3.1.12.3.8.1 Estimation of Genotypic variance and phenotypic variance:

To estimate phenotypic and genotypic components of variance, Johnson *et al.* (1955) suggested a formula which is mentioned below:

a. Genotypic variance, $\sigma_g^2 = \frac{\text{MSG}-\text{MSE}}{\text{r}}$

Where,

MSG = Mean sum of square for genotypes

MSE = Mean sum of square for error, and

r = Number of replication

b. Phenotypic variance, $\sigma_p^2 = \sigma_g^2 + \sigma_e^2$

Where,

σ_p^2= Phenotypic variance

σ_g^2= Genotypic variance

σ_e^2 = Environmental variance = Mean square of error

3.1.12.3.8.2 Estimation of genotypic and phenotypic coefficient of variation:

To compute genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) for all the characters, following formula was given by Burton, 1952:

$$\text{GCV} = \frac{\sigma_g \times 100}{\bar{x}}$$

$$\text{PCV} = \frac{\sigma_p \times 100}{\bar{x}}$$

GCV = Genotypic coefficient of variation

PCV = Phenotypic coefficient of variation

σ_g= Genotypic standard deviation

σ_p= Phenotypic standard deviation

$\bar{x}$ = Population mean

Sivasubramanian and Madhavamenon (1973) categorized phenotypic coefficients of variation (PCV) and genotypic coeffcients of variation (GCV) as
Low (0-10%),
Moderate (10-20%) and
High (>20%)

3.1.12.3.8.3 Estimation of heritability in broad sense:

Singh and Chaudhary (1985) suggested a formula to estimate broad sense heritability which is given below:

$$h_b^2(\%) = \frac{\delta_g^2}{\delta_p^2} \times 100$$

Where, h_b^2=Heritability in broad sense

σ_g^2= Genotypic variance

σ_p^2= Phenotypic variance

Robinson *et al.* (1966) suggested the following categories for heritability estimates in cultivated plants:

Categories: Low: 0-30%

Moderate: 30-60%

High: >60%

3.1.12.3.8.4 Estimation of genetic advance:

Allard (1960) suggested the following formula which was used to estimate the expected genetic advance for different characters under selection:

$$GA = \frac{\sigma_g^2}{\sigma_p^2} . K . \sigma_p$$

Where,

GA = Genetic advance

σ_g^2 = Genotypic variance

σ_p^2 = Phenotypic variance

σ_p = Phenotypic standard deviation

K= Standard selection differential which is 2.06 at 5% selection intensity.

Categories: Low (<10%)

Moderate (10-20%)

High (>20%)

3.1.12.3.8.5 Estimation of genetic advance in percentage of mean:

Following formula was given by Comstock and Robinson (1952) to compute genetic advance in percentage of mean:

$$\text{GA in percent of mean} = \frac{\text{GA}}{\text{Grand mean}} \times 100$$

Johnson *et al.* (1955) suggested that genetic advance in percent of mean was categorized into following groups:

Categories:

Less than 10% - Low

10-20% -Moderate

More than 20% -High

3.1.13 Statistical analysis

Collected data were statistically analyzed by 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 experimental work was accomplished for the evaluation of ten tomato genotypes to different drought treatments using agromorphogenic, physiological, antioxidant and nutritional traits. In this chapter the findings of performed experimental work have been put forwarded and discussed. Data have been presented in Table(s) for easy discussion, comprehension and understanding. A summary of the all parameters have been shown in appendices. Results have been presented, discussed and possible interpretations are given on the following heads.

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

This part discusses the genotypes stress interaction under drought condition in ten genotypes of tomato based on their agromorphogenic, physiological and nutritional traits .Three drought treatments like T_1; control, T_2; 15 days withhold of water, T_3; 35 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.

4.1.1 Agromorphogenic traits

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

4.2.1.1 Plant height (cm)

Ten genotypes of tomato showed statistically highly significant variation in term of plant height (Appendix IV). The tallest plant was observed in G_9 (88.22 cm) .Where the shortest plant was G_7 (22.14 cm) in the (Table 2).

Phenotypic variance was higher than the genotypic variance for all the characters in three treatments under the study. For the control and others two treatments the phenotypic variance were (396.60 for control),(498.99 for T_2 treatment) and (368.72 for T_3)and the genotypic variance was (395.23 for control), (497.62 for T_2 treatment) and(367.35 for T_3 for treatment) indicates that there were little environmental effect for this trait.(Table 2(a)).

Both the phenotypic coefficient of variation (29.46 for control), (34.66 for T_2 treatment), (29.71 for T_3 treatment) and genotypic coefficient of variation (29.41 for control), (34.62 for T_2 treatment), (29.65 for T_3 treatment) was high indicates presence of variability in this triat. (Table2a (cont'd))

High heritability (99.74 for control), (99.52 for T_2 treatment), (98.96 for T_3 treatment) and high genetic advance (59.35 for control), (43.20 for T_2 treatment), (29.22 for T_3 treatment) and genetic advance in percentage of mean (79.41 for control), (85.99 for T_2 treatment), (70.64 for T_3 treatment). (Table2a (cont'd))

4.2.1.2 Number of leaves per plant (cm)

All the genotypes of the tomato showed statistically highly significance in the term of number plant leaves (Appendix IV).The highest number of leaves was found in G_1(139) where lowest number of the leaves was G_7(30.89) (Table 2).

Phenotypic variance was higher than the genotypic variance for all the characters in three treatments under the study. For the control and others two treatments the phenotypic variance were (119.12 for control),(443.95 for T_1 treatment)and (205.44 for T_2 treatment)and the genotypic variance was (832.13 for control), (441.82 for T_1 treatment)and (203.31 for T_2 treatment) indicates that there were little environmental effect for this trait. (Table 2(a)).

Both the phenotypic coefficient of variation (38.65 for control), (41.94 for T_1 treatment), (34.65 for T_2 treatment) and genotypic coefficient of variation (38.60 for control), (41.84 for T_1 treatment), (34.47 for T_2 treatment) were high indicates presence of variability in this triat. (Table2a (cont'd))

High heritability (99.65 for control), (99.52 for T_1 treatment), (98.96 for T_2 treatment) coupled with high genetic advance (59.3 for control), (43.20 for T_1 treatment), (29.22 for T_2 treatment)and genetic advance in percentage of mean (60.48) that indicates this character was controlled by additive gene action and it may be improved by direct selection. (Table2a (cont'd))

4.2.1.3 Leaves area index (cm^2)

All the genotypes of the tomato showed statistically significance in the term of leaf area index in the (Appendix IV). The maximum leaves area index was found in the G_9 (36.77 cm^2) where the minimum leaves area index was G_6 (12.55 cm^2) .(Table 2)

Phenotypic variance was higher than the genotypic variance for all the characters in three treatments under the study. For the control and others two treatments the phenotypic variance were (119.12 for control), (132.73 for T_1 treatment) and (45.96 for T_2 treatment) and the genotypic variance was (113.43 for control), (127.04 for T_1 treatment) and (40.27 for T_2 treatment) indicates that there was little environmental effect for this trait. (Table 2(a)).

Both the phenotypic coefficient of variation were (60.75 for control), (52.29 for T_1 treatment), (48.31 for T_2 treatment) and genotypic coefficient of variation were (59.28 for control),(51.16 for T_1 treatment), (45.22 for T_2 treatment) were high indicates presence of variability in this triat. (Table2a (cont'd))

High heritability (95.22 for control), (95.71 for T_1 treatment),(87.62 for T_2 treatment)and high genetic advance (21.41 for control), (22.72 for T_1 treatment),(12.24 for T_2 treatment)and genetic advance in percentage of mean (119.16 for control), (103.10 for T_1 treatment), (87.20 for T_2 treatment) that indicates this character is controlled by additive gene action and it may be improved by direct selection. (Table2a (cont'd))

4.2.1.4 Number of branches per plant

All the genotypes of the tomato statistically significance in the term of number of branches per plant in the (Appendix IV).The highest number of the brances was found in G_1 (4.22) where lowest numbers of the branches was found in the G_4 and G_6 (2.66) (Table 2).

Phenotypic variance was higher than the genotypic variance for all the characters in three treatments under the study. For the control and others two treatments the phenotypic variance were (94.87 for control),(93.67 for T_1 treatment)and (93.56 for T_2 treatment)and the genotypic variance was (1.48), (0.28), and (0.17 for T_2 treatment) indicates that there were little environmental effect for this trait.(Table 2(a))

Both the phenotypic coefficient of variation were (356.35 for control), (492.11 for T_1 treatment),(518.16 for T_2 treatment) and genotypic coefficient of variation were (44.48 for control),(26.98 for T_1 treatment), (21.87 for T_2 treatment) was high indicates presence of variability in this triat. (Table2a (cont'd))

High heritability (1.56 for control), (0.30 for T_1 treatment), (0.18 for T_2 treatment) coupled with high genetic advance (0.31 for control), (0.06 for T_1 treatment),(0.04 for T_2 treatment)and genetic advance in percentage of mean (11.43 for control), (3.05 for T_1 treatment), (1.90 for T_2 treatment) that indicates this character were controlled by additive gene action and it may be improved by direct selection. (Table2a (cont'd))

4.2.1.5 Days of first flowering

All the genotypes of the tomato showed statistically significance in the term of day to first flowering found in (Appendix VI).The maximum first day of flowering was found in the G_9(29) and lowest number of the first flowering was found in the G_3 (17.5) where G_4(20.6) ,G_6 (20.11) was similar in days to flowerings. (Table 2)

Phenotypic variance was higher than the genotypic variance for all the characters in three treatments under the study. For the control and others two treatments the phenotypic variance were (12.71 for control), (11.41 for T_1 treatment) and (107.70 for T_2 treatment)and the genotypic variance was (10.14 for control), (8.84 for T_1

treatment), and (105.13 for T_2 treatment) indicates that there were little environmental effect for this trait. (Table 2(a))

Both the phenotypic coefficient of variation (17.22 for control), (11.95 for T_1 treatment), (31.17 for T_2 treatment) and genotypic coefficient of variation were (15.38 for control), (10.52 for T_1 treatment), (30.79 for T_2 treatment) that indicates presence of variability in this triat. (Table 2a (cont'd))

High heritability (79.77 for control), (77.47 for T_1 treatment), (97.61 for T_2 treatment) coupled with high genetic advance (5.86 for control), (5.39 for T_1 treatment),(20.87 for T_2 treatment)and genetic advance in percentage of mean (28.30 for control), (19.07 for T_1 treatment), (62.67 for T_2 treatment) that indicates this character is controlled by additive gene action and it may be improved by direct selection. (Table2a (cont'd))

4.2.1.6 First day of fruit setting

All the genotypes of the tomato showed statistically significance in the term of day to first fruit setting (Appendix IV).The early fruit setting found in the G_6(13) and lately fruit setting were found in the G_5(21.33) where G_7,$G_{8,}G_{10}$ was similar in fruit setting . (Table 2)

Table 2. The performance of the tomato genotype on the plant height, number of leaves per plant, leaves area, no. of brances per plant, day to first flowering, day to fruits setting, day to maturity, number of cluster per plant, and no. of flower per cluster

Genotype	Plant height (cm)	Number of leaves per plant	Leaf area index (cm^2)	No. of branches /plant	Days to first flowering	Days to first fruit setting	Days to maturity	Number of clusters per plant	Number of flowers per cluster
G1	64.9d	139a	25.8 b	4.22a	24.33b	13.66cd	57.11b	8.44a	9.66de
G2	69.11c	70.89c	22 bc	3.22bc	26.11ab	16.55bc	55.44c	4.55bc	10 cd
G3	61.0e	51.67e	23.22bc	3.22 bc	17.5d	16.44bc	41.88g	4 cd	9.33e
G4	42.44f	68.33d	18.77cd	2.66 c	20.6cd	19.33ab	39.66h	3.88cd	11.33a
G5	71.66bc	69d	21.77bc	2.77 bc	19.66d	21.33a	53d	4.22bcd	7.66f
G6	73.44b	38.7f	12.55d	2.66c	20.11cd	13d	45f	5 b	10.11cd
G7	22.14g	30.89g	19.77bc	3.33b	25.77ab	15.66cd	56bc	4.55bc	10.33bc
G8	42.07f	70.67c	20.66bc	2.78bc	28.77ab	15.44cd	52.66d	3.55d	10.66b
G9	88.22a	72.11c	36.77a	2.77 bc	29a	21.44a	47.88e	4.22bcd	10 cd
G10	42.44f	76.67 b	19.22ac	2.88bc	23.2bc	15.11cd	71.66a	3.44d	8 f
CV %	1.5	0.79	3.31	0.6	3.3	3.4	1.44	0.87	0.54
LSD 0.05	3.18	1.59	6.64	0.3	1.69	1.74	0.72	0.43	0.27

Table 2(cont'd).The performance of the tomato genotype on the no. of fruit/cluster , no. fruit/plant, length of fruit, fruit diameter, average wt. ,day to first flowering yield/plant, root length, shoot root ratio, skin diameter

Genotype	No. of fruit/cluster	No. of fruit/ plant	Length of fruit(mm)	Fruit diameter (mm)	Average fruit wt.(g)	Yield /plant (g/plant)	Root length(cm)	Shoot root ratio	Skin diameter (mm)
G1	8c	5b	42.66d	3.91d	268.7b	331.11d	60.97c	6.66g	4.98de
G2	7.55cd	4.77b	37.33e	8.06a	205.78c	295.67e	85.67ab	7 fg	5.65cd
G3	6.66e	4.77b	47.2 c	6.82b	172.22d	429.67b	74.51b	6.66g	6.54ab
G4	9.33b	5.77a	42d	8.68a	86.11fg	236.11f	36.26e	9.44c	4.56e
G5	8.33c	5.77a	55a	4.26c	294.44a	523.44a	40.43de	9 cd	5.98bc
G6	8.11c	4cd	50.11bc	2.65de	95.33f	221.11g	91.22a	7.66 efg	6.98a
G7	8.33c	3.66d	52.2 ab	2.55e	184d	296.56e	37.86e	8def	4.47e
G8	10.33a	3.77cd	53.4a	3.37de	68.89g	194.67h	74.27b	10.66b	5.66cd
G9	9.22b	4.44bc	54.1a	2.70f	122.67e	140.11i	78.17b	12a	3.76f
G10	7de	3.33d	52.4ab	2.76f	127.78e	411.22c	50.77cd	8.33de	7.12a
CV%	0.87	0.36	3.7	1.7	17.8	14	11.5	1.08	0.693
LSD 0.05	0.43	0.72	1.5	0.8	8.9	7	5.7	0.54	0.34

Wt. =weight, No=Number,

Table 2(cont'd). The performance of the tomato genotypes on ethylene conc., membrane stability index, chlorophyll content, relative water content, dry matter in fruit, proline content, brix (%),pH of fruit

Genotype	Ethylene concentration (ppm)	Membrane Stability Index (%)	Chlorophyll content (%)	Relative water content	Moisture in fruit (%)	Dry matter in fruit (%)	Proline content (µg/ g)	% Brix	pH of fruit
G1	0.18a-c	7a	121.28c	52.99d	4.33de	57.11b	124d	7.66c-e	3.08b-d
G2	0.18a-c	3.89de	158.67b	45.6e	8.94b	55.44bc	97.67d	10.95ab	3.35ab
G3	0.21a	6.08b	114.67d	66.79b	6.02c	41.86ef	270.7ab	8.68b-d	3.23a-c
G4	0.17bc	4.32d	252.56a	37.30f	8.89b	39.66f	341.8a	9.75a-c	3.45a
G5	0.16bc	3.5e	56.2g	42.88e	4.16de	53c	237bc	11.4a	3.09b-d
G6	0.15c	2.23f	61.67f	38.03f	3.90de	45de	221.67bc	5.55ef	3.18a-c
G7	0.16bc	2.23f	76.36e	59.37c	3.95de	56bc	161.67cd	8.54cd	3.32ab
G8	0.18ab	5.36c	116d	25.45g	3.46e	52.65c	119.56d	6.62d-f	2.81de
G9	0.18ab	3.33e	77.6e	56.81c	20.33a	47.88d	81.11d	5.07f	2.93c-e
G10	0.19ab	1.0g	56.06g	70.97a	4.68d	71.6a	76.33d	6.53d-f	2.74e
CV%	0.03	0.67	4.9 c	2.91	0.92	3.6	8	2.39	0.3
LSD 0.05	0.01	0.33	121.28	1.42	0.46	1.8	39	1.19	1.5

Table 2(cont'd). The performance of the tomato genotypes on Titrable acidity, Vit.-C, Lycopene

Genotype	Titrable acidity (%)	Vitamin C(mg/ 100 g)	Lycopene (472 nm)	Lycopene (502 nm)
G1	3.33ab	4.97ab	8.14e	6.14e
G2	3.83a	5.68a	13.76c	11.76c
G3	1.72fg	5.40a	19.87a	17.87a
G4	3.08 bc	4.26b	16.23b	14.23b
G5	2.30d-f	4.34b	10.46d	8.46d
G6	2.51 c-e	5.63a	4.61 g	2.61g
G7	1.58g	5.07ab	6.62f	4.62f
G8	2.77b-d	5.8a	4.14gh	2.14h
G9	2.01e-g	5.87a	3.45h	1.45i
G10	2.61c-e	5.54a	3.83gh	1.83h
CV%	0.64	1	0.89	0.33
LSD 0.05	0.32	0.5	0.44	0.16

Table 2(a) .Estimation of genotypic parameter for all characters of ten genotypes of tomato under control treatment

Character	σ_g^2	σ_p^2	GCV	PCV	h_b^2	GA	GAM (%)
Plant height	395.23	396.60	29.41	29.46	99.65	40.88	60.48
Number of leaves /plant	832.13	834.26	38.60	38.65	99.74	59.35	79.41
Leaf Area Index	113.43	119.12	59.28	60.75	95.22	21.41	119.16
Number of branches /plant	1.48	94.87	44.48	356.35	1.56	0.31	11.43
Days to first flowering	10.14	12.71	15.38	17.22	79.77	5.86	28.30
Fruits diameter	83.20	83.68	16.19	16.24	99.43	18.74	33.26
Number of cluster /Plant	3.32	4.11	45.57	50.68	80.83	3.38	84.39
Number of Flower/Cluster	0.85	7523.45	8.58	808.14	0.01	0.02	0.19
Number of Fruits/Cluster	1.53	1.62	13.25	13.64	94.44	2.48	26.53
Number of fruits/Plant	1.66	6.41	24.80	48.70	25.93	1.35	26.01
Fruits length	37.48	37.51	11.86	11.87	99.92	12.61	24.43
Average fruit weight	7278.60	7279.53	49.48	49.48	99.99	175.74	101.92
Yield/Plant	14586.03	14586.96	36.29	36.29	99.99	248.78	74.76
Root length	665.80	666.73	45.05	45.08	99.86	53.12	92.73
Shoot root ratio	4.82	5.75	24.12	26.35	83.82	4.14	45.49

Table 2a(cont'd) .Estimation of genotypic parameter for all characters of ten genotypes of tomato under T_1 treatment

Character	σ_g^2	σ_p^2	GCV	PCV	h_b^2	GA	GAM (%)
Plant height	497.62	498.99	34.62	34.66	99.73	45.89	71.21
Number of leaves/ plant	441.82	443.95	41.84	41.94	99.52	43.20	85.99
Leaves area index	127.04	132.73	51.16	52.29	95.71	22.72	103.10
Number of branches /plant	0.28	93.67	26.98	492.11	0.30	0.06	3.05
Days to first flowering	8.84	11.41	10.52	11.95	77.47	5.39	19.07
Dry matter content in fruit (%)	54.83	55.31	15.73	15.80	99.13	15.19	32.27
Number of cluster/ plant	3.55	4.34	38.73	42.81	81.84	3.51	72.17
Number of flower/Cluster	1.16	7523.76	11.83	953.18	0.02	0.03	0.30
Number of fruit/Cluster	0.71	0.80	10.03	10.64	88.82	1.64	19.46
Number of fruit /Plant	0.93	5.68	26.35	65.02	16.42	0.81	22.00
Fruit length	60.47	60.50	17.09	17.09	99.95	16.01	35.20
Average fruit weight	4440.87	4441.80	47.85	47.85	99.98	137.26	98.56
Yield /plant	10988.33	10989.26	44.27	44.27	99.99	215.93	91.20
Root length	250.68	251.61	24.91	24.95	99.63	32.56	51.21
Shoot root ratio	2.69	3.62	21.07	24.44	74.32	2.91	37.42

Table 2a(cont'd).Estimation of genotypic parameter for all characters of ten genotypes of tomato under T_2 treatment

Character	σ_g^2	σ_p^2	GCV	PCV	h_b^2	GA	GAM(%)
Plant height	367.35	368.72	29.65	29.71	99.63	39.41	60.97
Number of leaves/ plant	203.31	205.44	34.47	34.65	98.96	29.22	70.64
Leaves area index	40.27	45.96	45.22	48.31	87.62	12.24	87.20
Number of branches /plant	0.17	93.56	21.87	518.16	0.18	0.04	1.90
Days to first flowering	105.13	107.70	30.79	31.17	97.61	20.87	62.67
Dry matter content in fruit (%)	53.41	53.89	19.35	19.44	99.11	14.99	39.68
Number of cluster/ plant	2.93	3.72	34.03	38.33	78.82	3.13	62.23
Number of flower/Cluster	1.19	7523.79	13.10	1040.88	0.02	0.03	0.34
Number of fruit/Cluster	0.65	0.74	10.23	10.92	87.81	1.55	19.76
Number of fruit /Plant	4.83	9.58	59.94	84.41	50.42	3.21	87.67
Fruit length	120.73	120.76	29.80	29.81	99.98	22.63	61.39
Average fruit weight	2343.91	2344.84	48.67	48.68	99.96	99.71	100.25
Yield /plant	2714.12	2715.05	35.11	35.11	99.97	107.30	72.31
Root length	639.57	640.50	42.74	42.77	99.85	52.06	87.97
Shoot root ratio	3.78	4.71	26.38	29.45	80.25	3.59	48.69

σ_p^2 =Phenotypic varience, σ_g^2 =Genotypic Varience, PCV=Phenotypic co efficient variation, GCV=Genotypic co efficient variation, h_b^2= Heritability, GA=Genetic Advance, GAM (%)=Genetive advance in percentage of mean

4.2.1.7 Days to fruit maturity

All the genotypes of tomato showed statistically highly significance in the term of days to maturity (Appendix IV). The highest days of maturity were found in the G_{10} (71.66 days) and lowest day maturity was found in the G_4 (39.66 days). (Table 2)

4.2.1.8 Number of clusters per plant

All the genotypes of the tomato showed statistically highly significance in the term of number of clusters per plant (Appendix IV).The highest number of cluster was found in the G_1(8.44) and the lowest number of cluster were found in the G_{10} (3.44) and G_8 ,G_4 which were statically similar (Table 2).

Phenotypic variance was higher than the genotypic variance for all the characters in three treatments under the study. For the control and others two treatments the phenotypic variance were (4.11 for control), (4.34 for T_1 treatment) and (3.72 for T_2 treatment) and the genotypic variance was (3.32 for control), (3.55 for T_1 treatment), and (2.93 for T_2 treatment) indicates that there were little environmental effect for this trait.

Both the phenotypic coefficient of variation were (50.68 for control), (42.81 for T_1 treatment),(38.33 for T_2 treatment) and genotypic coefficient of variation were (45.57 for control),(38.73 for T_1 treatment), (34.03 for T_2 treatment) was high indicates presence of variability in this triat. (Table2a (cont'd))

High heritability (80.83 for control), (81.84 for T_1 treatment), (78.82 for T_2 treatment) coupled with high genetic advance (3.38), (3.51 for T_1 treatment), (3.13 for T_2 treatment) and genetic advance in percentage of mean (84.39 for control), (72.17 for T_1 treatment), (62.23 for T_2 treatment) that indicates this character is controlled by additive gene action and it may be improved by direct selection. (Table2a (cont'd))

4.2.1.9 Number of flowers per cluster

All the genotypes of the tomato showed statistically significance in the term of number of flowers per cluster (Appendix IV). The highest number of the flowers was found in the G_4 (11.33) and whereas the lowest number of the flowers was found in the G_5 (7.66).

Phenotypic variance was higher than the genotypic variance for all the characters in three treatments under the study. For the control and others two treatments the phenotypic variance were (7523.45 for control), (7523.76 for T_1 treatment) and (7523.79 for T_2 treatment) and the genotypic variance was (0.85 for control), (1.16 for T_1 treatment), and (1.19 for T_2 treatment) indicates that there were little environmental effect for this trait.

Both the phenotypic coefficient of variation were (808.14 for control), (953.18 for T_1 treatment), (1040.88 for T_2 treatment) and genotypic coefficient of variation were (8.58 for control),(11.83 for T_1 treatment), (13.10 for T_2 treatment) that indicates presence of variability in this triat. (Table2a (cont'd))

Low heritability (0.01 for control), (0.02 for T_1 treatment), (0.02 for T_2 treatment) coupled with high genetic advance (0.02 for control), (0.03 for T_1 treatment),(0.03 for T_2 treatment)and genetic advance in percentage of mean (0.19 for control), (0.30 for T_1 treatment), (0.34 for T_2 treatment) that indicates this character were controlled by additive gene action and it may be improved by direct selection. (Table2a (cont'd))

4.2.1.10 Number of fruits per cluster

All the genotypes of the tomato showed statistically highly significance in the term of number of fruits per cluster (Appendix IV). The highest number of the fruit found in the G_8 (10.33) and lowest number of the fruit per cluster is G_3(6.66) where G_5 ,G_7 (8.33) and G_6 (8.11) were statically similar (Table 2).

4.2.1.11 Number of fruits per plant

All the genotypes of the tomato showed statistically highly significance in the term of number of fruit per plant (Appendix IV). The highest number of the fruits per plant

found in the G_4, G_5 (5.77) and the lowest number of the fruits per plant was found in the G_7 (3.66) (Table 2).

Phenotypic variance was higher than the genotypic variance for all the characters in three treatments under the study. For the control and others two treatments the phenotypic variance were (1.62 for control), (0.80 for T_1 treatment) and (0.74 for T_2 treatment) and the genotypic variance were (1.53 for control), (0.71 for T_1 treatment), and (0.65 for T_2 treatment) indicates that there were little environmental effect for this trait.

Both the phenotypic coefficient of variation were (13.64 for control), (10.64 for T_1 treatment), (10.92 for T_2 treatment) and genotypic coefficient of variation were (13.25 for control),(10.03 for T_1 treatment), (10.23 for T_2 treatment) that indicates presence of variability in this triat. (Table2a (cont'd))

High heritability (94.44 for control), (88.82 for T_1 treatment), (87.81 for T_2 treatment) coupled with high genetic advance (2.48 for control), (1.64 for T_1 treatment), (1.55 for T_2 treatment) and genetic advance in percentage of mean (26.53 for control), (19.46 for T_1 treatment), (19.76 for T_2 treatment) that indicates this character were controlled by additive gene action and it may be improved by direct selection. (Table2a (cont'd))

4.2.1.12 Length of the fruit (mm)

All the genotypes of the tomato showed statistically highly significance in the term of length of the fruit (Appendix IV). The highest number of the fruits length was found in the G_5 (55 mm) where G_8(53.40 mm), and G_9 (54.1mm) were statically similar. On the other hand the lowest fruit length was found in the G_2 (37.33 mm) (Table 2)

Phenotypic variance was higher than the genotypic variance for all the characters in three treatments under the study. For the control and others two treatments the phenotypic variance were (6.41 for control), (5.68 for T_1 treatment) and (9.58 for T_2 treatment) and the genotypic variance was (1.66 for control), (0.93 for T_1 treatment), and (4.83 for T_2 treatment) indicates that there were little environmental effect for this trait.

Both the phenotypic coefficient of variation were (48.70 for control), (65.02 for T_1 treatment), (84.41 for T_2 treatment) and genotypic, (24.80 for control), (26.35 for T_1 treatment), (59.94 for T_2 treatment) that indicates presence of variability in this triat. (Table2a (cont'd))

High heritability (25.93 for control), (16.42 for T_1 treatment), (50.42 for T_2 treatment) coupled with high genetic advance (1.35 for control), (0.81 for T_1 treatment),(3.21 for T_2 treatment) and genetic advance in percentage of mean (26.01 for control), (22 for T_1 treatment), (87.67 for T_2 treatment) that indicates this character were controlled by additive gene action and it may be improved by direct selection. (Table2a (cont'd))

4.2.1.13 Fruit dia meter (mm)

All the genotypes of the tomato were showed statically significance in the term of fruit diameter (Appendix VI).The highest fruits diameter found in the G_4 (8.68 mm), G_2 (8.02 mm). On the other hand lowest diameter was found length in G_9 (2.70 mm) and G_{10} (2.76 mm) which was similar (Table 2).

4.2.1.14 Average fruit weight (g)

All the genotypes of the tomato were showed statistically highly significance in the term of average fruit weight (g) (Appendix IV). The highest weight of the tomato was found in the G_5 (294.44 g) and lowest average number of the fruit weight was found in G_8 (68.99 g) (Table 2).

Phenotypic variance was higher than the genotypic variance for all the characters in three treatments under the study. For the control and others two treatments the phenotypic variance were (7279.53 for control),(4441.80 for T_1 treatment)and (2344.84 for T_2 treatment)and the genotypic variance was (7278.60 for control), (4440.87 for T_1 treatment), and (2343.91 for T_2 treatment) indicates that there were little environmental effect for this trait.

Both the phenotypic coefficient of variation were (49.48 for control), (47.85 for T_1 treatment), (48.68 for T_2 treatment) and genotypic coefficient of variation were (49.48 for control),(47.85), (48.67 for T_2 treatment) was high indicates presence of variability in this triat. (Table2a (cont'd))

High heritability (99.99 for control), (99.98 for T_1 treatment), (99.96 for T_2 treatment) coupled with high genetic advance (175.74 for control), (137.26 for T_1 treatment),(99.71 for T_2 treatment)and genetic advance in percentage of mean (101.92 for control), (98.56 for T_1 treatment), (100.259 for T_2 treatment) that indicates this character were controlled by additive gene action and it may be improved by direct selection. (Table 2a (cont'd))

4.2.1.15 Yield (g/ plant)

All the genotypes of the tomato were showed statistically highly significance in the term of yield per plant (Appendix IV). The highest yield was found in the G_5 (523.44 g) and lowest number of the yield was found in the G_8 (140.11 g) (Table 2).

Phenotypic variance was higher than the genotypic variance for all the characters in three treatments under the study. For the control and others two treatments the phenotypic variance were (14586.96 for control), (10989.26 for T_1 treatment) and (2715.05 for T_2 treatment) and the genotypic variance was (14586.03 for control), (10988.33 for T_1 treatment), and (2714.12) indicates that there were little environmental effect for this trait.

Both the phenotypic (36.29 for control), (44.27 for T_1 treatment), (35.11 for T_2 treatment) and genotypic, (36.29 for control),(44.27 for T_1 treatment), (35.11 for T_2 treatment)coefficient of variation was high indicates presence of variability in this triat. (Table2a (cont'd))

High heritability (99.99 for control), (99.99 for T_1 treatment), (99.97 for T_2 treatment) coupled with high genetic advance (248.78 for control), (215.93 for T_1 treatment), (107.30 for T_2 treatment) and genetic advance in percentage of mean (74.76 for control), (91.20 for T_1 treatment), (72.31 for T_2 treatment) that indicates this character were controlled by additive gene action and it may be improved by direct selection. (Table2a (cont'd))

4.2.1.16 Root length (cm)

All the genotypes of the tomato showed statistically highly significance in the term of root length of tomato plant (Appendix IV). The highest number of the root length

found in G_6 (91.22 cm) and lowest root the length was found in G_4 (36.26 cm) (Table 2)

Phenotypic variance was higher than the genotypic variance for all the characters in three treatments under the study. For the control and others two treatments the phenotypic variance were (666.73 for control), (251.61 for T_1 treatment) and (640.50 for T_2 treatment) and the genotypic variance was (665.80 for control), (250.68 for T_1 treatment), and (639.57 for T_2 treatment) indicates that there were little environmental effect for this trait.

Both the phenotypic coefficient of variation were (24.95 for control), (24.95 for T_1 treatment), (42.77 for T_2 treatment) and genotypic coefficient of variation were (99.63 for control), (24.91 for T_1 treatment), (29.80 for T_2 treatment) that indicates presence of variability in this triat. (Table2a (cont'd))

High heritability (99.86 for control), (99.63 for T_1 treatment), (99.85 for T_2 treatment) coupled with high genetic advance (53.12 for control), (32.56 for T_1 treatment), (22.63 for T_2 treatment) and genetic advance in percentage of mean (92.73 for control), (51.21 for T_1 treatment), (87.97 for T_2 treatment) that indicates this character were controlled by additive gene action and it may be improved by direct selection. (Table2a (cont'd))

4.2.1.17 Root and shoot ratio

All the genotypes of the tomato were showed statistically highly significance in the term of shoot root ratio (Appendix IV). The highest ratio of root and shoot was found in the G_9 (12) and lowest ratio of the shoot and root was found G1 and G3 (6.66) (Table 2).

Phenotypic variance was higher than the genotypic variance for all the characters in three treatments under the study. For the control and others two treatments the phenotypic variance were (5.75 for control),(3.62 for T_1 treatment)and (4.71 for T_2 treatment)and the genotypic variance was (4.82 for control), (2.69 for T_1 treatment), and (3.78 for T_2 treatment) indicates that there were little environmental effect for this trait.

Both the phenotypic coefficient of variation were (29.45 for control), (24.95 for T_1 treatment),(29.45 for T_2 treatment) and genotypic coefficient of variation were (24.12 for control),(21.07 for T_1 treatment), (26.38 for T_2 treatment) that indicates presence of variability in this triat. (Table2a (cont'd))

High heritability (83.82 for control), (21.07 for T_1 treatment), (80.25) coupled with high genetic advance (4.14 for control), (2.91 for T_1 treatment), (3.59 for T_2 treatment) and genetic advance in percentage of mean (45.49 for control), (37.42 for T_1 treatment), (48.69 for T_2 treatment) that indicates this character were controlled by additive gene action and it may be improved by direct selection. (Table2a (cont'd))

4.2.1.18 Skin diameter (mm)

All the genotypes of the tomato were showed statistically highly significance in the term of the skin diameter (mm) of the fruit (Appendix IV). The highest number of the skin diameter of fruit was found G_{10} (7.12 mm) followed by the lowest skin diameter was in the G_6 (6.98 mm) (Table 2).

4.2.2 Physiological traits

4.2.2.1 Ethylene concentration (ppm)

All the genotypes of the tomato showed statistically highly significance in the term of ethylene concentration (Appendix IV). The highest ethylene concentration was found in the G_3 (0.21 ppm) and lowest concentration was the G_6 (0.15 ppm) (Table 2)

4.2.2.2 Membrane stability index (%)

All the genotypes of the tomato showed statistically highly significance in the term of membrane stability index (%) (Appendix IV). The highest membrane stability index was found in the G_1 (7 %) where lowest membrane stability index was found in G_6 &G_7 (2.23 %) (Table 2). Both were statistically similar.

4.2.2.3 Chlorophyll content (%)

All the genotypes of the tomato showed statistically highly significance in the term of chlorophyll contents (Appendix IV). The highest amount of chlorophyll was found in

the G_4 (252.4%) and the lowest amount of chlorophyll was found in G_{10} (56.06 %) (Table 2)

4.2.2.4 Relative water content (%)

The ten genotypes of the tomato showed statistically highly significance in the term of relative water content (Appendix IV). The highest amount of relative water content was found in the G_{10} (70.97) and on the other hand the lowest amount of relative water content found in the G_8 (25.45) where G_4 (37.30) and G_7 (38.03) were statistically similar (Table 2)

4.2.2.5 Moisture content in fruit (%)

All the genotypes of the tomato were showed statistically highly significance in the term of moisture (%) in the fruit (Appendix IV). The highest amount of moisture was found in the G_9 (20.33 %) and lowest amount of moisture was found in the G_8 (3.46 %). Where G_5 (4.19 %), G_6 (3.90 %),& G_7(3.95 %) were statistically similar. (Table 2)

4.2.2.6 Dry matter content in fruit (%)

All the genotypes of the tomato showed statistically significance in the term of dry meter percentage (%) (Appendix IV). The highest amount of the dry matter was found in the G_{10} (71.60 %) and lowest amount of the dry matter was found in the G_4 (39.61%)(Table 2).

Phenotypic variance was higher than the genotypic variance for all the characters in three treatments under the study. For the control and others two treatments the phenotypic variance were (83.68 for control), (55.31 for T_1 treatment) and (53.89 for T_2 treatment) and the genotypic variance was (83.20 for control), (54.83 for T_1 treatment), and (53.41 for T_2 treatment) indicates that there were little environmental effect for this trait. (Table2a (cont'd))

Both the phenotypic coefficient of variation were (16.24 for control), (15.80 for T_1 treatment), (19.44 for T_2 treatment) and genotypic coefficient of variation were (16.19 for control), (15.73 for T_1 treatment), (19.35 for T_2 treatment) that indicates presence of variability in this triat.

High heritability (99.43 for control), (99.13 for T_1 treatment), (99.11 for T_2 treatment) coupled with high genetic advance (18.74 for control), (15.19 for T_1 treatment), (14.99 for T_2 treatment) and genetic advance in percentage of mean (33.26 for control), (32.27 for T_1 treatment), (39.68 for T_2 treatment) that indicates this character is controlled by additive gene action and it may be improved by direct selection. (Table2a (cont'd))

4.2.2.7 Proline content (ug/g)

All the genotypes of the tomato were showed statistically highly significance in the term of proline content (µg/g) (Appendix IV).The highest amount of the proline contents was found in the G_4(341.81 µg/g) and lowest amount of the proline content was found in the G_7 (161.67 µg/g) (Table 2) .Where G_1.G_2,G_8,G_9 &G_{10} were statistically similar.

4.2.3 Nutritional traits

Nutritional traits viz, % Brix, pH of fruit, % titrable acidity, vitamin C lycopene content are presented and discussed in this section. ANOVA was presented in (Appendix IV) respectively. Data were arranged in table and figure for better understanding.

4.2.3.1 Brix content (%)

All the genotypes of the tomato were showed statistically highly significance in the term of the Brix (%) (Appendix IV).The highest amount of the brix percentage was the G_5 (11.6%) and lowest amount of the brix percentage was observed in G_9 (5.07 %) (Table 2)

4.2.3.2 pH of fruit

All the genotypes of the tomato were showed statistically highly significance in the term of pH (Appendix IV). The highest amount of pH percentage was found G_4 (3.45 %) and the lowest amount of the pH was found in G_{10} (2.74 %).(Table 2)

4.2.3.3 Titrable Acidity (%)

All the genotypes of the tomato were showed statistically significance in the term of tartaric acid (Appendix IV).The highest amount of the tartaric acid was found in the G_3(3.82 %) and lowest amount of tartaric acid was found in G_7 (1.78 %) (Table 2)

4.2.3.4 Vitamin C content (mg/ 100 g)

All the genotypes of the tomato were showed statistically significance in the term of vitamin c (Appendix VI) . The highest amount of the vitamin C was found in G_2 (5.68 %) and G_2,G_8,G_9,& G_{10} were statically similar. On the other hand the lowest amount of the vitamin C were found G_4 (4.26) G_5 (4.34) which were statistically similar. (Table 2)

4.2.3.5 Lycopene content (mg/ g)

All the genotypes of the tomato showed statistically highly significance in the term of lycopene (Appendix IV). The highest amount of the lycopene was found in the G_3(19.87) at (472 nm) and G_3 (17.87) from(502 nm). On the other hand the lowest amount of lycopene was found in G_9 (3.45) at the (472 nm) and G_9 (1.45) from (502 nm) (Table 2)

4.2.1.1 The effect of the treatments on the genotypes with ANOVA analysis of the agronomical traits were given bellow

4.2.1.1.1 Plant height (cm)

The performance of the plant height at different drought treatment were showed statistically significant variation among the drought treatments (Appendix IV).The tallest plant was observed in T_1 (67.59 cm) whereas the shortest plant was found in T_3 (47.26 cm) in (Table 3).The plant height decrease with the increase of drought treatment. Begum (2016) found same result of decrease of plant height with the increase of drought treatment. When plant faces severe drought stress, all physiological process become limited 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).

4.2.1.2.1 Numbers of the leaves per plant

The performances of the number of the plant leaves at different drought treatment were showed statistically significant variation among the drought treatments in the (Appendix IV). The highest number of the leaves was found from the treatment T_1 (74.73) and lowest number of the leaves was found from the treatment T_3 (61.03). So this result showed the number of the leaves reduces due to increase the drought level in the tomato plant (Table 3).

4.2.1.3.1 Leaves area index (cm^2)

The Leaf area index at different drought treatments were showed statistically significant variation among the drought treatments in the (Appendix IV). The maximum leaf area index was found in the T_1 (26.66 cm^2) whereas the minimum leaf area index was found from treatment T_3 (16.6 cm^2) (Table 3).So this result showed that the increase of drought stress , leaf area index decreased in the tomato plant (Table3)

Table 3. Effect of drought treatments on plants height, number of leaves/ plant, leaf area, no. of branches /plant, days to first flowering ,days to first fruit setting, days to maturity, no. of cluster/plant, no. of flower /Cluster, no. of fruits /cluster.

Drought treatments	Plant height (cm)	Number of leaves/ plant	Leaf area (cm^2)	No. of branches /plant	Days to first flowering	Days to first fruit setting	Days to maturity	Number of clusters per plant	Number of flowers per cluster	Number of fruit per cluster
T_1	67.59a	74.73a	26.6a	4.16a	26.73a	19.76a	56.43a	5.73a	11.03a	9.6a
T_2	58.5b	70.6b	22.9b	2.96b	23.8b	17.23b	53.23b	4.6b	10.03b	8.6b
T_3	47.26c	61.06c	16.6c	2.03c	20.03c	13.4 c	46.43c	3.43c	8.06c	6.6c
CV%	0.872	0.49	1.81	0.32	1.85	1.8	0.79	0.48	0.29	0.41
LSD0.05	1.74	0.88	3.63	0.16	0.93	0.93	0.39	0.23	0.14	0.24

Three drought treatments viz. T_1, Control; T_2 15 days withhold of water; T_3, 35 days withhold of water;
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(cont'd).Effect of drought treatments on number of fruit/plant, length of fruit, fruit dia meter ,average fruit wt. yield /plant, roots /plant, shoot root ratio, skin diameter, ethylene concentration, membrane stability index

Drought treatments	Number of fruit per plant	Length of fruit (mm)	Fruit dia meter (g)	Average fruit wt.(g)	Yield /plant (g/plant)	Root length (cm)	Shoot root ratio	Skin diameter of fruit (mm)	Ethylene concentration (ppm)	Membrane Stability Index
T_1	5.76a	51.6 a	6.70a	191.9a	333.4a	65.05a	9.86a	5.75a	0.20a	4.34a
T_2	4.63b	49.56b	6.05ab	169.87b	312.17b	63.33a	8.86b	5.66a	0.18b	3.92b
T_3	3.2c	44.76c	5.28b	126.03c	278.33c	60.66a	6.9c	5.28b	0.14c	3.43c
CV%	0.39	1.6	0.93	9.7	8	6.3	0.59	0.383	0.02	0.369
LSD0.05	0.19	0.82	0.46	4.88	4	3.15	0.3	0.2	9.28	0.187

Three drought treatments viz. T_1, Control; T_2 ,15 days withhold of water; T_3, 35 days withhold of water;
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(cont'd). Effect of drought treatments on chlorophyll content, relative water content, moisture in fruit, dry matter in fruit, proline content, pH of fruit, titrable acidity, Vitamin C, lycopene content

Drought treatments	Chlorophyll content (%)	Relative water content	Moisture in fruit (%)	Dry matter in fruit (%)	proline content (ug/g)	Brix (%)	pH of fruit	Titrable acidity (%)	Vitamin C	Lycopene (472 nm)	Lycopene (502 nm)
T_1	113.61a	53.89a	7.15a	56.43a	201.45a	9.38a	3.33a	2.85a	5.63a	10.36a	9.80a
T_2	110.47b	51.32b	6.94ab	53.23b	178.17ab	8.36b	3.15ab	2.59ab	5.34ab	9.36b	9.20b
T_3	103.27c	43.69c	6.51b	46.43c	139.8b	6.46c	2.88b	2.28b	4.80b	7.62c	8.34c
CV%	2.7	1.5	0.5	2.01	8	1.3	0.16	0.35	0.54	0.49	0.18
LSD0.05	1.36	0.79	0.25	1	46	0.65	0.08	0.17	0.27	0.24	0.09

Three drought treatments viz. T_1, Control; T_2 15 days withhold of water; T_3, 35 days withhold of water;
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.

4.2.1.4.1 Number of branches per plant

The number of the branches per plant were showed statistically significance variation among the drought treatment (Appendix IV).The highest number of the branches was found from the treatment T_1(4.16) and lowest number of the branches was found from the treatment of T_3(2.03). So these results showed that the number of the branches reduces due to the drought stress increases in the tomato plant (Table 3).

4.2.1.5.1 Days to first flowering

The days to first flowering was showed statistically significance variation among the different level of the drought treatment (Appendix IV).The maximum first day of flowering of the tomato was found from the treatment of T_1(26.73) and minimum flowering of the tomato plant was found from the treatment of T_3(20.03). Drought stress at flowering stage not only reduces flower formation but also proliferations flower shedding (Table 3).

Mahendran and Bandara (2000) also showed that when plants were exposed to moisture stress at the flowering stage, a severe drop of flowering occurred. Reduction in flower number declines the amount of final yield. So, water stress during the flowering stage may have resulted in the highest reduction in yield. The plants which were exposed to water stress during the vegetative stage showed the next highest yield reduction.

According to the Kirnak *et al.* (2001) drought stress reduces the flowering comparatively that greenhouse-grown tomato which was fully irrigated. They informed that marketable tomatoes yield were lowest under conventional shortage irrigation treatments. So due to the increase of drought level reduces the flowering of the tomato plant and finally reduce the final yield of the crop.

4.2.1.6.1 First day of fruit setting

Day to first fruit setting were showed statistically significance variation among the different level of drought in the (Appendix IV).The early fruit setting was found from the treatment of T_1(19.76) and lately fruit setting was found from the treatment of

T_3(13.4). So the fruit setting of the tomato plant reduces due to the increase the drought level (Table 3).

4.2.1.7.1 Day to fruit maturity

The days to fruit maturity were showed statistically significance variation among different level of the drought treatment .The longest time of fruit maturity was found from the treatment of the T_1(56.43) and lowest time of fruit maturity was found from the treatment of the T_3(46.43). Plant takes less amount of time for fruit maturity under drought treatment than control. Similar result was also found by Begum (2016). (Table 3)

4.2.1.8 .1 Number of cluster per plant

The numbers of the cluster per plant were showed statistically significance among the various level of the drought treatment (Appendix IV). The highest level of the cluster was found from the treatment T_1 (5.73) and lowest number of the cluster per plant was found from the treatment of T_3 (3.43). Similar results also noted by Wahb-Allah *et al*. (2001). (Table 3)

4.2.1.9.1 Number of flower per cluster

The number of flowers per cluster were showed statistically significance among various level of the drought treatment (Appendix IV).The highest number of the flower cluster was found from the treatment T_1 (11.03) and lowest number of the flower cluster was found from the treatment from T_3 (8.06).This result showed that increase the drought levels reduces the number flowers per cluster in tomato plant. (Table 3)

4.2.1.10.1 Number of fruit per cluster

The number of fruit per cluster were showed statistically significance among various levels of the drought treatments (Appendix IV).The highest level of the fruit found from the treatment T_1 (9.6) and lowest number of the fruit per cluster found from T_3 (6.6). So result showed increase the drought level, number of the fruits per cluster reduces (Table 3).No. of fruits per cluster is related with the no. of flower formation

per cluster. As drought decrease the flower formation .So no. of fruits per cluster is also reduced.

4.2.1.11.1 Number of fruit per plant

The number of the fruit per plant were showed statistically significance among the various level of the drought treatments (Appendix IV).The highest number of the fruit was found from the treatment in the T_1(5.76) and lowest number of the fruit per plant was found from the T_3(3.2) **(**Table 3). So this result showed that increase the drought stress reduces the number of fruit per plant.

4.2.1.12.1 Length of the fruit

The length of the fruits were showed statistically significance among various level of the drought stress in the (Appendix IV). The highest length of tomato found from T_1 (51.6 mm) and lowest length of the tomato was found from T_3 (44.76 mm). This result indicated that increase the drought stress reduces the length the of tomato fruit **(**Table 3).

4.2.1.13.1 Fruit dia meter (mm)

The fruit dia meter (mm) of the fruits were showed statistically significance difference among the various level of the drought stress in the tomato (Appendix IV).The highest diameter of the tomato fruit was found from T_1(6.07 mm) and the lowest diameter was found from the T_3(5.38 mm) **(**Table 3)

According to Klepper *et al*. (1971) the reduction of the fruit length and diameter due to the increase of drought stress . This result indicated that the fruit length and diameter changes in fruit by hydration of the tissue. So it can be said that the increase the drought stress reduces the length of the fruit.

4.2.1.14.1 Average fruit weight (g)

The average fruit weight (g) of the tomato was showed statistically significance among various level of the drought stress (Appendix IV).The maximum average fruit weight was found from the treatment T_1(191) and minimum average weight of fruit was found from the T_3(126.03) **(**Table 3).

Nyabundi and Hsiao (2009); showed that different levels of drought stress under field conditions, vegetative growth is inhibited. Less water flow in the fruit cause reduction in fruit size and thus reduces the fruit weight.

Tuberosa and Salvi (2006) conveyed that tomato growth parameters and yield were higher at a high irrigation rate and decreased significantly at drought stress. This result were showed that average fruit weight decreases the increase of the drought stress.

4.2.1.15 .1 Yields (g/ plant)

The yield per plant (g/plant) showed statistically significance among various level of the drought stress (Appendix IV). The maximum yield of the tomato plant found from the T_1(333.4 g/plant) and on the other hand the minimum fruit weight found from T_3(278.33) .This experiment showed that the average weight of the fruit reduced with the increased the drought stress **(**Table 3).

4.2.1.16.1 Root length (cm)

The root length (cm) was showed statistically significance among various level of drought stress in the (Appendix IV).The highest root length was found from the treatment T_1 (65.05 cm) and lowest root length was found in the T_3(60.66 cm).This result indicated that root length reduces due to the increase the drought stress **(**Table 3).

4.2.1.17.1 Root and shoot ratio

The root and shoot ratio were showed statistically significance in among various drought stress in the (Appendix IV).The maximum length and root ratio was found from the treatment of T_1(9.86) and minimum length was found in the T_3(6.9) .This result showed that shoot and root ration reduces with the increase of the drought stress.

4.2.1.18 .1 Skin diameters (mm)

The skin diameter of the tomato was showed statistically significance among various different level of the drought stress in the (Appendix IV).The maximum diameter of the tomato was found from the treatment of the T_1 (5.75 mm) and the lowest diameter was found from T_3 (5.28 mm) .This result was showed that skin diameter reduces with the increases of drought stress in tomato plant. **(**Table 3)

4.2.2 Physiological traits

The treatment wise performance of all genotypes' physiological traits (ethylene concentration (ppm) , membrane stability index (%), chlorophyll content (%), relative water content (%), moisture content in the fruit and proline content (µg/g)) were described below.

4.2.2.1.1 Ethylene concentration (ppm)

The ethylene concentration of the tomato showed statistically significance among various drought treatments (Appendix IV).The maximum ethylene concentration found was from the treatment from the T_1(0.20 ppm) and the minimum ethylene concentration was found from the T_3 (0.14 ppm) .Ethylene is the gaseous substances which is evaporated with increases of the temperature. This concentration showed that ethylene concentration reduces with the increases of the drought stress. **(**Table 3)

4.2.2.2.1 Membrane Stability Index (%)

Membrane stability index of tomato were showed statistically significance among various drought stress (Appendix IV).The maximum membrane stability index concentration was found from the T_1(4.34) and minimum membrane stability index was found in the T_3(3.43).Electrolytes and fiber content is associated with membrane stability index. When temperature increases the amount of fiber and electrolytes reduces. This result showed that membrane stability index reduces with the increase of the drought stress **(**Table 3).

4.2.2.3 .1 Chlorophyll content (%)

The chlorophyll content of the tomato genotypes were showed statistically significance among various drought treatments (Appendix IV).The highest amount of the chlorophyll was found from the treatment of T_1 (113.61) and the lowest amount of the chlorophyll content was found from the T_3(103.27).This result showed that chlorophyll content reduces with the increase of the drought stress (Table 3).

4.2.2.4.1 Relative water content (%)

The relative water content were showed statistically significance variation among the treatment (Appendix IV).The highest amount of relative of water content was found from the T_1 (53.89) and lowest amount of the relative water content was found from the treatment of T_3(43.69) (Table 3).

Kirnak *et al*. (2001) Showed that drought stress markes in significant decreases in relative water content.

Haloi and Baldev (1986) reported that the higher relative water content was 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.

Siva Kumar (2014) also reported that relative water content decreased under drought stress than control.

4.2.2.5.1 Moisture content in fruit (%)

The moisture in the fruit was showed statistically significance among various treatment of drought (Appendix IV).The maximum amount of the moisture content was found in the fruit from the treatments of T_1(7.15) and lowest amount of the moisture content was found from the T_3(6.51). So, it is indicated that moisture content reduces with the increases of the drought stress (Table 3).

4.2.2.6.1 Dry matter content in fruit (%)

The dry matter of the fruit showed statistically significance variation among the different level of the drought treatment (Appendix IV).The maximum amount of the

dry matter found in the T_1(56.43) and the lowest amount of dry amount was found in the treatment T_3(46.43). This showed that dry matter content of the fruit reduces with increase of the drought stress (Table 3)

4.2.2.7.1 Proline content (µg/g**)**

The proline content of the tomato genotypes were showed statistically significance variation among different level of drought stress (Appendix IV).The maximum amount of the proline content found from T_1(201.45 µg/g) and lowest amount of the proline found T_3(139.84 µg/g) (Table 3).

Pan *et al.* (2006) showed that the amount of proline in grown tomatoes under drought stress increased proline concentrations.

According to Ullah *et al. (*1994) with the increase in water stress, proline contents in tomato plants were also increased.

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.

4.2.3.1.1 Brix content (%)

The brix content of the tomato genotypes showed statistically significance variations among various level of the drought treatment (Appendix VI).The maximum amount of Brix found from the T_1(9.38 %) and minimum amount of the Brix found from the T_3(6.46 %) . (Table 8)

Patanè and Cosentino (2010) showed that greatest effect of soil water deficit was the rise in fruit firmness, soluble solids and a decrease in fruit size and yield.

Helyes *et al.* (2012) also showed that in drought condition Brix% is increased than control.

4.2.3.2.1 pH of fruit

pH of fruit showed statistically significant variation among the drought treatments (Appendix VI).The highest pH was found in T_1 (3.33) and the lowest pH was found in

T_3 (2.88) .With the increase of drought treatment, pH of fruit juice was reduced as the titrable acidity was increased (Table 3).

4.2.3.3.1 Titrable Acidity (%)

Titrable acidity was showed statistically significant among the drought treatments (Appendix VI). The highest titrable acidity was found in T_1 (2.85 %) whereas the lowest titrable acidity was found in T_3 (2.28 %).With the increase of drought stress, titrable acidity decreased (Table 3).

4.2.3.4.1 Vitamin C content (mg/ 100 g)

Vitamin C content showed statistically variation among the drought treatments (Appendix VI).The highest vitamin C content was found in T_1 (5.63 mg/ 100 g) whereas the lowest vitamin C content was found in T_3 (4.80 mg/ 100 g) (Table 3). With the increase of drought treatments, vitamin c content was reduced. Under water stress condition, stomata remain closed most of the times that hamper the absorption of CO_2 and synthesis of Vitamin C reduced (Table 3).

4.2.3.5.1 Lycopene content (mg/ g)

Lycopene content was showed statistically significant among the drought treatments (Appendix VI).

In case of 472 nm wavelength, the highest lycopene content was found in T_1 (10.36 mg/ g) whereas the lowest lycopene content was found in T_3 (7.62 mg/ g).

In case of 502 nm wavelength, the highest lycopene content was found in T_1 (9.8 mg/ g) whereas the lowest content was found in T_3 (8.34 mg/ g) (Table 3).

In both cases, with the increase of drought stress, the lycopene content decreased. Under water stress, the pigment break down and thus lycopene content reduced. Begum (2016) found similar findings (Table 3).

Table 3. (Cont'd) Effect of drought treatments on plants height, number of leaves/ plant, leaf area, no. of branches /plant, day to first flowering ,day to first fruit setting, day to maturity, num. of cluster/plant, num. of flower /Cluster, num. of fruit /cluster

Drought treatments	Plant height (cm)	Number of leaves/ plant	Leaf area (cm^2)	No. of branches /plant	Days to first flowering	Days to first fruit setting	Days to maturity	Number of clusters per plant	Number of flowers per cluster	Number of fruit per cluster
T_1	67.5a	74.73a	26.6a	4.16 a	26.73a	19.76a	56.43a	5.73a	11.03a	9.6 a
T_2	58.5b	70.6 b	22.9b	2.96 b	23.8 b	17.23b	53.2 b	4.6b	10.03b	8.6 b
T_3	47.26c	61.06c	16.6c	2.03 c	20.03c	13.4c	46.43c	3.43c	8.06c	6.6 c
CV%	0.872	0.49	1.81	0.32	1.85	1.8	0.79	0.48	0.29	0.41
LSD0.05	1.74	0.88	3.63	0.16	0.93	0.93	0.39	0.23	0.14	0.24

Three drought treatments viz. T_1, Control; T_2 15 days withhold of water; T_3, 35 days withhold of water;
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 (cont'd). Effect of drought treatments on number of fruit/plant, length of fruit, fruit dia meter ,average fruit wt. yield /plant, root /plant, shoot root ratio, skin diameter, ethylene concentration, membrane stability index

Drought treatments	Number of fruit per plant	Length of fruit (mm)	Fruit dia meter (g)	Average fruit wt.(g)	Yield /plant (g/plant)	Root length (cm)	Shoot root ratio	Skin diameter of fruit (mm)	Ethylene concentration (ppm)	Membrane Stability Index
T_1	5.76a	51.6 a	6.70a	191.9a	333.4a	65.05a	9.86a	5.75a	0.20a	4.34a
T_2	4.63b	49.56b	6.05ab	169.87b	312.17b	63.33a	8.86b	5.66a	0.18b	3.92b
T_3	3.2 c	44.76c	5.28b	126.0 c	278.33c	60.66a	6.9c	5.28b	0.14c	3.43 c
CV%	0.39	1.6	0.93	9.7	8	6.3	0.59	0.383	0.02	0.369
LSD0.05	0.19	0.82	0.46	4.88	4	3.15	0.3	0.2	9.28	0.187

Three drought treatments viz. T_1, Control; T_2 ,15 days withhold of water; T_3, 35 days withhold of water;
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(cont'd). Effect of drought treatments on chlorophyll content, relative water content, moisture in fruit, dry matter in fruit, proline content, pH of fruit, titrable acidity, Vitamin C, lycopene content

Drought treatments	Chlorophyll content (%)	Relative water content	Moisture in fruit (%)	Dry matter in fruit (%)	proline content (µg/g)	Brix (%)	pH of fruit	Titrable acidity (%)	Vitamin C	Lycopene (472 nm)	Lycopene (502 nm)
T_1	113.61 a	53.89 a	7.15 a	56.43 a	201.45 a	9.38 a	3.33 a	2.85 a	5.63 a	10.36 a	9.80 a
T_2	110.47 b	51.32 b	6.94 ab	53.23 b	178.17 ab	8.36 b	3.15 ab	2.59 ab	5.34 ab	9.36 b	9.20 b
T_3	103.27 c	43.69 c	6.51 b	46.43 c	139.84 b	6.46 c	2.88 b	2.28 b	4.80 b	7.62 c	8.34 c
CV%	2.7	1.5	0.5	2.01	8	1.3	0.16	0.35	0.54	0.49	0.18
LSD0.05	1.36	0.79	0.25	1	46	0.65	0.08	0.17	0.27	0.24	0.09

Three drought treatments viz. T_1, Control; T_2 15 days withhold of water; T_3, 35 days withhold of water;
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.

4.2.1.1.1. Interaction between genotype and stress treatment

The value of interaction were showed in the three replication ,three drought treatment were like as 0 days control, 15 days drought stress and 35 days drought stress and vertical bar represent ± SE (standard Error).Columns with the different letter represent values that are significantly different to the LSD test ($p \leq 0.05$)

4.2.1.1.2 Plant height (cm)

Plant height was showed significance variation with the response of the genotype and drought stress interaction (Appendix IV).The tallest plant was found from the G_9T_1(97.33 cm) and the lowest plant height was found from the G_7T_3(14.66 cm). (Table 4)**.**This result showed that higher water stress gradually decreases plant height. This related result was reported by Wahb-Allah *et al.*(2001).

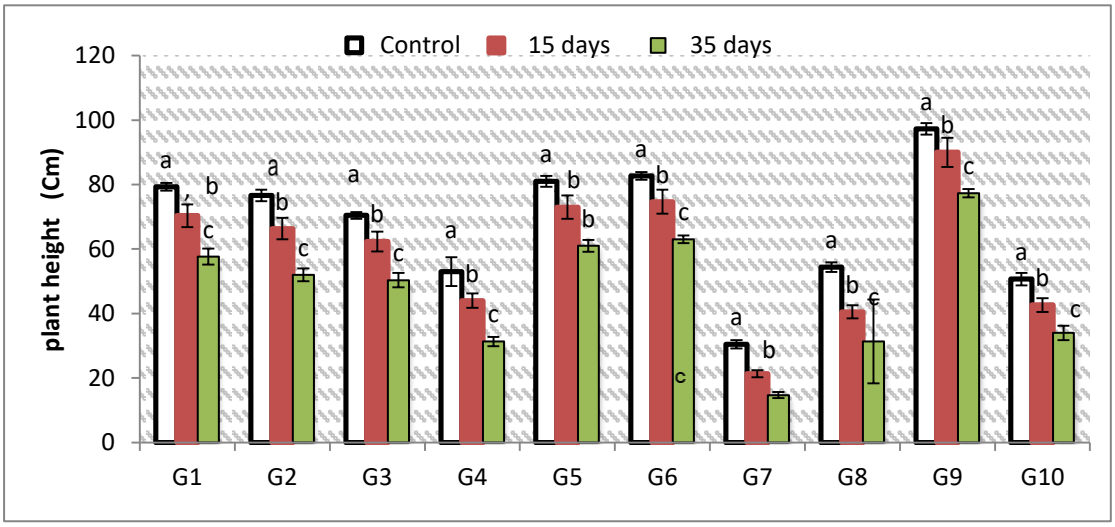


Figure 1. Interaction of genotype and stress treatment effect on the plant height

Table 4. Interaction effect of tomato and drought treatments on the following parameters of tomato

Interaction	Plant height (cm)	Num. of leaves/plant	Leaf area (cm^2)	No. of branches /plant	Days to first flowering	Days to first fruit setting	Days to maturity	Num. of clusters per plant	Num. of flowers per cluster	Num. of fruit per cluster
G1 T1	76.65 d-f	144.33a	32a	5.33 a	27b-d	17.33b-i	61d	9.33a	11c-e	9.33b-d
G1 T2	66.33hi	140b	29b-d	4.33a-c	24.6b-f	14e-h	58ef	9.1a	10f-h	8.33c-g
G1 T3	52 l	132.6c	16.66e-k	3d-g	21.3d-i	9.6 j	52.33gh	7 b	8lm	6.33i-l
G2 T1	79.33 c-e	76.67ef	29.66b-d	4.33a-c	29a-c	19.33a-f	60.33de	5.66 bc	11.33b-d	9c-e
G2 T2	70.3 g-h	72.67hi	25b-g	3d-f	26.3b-e	16.66b-i	57f	4.67c-e	10.33e-g	8d-h
G2 T3	57.66jk	63.33l	15f-k	2.33f-h	23d-g	13.66f-j	49ij	3.33e-g	8.33k-m	5.66 kl
G3 T1	70.44 gh	57.67 n	24.66c-h	4.66ab	20.33f-j	19.66 a-e	46.33kl	5cd	10.66d-f	8d-h
G3 T2	62.33ij	53.67o	18.66d-k	3d-g	17.66g-j	17b-i	43mn	4d-f	9.66g-i	7g-k
G3 T3	50.33l	43.67pq	13i-k	2gh	14.66j	12.66h-j	36.33p	3fg	7.66m	5l
G4 T1	53kl	74.33f-h	30b-d	3.33c-f	24.33b-e	22a-c	4lm	5cd	12.60a	10.66 ab

Table 4 (cont'd).

Interaction	Plant height (cm)	Num. of leaves/plant	Leaf area (cm^2)	No. of branches /plant	Days to first flowering	Days to first fruit setting	Days to maturity	Num. of clusters per plant	Num. of flowers per cluster	Num. of fruit per cluster
G4 T2	44 m	70.33 ij	20.6 c-k	2.66 e-h	21.6 d-i	20 a-d	41no	4 d-f	11.66 bc	9.66 bc
G4 T3	31.3 n	60.33 mn	14.66g-k	2 gh	16 ij	16 d-i	34 p	2.60 fg	9.66 g-i	7.66 e-i
G5 T1	81c d	75.67 fg	15.33f-k	4 b-d	22 d-h	24 a	57.33f	5 cd	9 i-k	9.66 bc
G5 T2	73f g	71ij	13 i-k	2.66 e-h	20 f-j	22 a-c	54.30 g	4 d-f	8 lm	8.66 c-f
G5 T3	61ij	60.33 mn	9.33 k	1.66 h	17 h-j	18 b-i	47.33 jk	3.66 d-g	6 n	6.66 h-k
G6 T1	82.6 c	45p	26.33 b-f	3.66 b-e	21.3 d-i	16.33 c-i	49.33 ij	6 bc	11.3 b-d	9.33 b-d
G6 T2	74.6 e-g	41q	19.66 d-k	2.66 e-h	19 f-j	13g-j	46.33 kl	5cd	10.3 e-g	8.33c-g
G6 T3	63ij	30.33 s	13.33 h-k	1.67 h	20 f-j	9.60 j	39.33o	4 d-f	8.66 j-l	6.66 h-k
G7 T1	30.44 n	37.33 r	25.66 b-g	4.33 a-c	30 ab	18.6 a-g	60.30 de	6 bc	11.6 bc	9.66 bc
G7 T2	21.33 o	33 s	22 c-j	3.33 c-f	26.6b-d	16 d-i	57.33 f	4.66 c-e	10.6 d-f	8.66 c-f

Table 4 (cont'd).

Interaction	Plant height (cm)	Number of leaves/plant	Leaf area (cm^2)	No. of branches /plant	Days to first flowering	Days to first fruit setting	Days to maturity	Num. of clusters per plant	Num. of flowers per cluster	Num. of fruit per cluster
G7 T3	14.66 p	22.33 t	14.33g-k	2.3 f-h	20.60 e-i	12.33 h-j	50.3 hi	3fg	8.66j-l	6.66 h-k
G8 T1	54.38 kl	76.67 ef	27.66 b-e	4b-d	33.3 a	18.6 a-g	57.33f	5cd	12 ab	11.66a
G8 T2	40.5 m	72.67 hi	26.33 b-f	2.6 e-h	29 a-c	16 d-i	53.3 g	3.33 e-g	11 c-e	10.66 ab
G8 T3	31.33 n	62.67 lm	23.33 c-h	1.66h	24 c-f	11.66 ij	47.33jk	2.3 g	9 i-k	8.66 c-f
G9 T1	97.33 a	77 ef	25 b-j	4 b-d	33.33 a	24.33 a	52.3gh	5.66 bc	11.3b-d	10.66 ab
G9 T2	90 b	73 g-i	21c-j	2.6e-h	29.3 a-c	22.33 ab	49 ij	4 d-f	10.33 e-g	9.66 bc
G9 T3	77.3 c-f	66.3k	11.66jk	1.66 h	24.33 b-f	17.6 b-h	42.3 mn	3 fg	8.33 k-m	7.33f-j
G10 T1	50.66 l	82.67 d	29.66 b-d	4 b-d	26.66 b-d	17.3b-i	76 a	4.66 c-e	9.33h-j	8 d-h
G10 T2	42.66 m	78.67 e	24 c-i	2.66e-h	23.66 c-f	15.33 d-j	73 b	3.33 e-g	8.33 k-m	7g-k
G10 T3	34 n	68.67 jk	12.33 jk	2 gh	19.33 f-j	12.66 h-j	66 c	2.33 g	6.33 n	6 j-l
CV%	2.7	1.38	11	1	5.8	5.9	2.5	1.5	0.94	1.5
LSD 0.05	5.5	2.76	5.74	0.51	2.29	2.9	1.25	0.75	0.47	0.74

Three drought treatments viz. T_1, Control; T_2 15 days withhold of water; T_3, 35 days withhold of water;
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. (cont'd).

Interaction	Num. of fruit/plant	Length of fruit (mm)	Fruit diameter (mm)	Average fruit wt. (kg/plant)	Yield (g/plant)	Root length (cm)	shoot root ratio	Skin diameter fruit (mm)	Ethylene concent. (ppm)	Membrane stability (%)
G1 T1	6.33 a-c	45.33 h-l	4.15g-j	297.67ab	0.360 g	76.6a-d	7.66g-k	7.50g-k	0.20a-d	7.50 a
G1 T2	5.33 c-f	43.33 j-n	3.92 h-j	277.67bc	0.333 h	75.20a-d	6.66j-o	6.55j-o	0.18a-h	7.10ab
G1 T3	3.33 i-k	39.33n-p	3.66 h-j	231de	0.300 i	71.66b-e	5.66m-o	5.61m-o	0.15d-i	6.40a-c
G2 T1	6.33 a-c	40 m-p	9.36 cd	321.67 a	0.323 hi	38.07i	8.33f-j	8.29f-j	0.20a-d	4.46e-h
G2 T2	5d-g	38 pq	8.33c-e	301.67ab	0.303i	36.44i	7.33h-m	7.29h-m	0.18a-h	4.06g-i
G2 T3	3jk	34q	6.5d-h	260 cd	0.260 j	35.7i	5.33no	5.29no	0.14e-i	3.13i-l
G3 T1	6b-d	50e-h	7.66 c-f	350a	0.456 c	42.22g-i	8f-k	7.50l-k	0.23a	6.5a-c
G3 T2	5d-g	47.67 g-k	6.96 c-g	180gh	0.436cd	40.5 hi	7i-n	6.50i-n	0.21ab	6.10bc
G3 T3	3.33i-k	44j-n	5.84 e-i	136.67i-k	0.396ef	38.59i	5o	4.50 o	0.18a-h	5.63c-e
G4 T1	7.33 a	44.67 i-m	9.6a	114.3k-n	0.262 j	80.62a-c	10.66b-d	10.61b-d	0.2a-e	4.83d-g

Table 4 (cont'd).

Interaction	Num. of fruit/plant	Length of fruit (mm)	Fruit diameter (mm)	Average fruit wt. (kg/plant)	Yield(kg/plant)	Root length (cm)	shoot root ratio	Skin diameter fruit (mm)	Ethylene concent. (ppm)	Membrane stability (%)
G4 T2	5.66c-e	42.66k-p	8.58 c-e	90n-p	0.242j-l	91.33ab	9.66c-f	9.61c-f	0.17b-h	4.43f-h
G4 T3	4.33f-i	38.66o-q	7.84 c-e	54qr	0.203m-o	89ab	8f-k	7.45f-k	0.14f-i	3.70g-j
G5 T1	7a	57a	5f-j	245.33de	0.248jk	39.81hi	10.33c-e	10.29c-e	0.19a-g	3.96g-i
G5 T2	6b-d	56.30ab	4.3g-j	222ef	0.228k-m	38.06i	9.33d-g	9.29d-g	0.18a-h	3.60 hij
G5 T3	4.33f-i	51.60b-g	3.5ij	150hij	0.492b	34.28i	7.33 h-m	7.29h-m	0.13hi	2.93b-m
G6 T1	5d-g	55.30a-d	2.91ij	122j-m	0.549 a	76.46a-d	9d-h	8.5d-h	0.17b-h	2.66j-n
G6 T2	3.66 h-j	53.33a-f	2.7j	102l-o	0.529a	74.33a-d	8f-k	7.50f-k	0.15c-i	2.2l-o
G6 T3	3.33i-k	41.66l-p	2.36j	62p-r	0.186op	72.03b-e	6l-o	5.50l-o	0.11i	1.83m-p
G7 T1	5d-g	55a-e	2.7j	215.3ef	0.323hi	93.33 a	9.33d-g	9.29d-g	0.19a-g	2.63j-n
G7 T2	3.67h-j	52.37a-g	2.5j	193.3fg	0.300i	78.55a-d	8.33f-j	8.29f-j	0.17 b-i	2.33k-o

Table 4 (cont'd).

Interaction	Num. of fruit/ plant	Length of fruit (mm)	Fruit diameter (mm)	Average fruit wt. (g/plant)	Yield (kg/plant)	Root length (cm)	shoot root ratio	Skin diameter fruit (mm)	Ethylene concent. (ppm)	Membrane stability (%)
G7 T3	2.33k	49.33f-i	2.3j	143.33i-k	0.266j	75.3a-d	6.33k-o	6.24k-o	0.13g-i	1.73n-q
G8 T1	5d-g	56.33ab	3.6h-j	200fg	0.217l-n	53e-i	12.33ab	12.29ab	0.21a-c	5.80cd
G8 T2	4g-j	53.37a-f	3.4ij	72.67o-q	0.196no	51.3f-i	11.33bc	11.29bc	0.19a-g	5.43c-f
G8 T3	2.33k	50.66c-g	3.1ij	90np	0.17pq	48f-i	8.3f-j	8.29f-j	0.15c-i	4.80d-g
G9 T1	5.33c-f	57a	3.6i-k	152h-j	0.156qr	11.00a-c	13.33a	13.29a	0.21a-c	3.50h-k
G9 T2	4.67e-h	55a-e	3.4ij	126i-l	0.136rs	9.90a-d	12.33ab	12.29ab	0.19a-f	3i-m
G9 T3	3.33i-k	50.33d-h	3.01ij	39.33r	0.380fg	76.66a-d	10.33c-e	10.29c-e	0.16b-i	2.8h-k
G10 T1	4.33f-i	55.66a-c	3.20ij	156hi	0.438cd	75.20a-d	9.66c-f	9.60c-f	0.21ab	1.43o-q
G10 T2	3.33i-k	53.66a-f	2.77j	133.33i-k	0.415de	71.66b-e	8.66e-i	8.61e-i	0.19a-f	0.93pq
G10 T3	2.33k	48g-j	2.3j	94m-o	0.127s	38.07 i	6.66j-o	6.6jo	0.15c-i	0.65q
CV%	1.2	5.22	2.9	15	15	16	1.8	1.3	0.06	1.1
LSD 0.05	0.62	2.6	1.4	7.5	7.5	8	0.93	0.98	0.03	0.58

Table 4 (cont'd).

Interaction	Chlorophyll content (%)	Relative water content	Moisture In fruit (%)	Dry matter in fruit(%)	Proline content (µg/g)	Brix (%)	pH of fruit	Titrable acidity (%)	Vitamin-C	Lycopene (472nm)	Lycopene (502 nm)
G1 T1	126.8e	57.64ef	9.24a-d	76 a	153.33c-j	9.1a-h	3.26a-g	3.58a-c	6 a-c	9.49 fg	8.4kl
G1 T2	123.67ef	55c-e	5.01c-f	61bc	131f-j	7.96 c-j	3.13d-k	3.1b-f	5.21ab	5.68l-n	15qs
G1 T3	113.33gh	50.09gh	9b	60.33 b-d	122d-j	5.93a-e	2.86a-c	2.9 a-d	4.7a-c	4.71d	14fg
G2 T1	257 a	60.06ab	9.11c	46.33h-k	291.82a-c	7.76a-e	2.96a-e	4.03a-c	6.15a-c	21.23ab	21.3a
G2 T2	160cd	55k-m	6.14b	44i-l	271a-e	6.7a-d	2.76a-f	3.33a-d	5.68a-d	17.63bc	17.36d
G2 T3	153 d	47h-j	4.50d-g	41k-m	261.33a-e	5.13a-e	2.25a-g	2.58c-h	5.21a-d	12.6q	12.06i
G3 T1	119 e-g	55j-l	5.23e-g	60.3f-j	250a-f	12.2ab	3.51b-e	4.7 a	6.03a-c	22 a	8.3o
G3 T2	116f-h	40d	4.26 e-g	49.33 b-d	189.3b-j	11.3a-c	3.36 ab	4.1ab	5.43a-d	12g-i	7.1 m
G3 T3	109 h	29.45o	3.8fg	47.3c-e	145c-j	9.33 c-j	3.05b-j	2.05a-e	6.13a-b	5.46j-l	4.5p
G4 T1	163c	61.0de	20.66 a	58.33e-h	291.92a	10.6a-e	3.41a-i	4.29d-j	6a	9.42l-o	19.6a

Table 4 (cont'd).

Interaction	Chlorophyll content (%)	Relative water content	Moisture in fruit (%)	Dry matter in fruit(%)	Proline content (µg/g)	Brix (%)	pH of fruit	Titrable acidity (%)	Vitamin C	Lycopene (472nm)	Lycopene (502 nm)
G4 T2	254ab	54fg	4.76 d-g	52c-e	123.67d-j	8.9c-j	3.25a-i	3.33a-d	5.43a-d	8.49gh	7 kl
G4 T3	246.67 b	50 ab	4.50c-f	50 c-e	80.33h-j	6.85e-k	3.04 h-k	1.41 ij	1.4 e	3.53m-p	13.78qr
G5 T1	60.93no	47.33hi	8.99b	57 c-e	92f-j	10.96a-c	3.64a	2.3c-h	4.6a-c	20d	12.03g
G5 T2	57op	40bc	8.86bc	43j-l	271.98a-d	10.06a-i	3.49a-h	2.72g-j	4.35a-d	18.2a	19.66b
G5 T3	50.67 p	39.33lm	6.06b-d	41k-m	236.43ab	8.23a-e	3.21a-d	3a-e	3.85cd	16.6c	12e
G6 T1	66l-n	56i-l	4.25e-g	34d-f	241.33a-g	12.66 a	3.31a-i	2.53d-j	4.66b-d	10.83ef	10.6 j
G6 T2	63m-o	39.66km	4.01fg	46.33h-k	230b-h	11.06f-k	3.21a-i	2.35c-h	4.46a-c	9 k-m	8.7p
G6 T3	56o-p	37de	3.80fg	37.33c-e	168.67 c-j	9.83 a-i	2.83a-f	1.62h-j	3.39a-d	7 h-j	5m
G7 T1	80.73ij	68a	3.30fg	53.33e-g	125d-j	6.86d-k	3.41f-k	2.80b-g	6.03a-c	11.46l-o	6.13pq
G7 T2	77.67 i-k	58.33 ef	12b	52f-j	92.33g-j	5.86g-k	3.36 e-k	2.50 e-j	5.68 a-c	8m-p	8rs

Table 4 (cont'd).

Interaction	**Chlorophyll content (%)**	**Relative water content**	**Moisture in fruit (%)**	**Dry matter in fruit (%)**	**Proline content (ug/g)**	**Brix (%)**	**pH of fruit**	**Titrable acidity (%)**	**Vitamin C**	**Lycopene (472nm)**	**Lycopene (502 nm)**
G7 T3	70.67 k-m	47.33 hi	3.09 e-g	43.33e-h	85 h-j	3.93 e-k	3.03 f-k	2.28 a-e	5.02 a-d	6.46 i-k	3.90 l
G8 T1	120.33 e-g	65.12 cd	4 h	66 b	80 j	9.86 h-k	3.56 k	2 d-j	5.35 a-d	2 p	16.13pq
G8 T2	117.33 f-h	39.6k-m	6 bc	49f-j	69 ij	8.83a-g	3.56a-i	2.85 a-c	5.21 a-d	12.26 e	14.66 h
G8 T3	110.33 h	35de	5.66c-e	36.33 mn	50 c-f	6.93d-k	3.36 c-j	2.65c-h	4.73 a-d	10.2 b	12.66 c
G9 T1	81.73 i	50 o	5 ef	3 n	210 a-c	7.96b-i	3.03a-i	2.83 b-g	6.13 d	14.44 d	10 f
G9 T2	78.67 i-k	37 mn	3.7 fg	34g-k	208.33b-i	6.96 a-f	2.86 g-k	2.5 e-j	5.91 d	8.83 g	8.66 k
G9 T3	72.67 j-l	32.22 no	3.4 fg	39.33 l-n	185 b-j	4.9 jk	2.53 e-k	2.21 e-j	5.31 a-d	2.93 op	3.83 qr
G10 T1	56 no	53.5 fg	3.59 fg	34 f-i	127 d-j	6.93 d-k	3.15 c-j	3.29 j	6.23 a-d	4.86 lm	6.86 n
G10 T2	57.33 op	40 p	3.05g	55 g-k	88.67 g-k	5.33 i-k	2.93 jk	2.47c-i	5.91 a-d	2.5 p	3.76qr
G10 T3	50.33 p	34 gh	10a-c	42.33 k-m	38.67 ju	3.56 k	2.71 i-k	1.72 g-j	5.35 a-d	2.427 p	3.06 s
CV%	8.6	5.01	1.6	6.36	16	4.1	0.53	1.16	1.71	1.55	0.58
LSD 0.05	4.3	2.5	0.8	3.18	8	2.06	0.25	0.55	0.86	0.77	0.29

4.2.1.2.2 Number of leaves per plant

The number of the leaves per plant was found statistically significance in the term of interaction of genotype and drought stress (Appendix IV). The highest number of the brances per plant was found from the G_1T_1 (144.33) and lowest number was found from the G_7T_3 (22.33) (Table 4). This result was showed that higher water stress gradually decreases number of leaves per plant. Related results reported by Wahb-Allah *et al.* (2001).

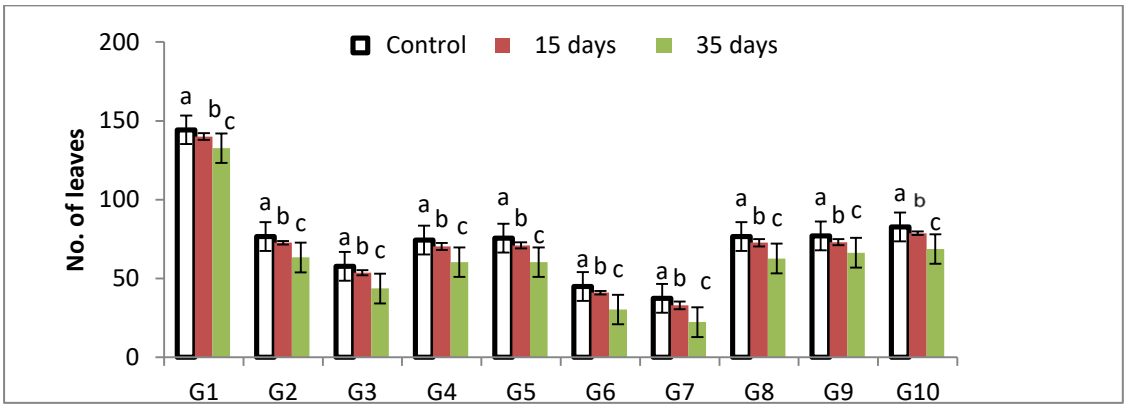


Figure 2. Interaction of genotype and stress treatment effects on number of leaves per plant

4.2.1.3.2 Leaf area index (cm^2)

Interactions of tomato genotype and drought stress should significantly variation in the term of leaf area (Appendix IV). The maximum leaves area index was found in the treatment from G_1T_1(32 cm^2) and minimum leaves area index was found in G_5T_3(9.33 cm^2) (Table 4).This result showed that drought stress decreses the leaf area index similar result was found in Pigeonpea of F.B. Lopez *et al.*(2018).

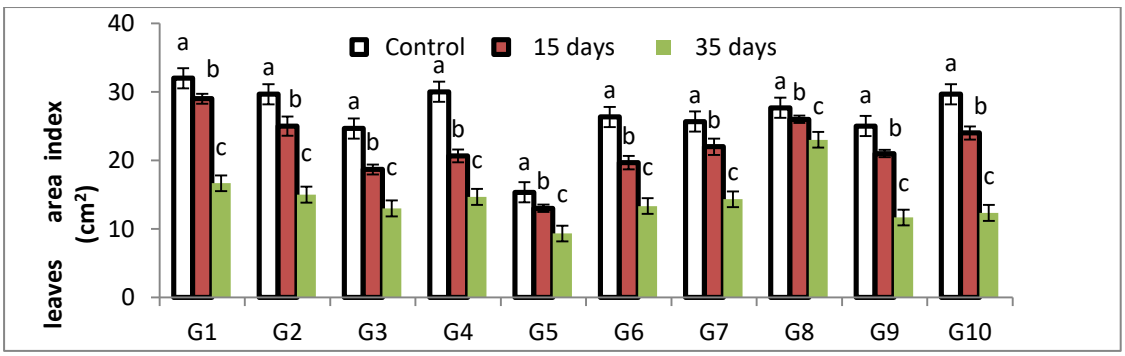


Figure 3. Interaction of genotype and stress treatment effects on leaves area index

4.2.1.4.2 Number of branches per plant

The number of branches per plant was found statistically significant in interaction between genotype and drought stress (Appendix IV).The highest number of the branches was found from the G_1T_1(5.33) and lowest number of the branches was found from the G_9T_3(1.66) and G_5T_3,G_8T_3(1.66) both was similar (Table 4) **.**This result showed that number of branches reduced due to drought stress Similar result was founded in Chick pea experiment by Muruiki *et al* .(2018) .

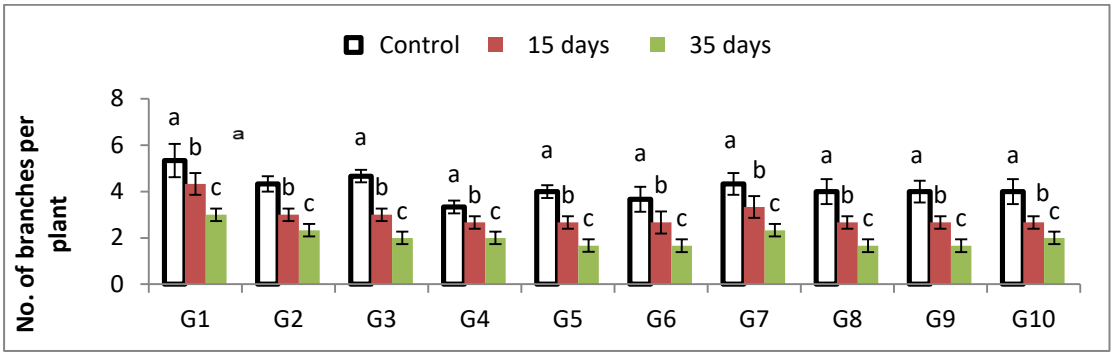


Figure 4. Interaction of genotype and stress treatment effects on number of branches per plant

4.2.1.5.2 Days to first flowering

Interaction of the tomato genotype and drought stress affected statistically significance in the term of days to first flowering (Appendix IV).The longest day of the first flowering was found in the G_8T_1 (33.33 day) ,G_9T_1(33.33 day) and shortest day of the first day flowering found from the G_3T_3(14.66 day) (Table 9) **.** This result showed that first flowering reduces due to drought stress and similar result was found in rice of Kang, D.J. *et al* (2019).

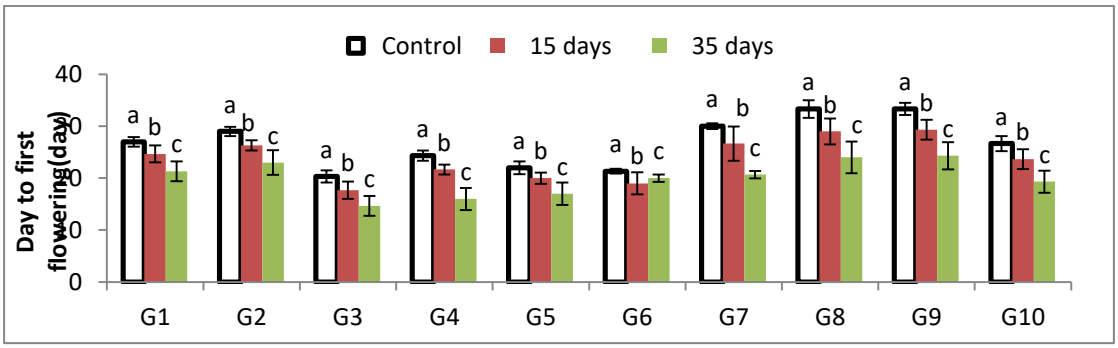


Figure 5. Interaction of genotype and stress treatment effects on the days to first flowering

4.2.1.6.2 Days to first fruit setting

Interaction of the tomato genotypes and the drought stress was showed statistically significance in the term of days to first fruit setting in the (Appendix IV). The longest day of the first fruit setting was found in the G_9T_1 (24.33) similar result found from G_5T_1 (24) and lowest day was found from the G_6T_3 (9.60) (Table 4) .The drought stress reduces the fruit setting similar result was founded in Stagnaria *et al.* (2019).

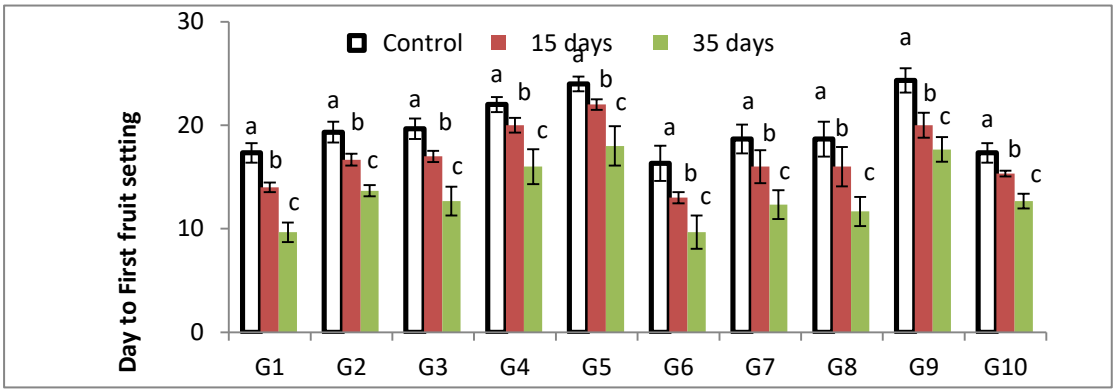


Figure 6. Interaction of genotype and stress treatment effects on the days to first fruit setting

4.2.1.7.2 Days to maturity

Interaction of the tomato genotype and drought treatment showed statistically significance in the term of the days to maturity (Appendix IV).The highest days of the fruit maturity was found from the $G_{10}T_1$ (76 days) and the lowest days of fruit maturity was found from the G_4T_3 (34 days). (Table 4).This type of the result was showed that fruit maturity reduced with the increase of the drought stress .Similar result found in the Stagnaria *et al.* (2019).

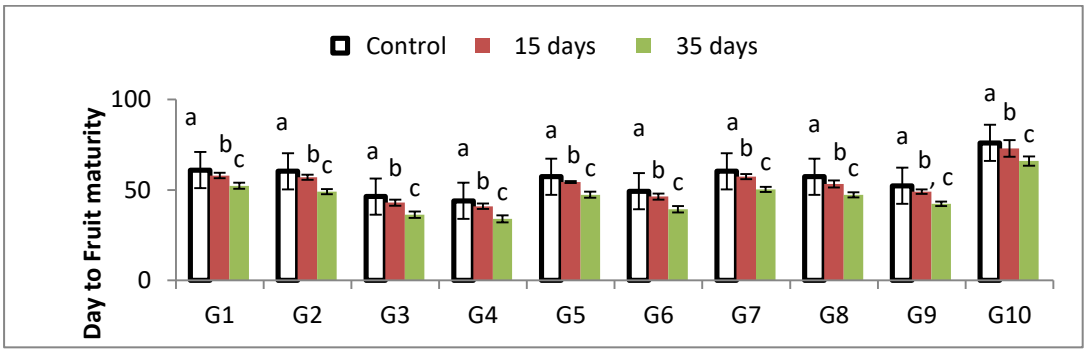


Figure7. Interaction of genotype and stress treatment effects on the days to maturity

4.2.1.8.2 Number of clusters per plant

Interaction of the tomato genotype and drought stress was showed statistically significant in the term of number of clusters per plant was found in (Appendix IV). The highest number of the cluster per plant was found from the G_1T_1 (9.33) and similarly G_1T_2(9.1) and lowest number was found from G_8T_3(2.33) and $G_{10}T_3$(2.33) both are similar (Table 4) .This result showed that drought stress decrease the number of the cluster. Similar result was founded in the potato from the Nassar *et al.* (2018)

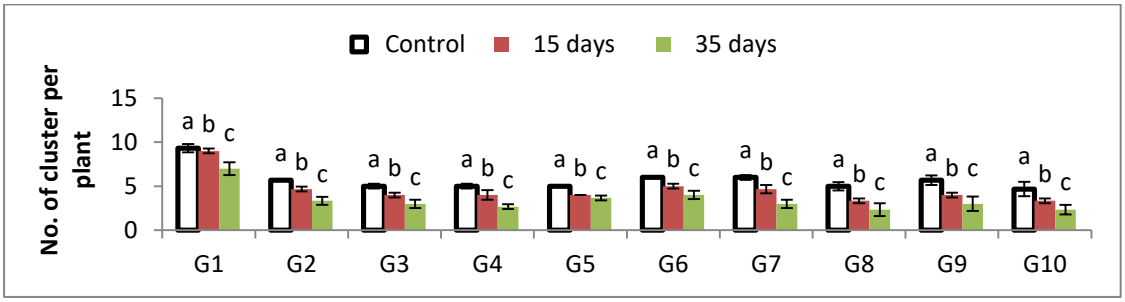


Figure 8. Interaction of genotype and stress treatment effects on number of cluster per plant

4.2.1.9.2 Number of flowers per cluster

Interaction of the tomato genotypes and drought stress was showed statistically significant variation in the term of the number of the flower per cluster was found in the (Appendix iv). The highest number of the flower per cluster was founded from G_4T_1(12.60) and lowest number of the flower per cluster was founded from the G_5T_3(6) (Table 4). Increasse the drought stress reduces the flower cluster. Similar result found from the Nassar *et al.* (2018).

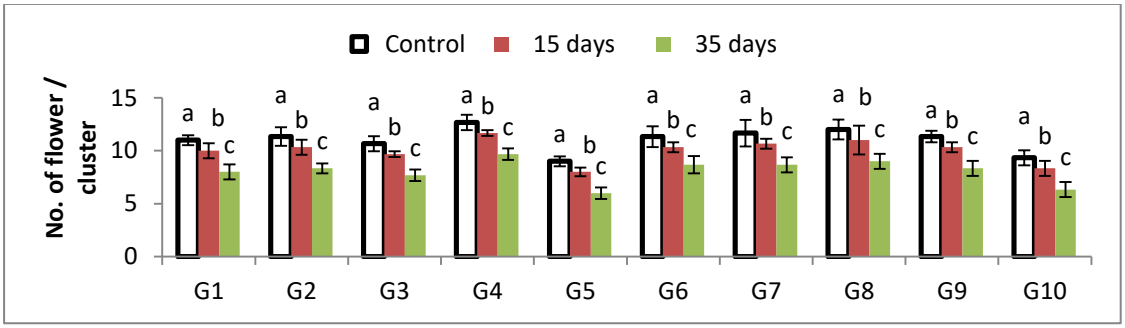


Figure 9. Interaction of genotype and stress treatment effects on number of flower per cluster

4.1.1.10.2 Number of fruit per cluster

Interaction of the genotype and drought stress was showed statistically significant variation in the term of number of fruit per cluster in the(Appendix IV).The highest number of the fruit per cluster was found from the G_8T_1(11.66) and lowest number of the fruit per cluster was found from the G_3T_3(5) (Table 4). Due to increase the drought stress number of fruit per cluster reduces. Similar result was found in sweet potato of Nassar *et al.* (2018)

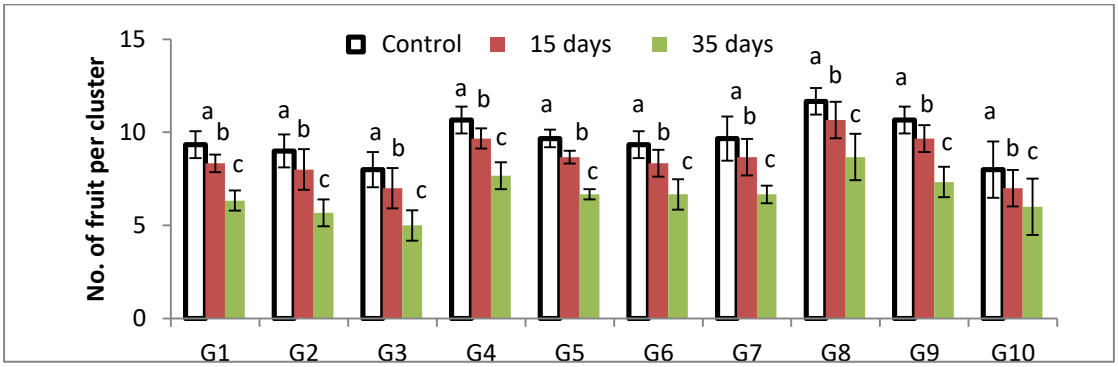


Figure 10. Interaction of genotype and stress treatment effects on number of fruit per cluster

4.2.1.11.2 Number of fruit per plant

Interaction of the tomato genotypes and drought stress was showed statistically significant variation in the term of number of the fruit per plant (Appendix IV). The highest number of the fruit per plant was found in the G_4T_1 (7.33) and lowest number of the fruit was found in the G_7T_3, G_8T_3, and in $G_{10}T_3$ (2.33) were similar (Table 4) . This result showed that increase the drought stress interaction reduced the number of fruit similar result was found in the Nassar *et al.* (2018).

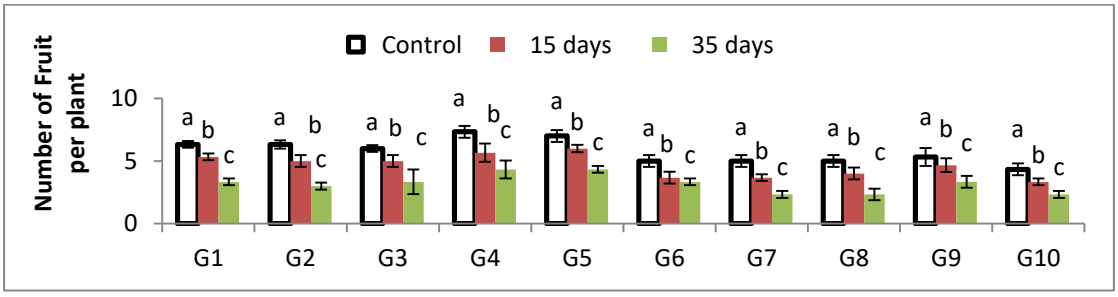


Figure 11. Interaction of genotype and stress treatment effects on the number of fruit per plant

4.2.1.12.2 Lengths of fruit (mm)

Statistically significance variation was found among the interaction of tomato genotypes and drought stress in the (Appendix IV). The maximum fruit length was found in the G_4T_1 (7.33mm). On the other hand the minimum fruit length was found in the G_2T_3 (3mm) (Table 4).This result showed that due to increase the interaction of the drought stress decreases the fruit length similar result was found in the Stagnaria *et al.* (2018).

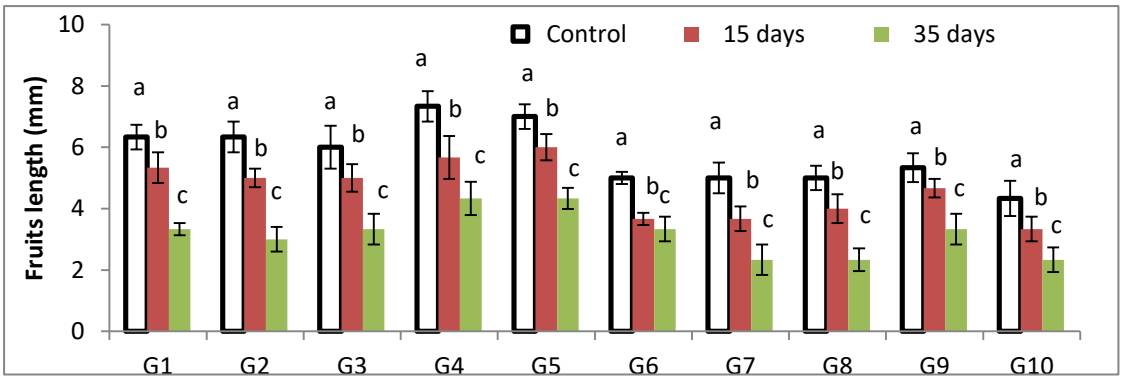


Figure 12. Interaction of genotype and stress treatment effects on length of fruits

4.2.1.13.2 Fruit diameter (mm)

Interaction of the tomato genotypes was showed significant variation in the term of fruit dia meter (Appendix IV). The highest diameter of the tomato was found from the G_4T_1(9.6mm) and lowest diameter was found in the G_7T_3(2.3) followed by G_6T_1,G_6T_2,G_6T_3,G_7T_1,G_7T_2,G_7T_3 ,$G_{10}T_3$ (Table 4).Drought stress interaction reduces the fruit diameter similar result was found in Stagnaria *et al.*(2018) .

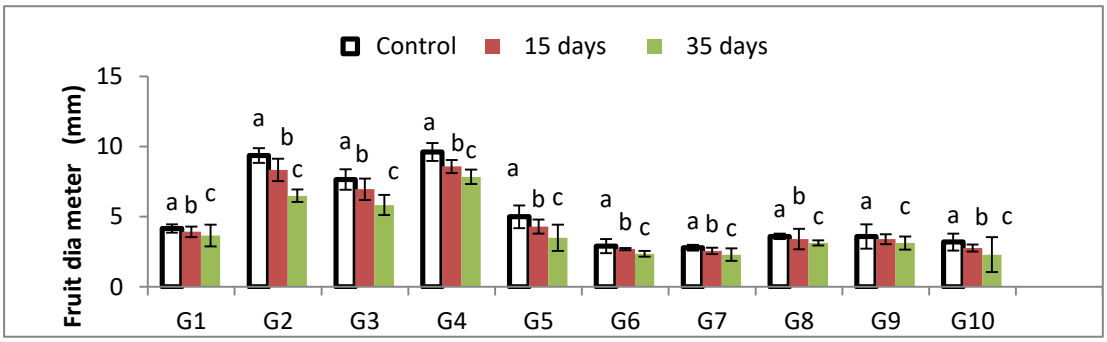


Figure 13. Interaction of genotype and stress treatment effects on the fruit diameter

4.2.1.14.2 Average fruit weight (g)

Interaction of the tomato genotypes and drought stress were showed statistically significant variation in the term of average fruit weight (gm) in the (Appendix IV).The maximum average fruit weight was found in the G_3T_1 (350 gm) and minimum weight was found from the G_9T_3 (39.33gm) (Table 4) .This result showed that increase the drought stress reduced the average fruit weight similar result was found in Sivakumar *et al* .(2016).

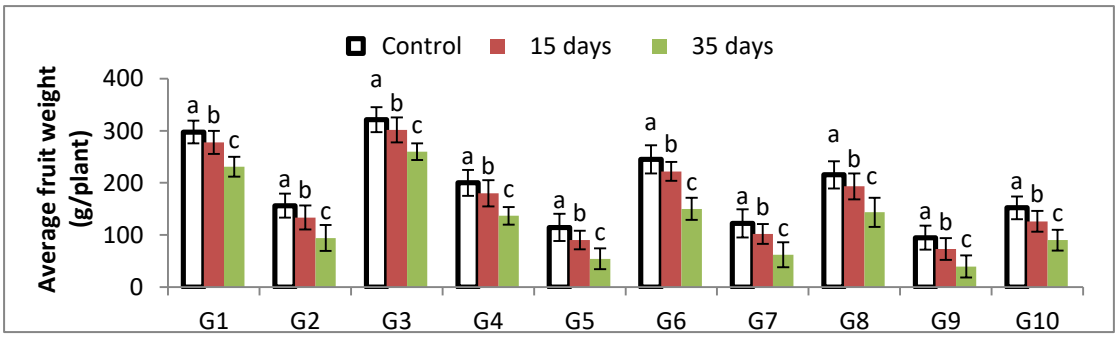


Figure 15. Interaction of genotype and stress treatment effects on the average fruit weight

4.2.1.15.2 Yield per plant (g/Plant)

Interaction of the tomato genotypes and drought stress was showed statistically significant variation in the term of the yield per plant in the (Appendix IV).The highest yield was found in G_6T_1 (549 gm), and G_6T_2(529 gm) both were similar and on the other hand the lowest the yield per plant was found in the $G_{10}T_3$(27.67 gm) (Table 4) .This result was showered that increase the drought stress it reduces the yield of tomato similar result was found from the Sivakumar *et al.*(2016) .

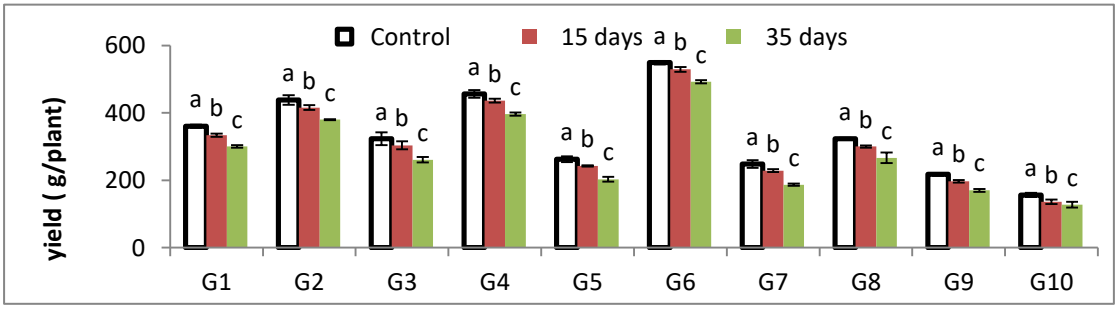


Figure 15. Interaction of genotype and stress treatment effects on the yield per plant

Comparison of the fruit morphology in different genotypes of tomato under drought stress treatment was showed in the (Plate 6).

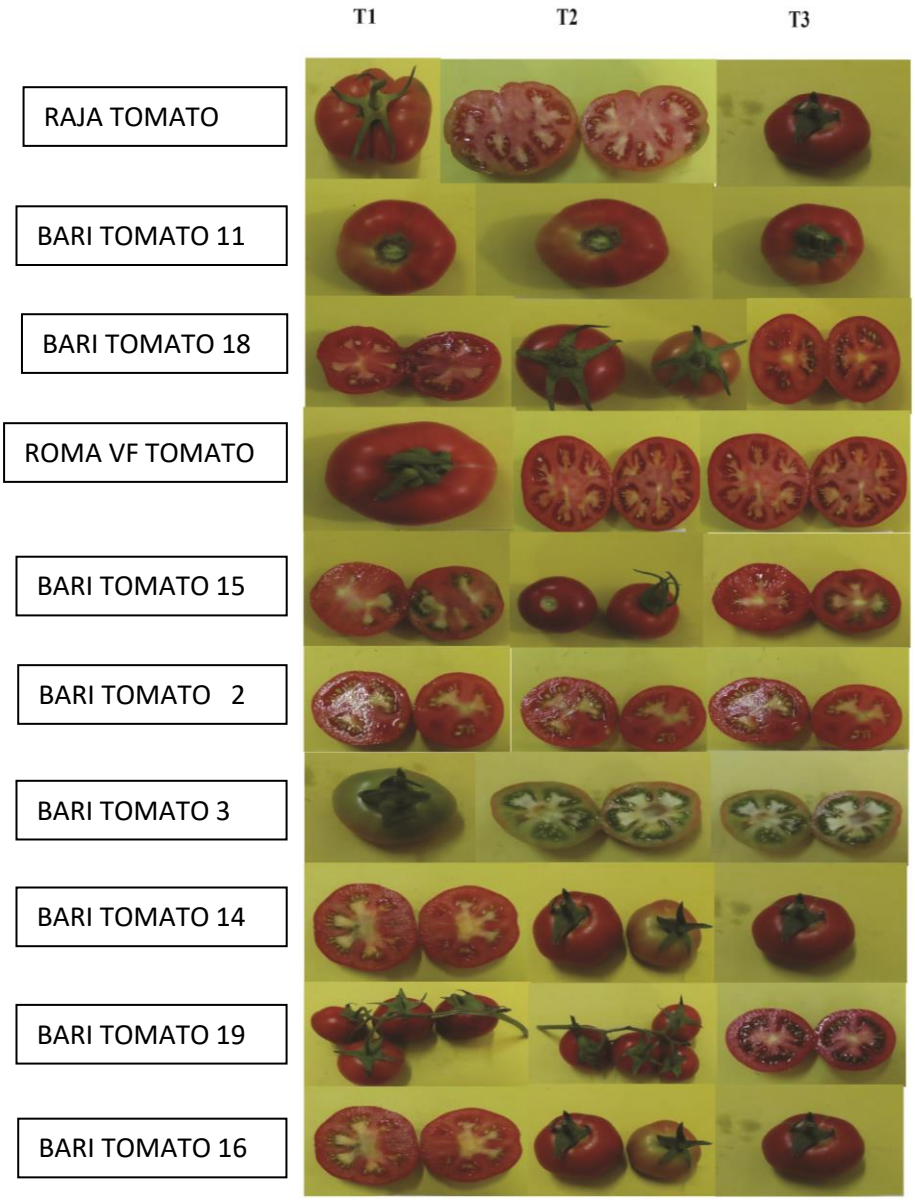


Plate 6. Comparison of the fruit morphology in different genotypes of tomato under control, 15 days and 35 days drought stress treatments

4.2.1.16.2 Root length (cm)

Interaction of the genotypes and drought stress showed statistically significant in variation in the term of the root length (cm) (Appendix IV). The maximum root length (cm) found from the G_7T_1 (93.33cm) and minimum root length was found in G_5T_3 (34.28 cm) in length (Table 4). This result was showed that increase the drought stress interaction reduces the root length of the crop similar result was found from Abdulallah, A.A. *et . al.*, (2010).

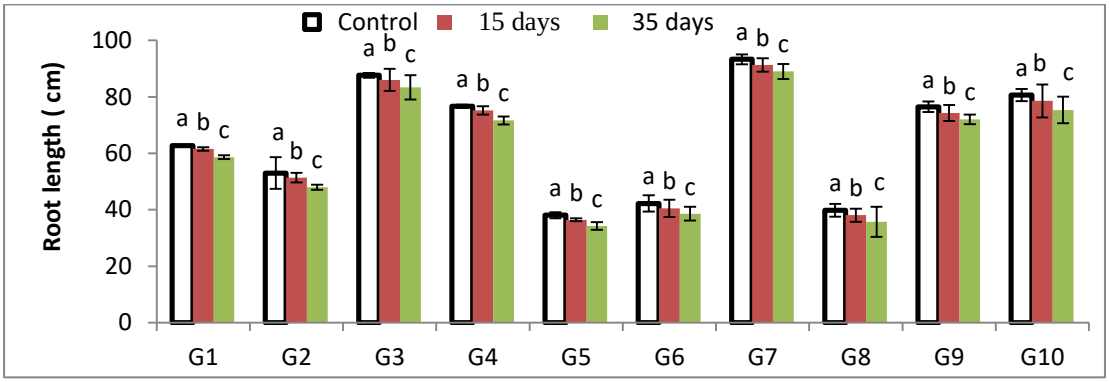


Figure 16. Interaction of genotype and stress treatment effects on the root length

4.1.1.17.2 Shoot root ratio

Interaction of the tomato genotypes and drought stress were showed statistically significant variation in the term of the shoot root ratio in the (Appendix IV). The longest shoot root ratio was found in the G_9T_1 (13.33) and the shortest shoot root ratio found from the G_3T_3(5) (Table 4). This result showed that increase the drought stress interaction decreases the shoot root ratio similar result was found in Abd Allah, A.A. *et.al.(*2010).

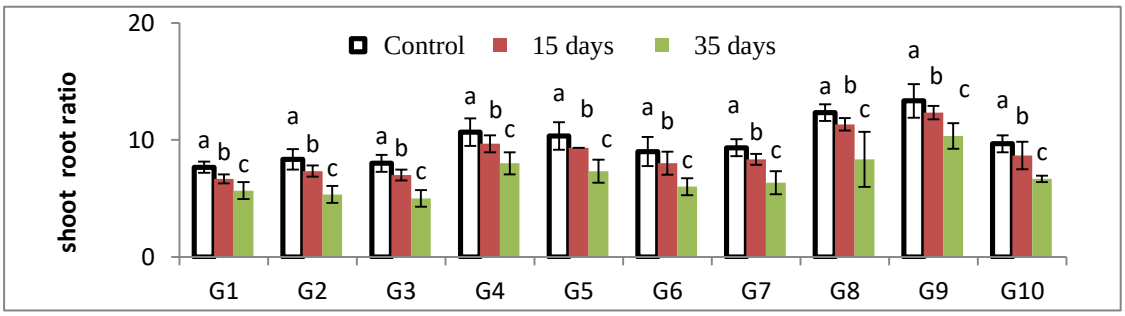


Figure 17. Interaction of genotype and stress treatment effects on the shoot root ratio

4.1.1.18.2 Skin diameter of fruit (mm)

Interaction of the tomato genotypes and drought stress was showed statistically significant variation in the term of the skin diameter in the (Appendix IV).The maximum skin diameter was found in the G_9T_1 (13.29 mm) and minimum skin diameter was found in the G_3T_3(4.50 mm) (Table 4).This result showed that interaction effect of drought stress and genotype decreased the skin dia meter .Similar result was found from the in Stagnaria *et al.* (2018).

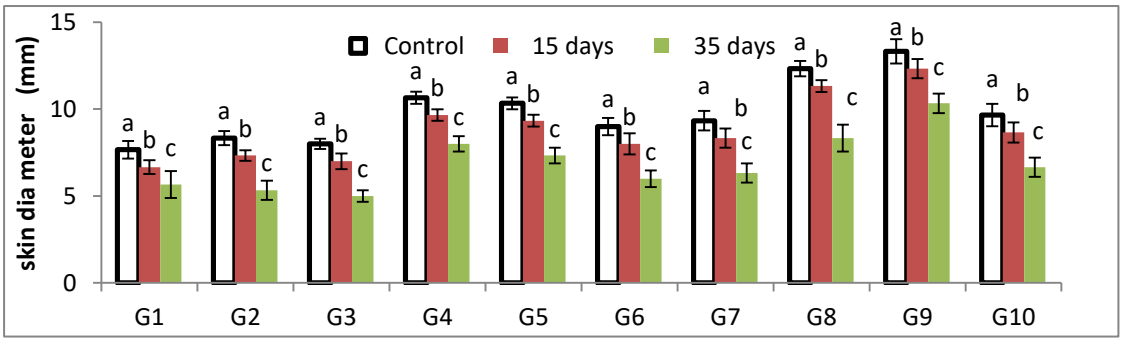


Figure 18. Interaction of genotype and stress treatment effects on the skin diameter

4.2.2.2 Physiological traits

Physiological traits like ethylene concentration, % membrane stability index, chlorophyll content were relative water content, % moisture content, % dry matter content was determined on the base of genotypes and drought stress interaction.

4.2.2.1.2 Ethylene concentration (ppm)

Interaction of the genotypes and drought stress showed significant variation in the term of the ethylene concentration (mm) (Appendix IV). The maximum concentration of the ethylene concentration was found in the G_3T_1 (0.23 mm) and minimum concentration was found in the G_6T_3(0.11 mm) (Table 4) .This result similar with Riyazudddin *et al*.(2020).

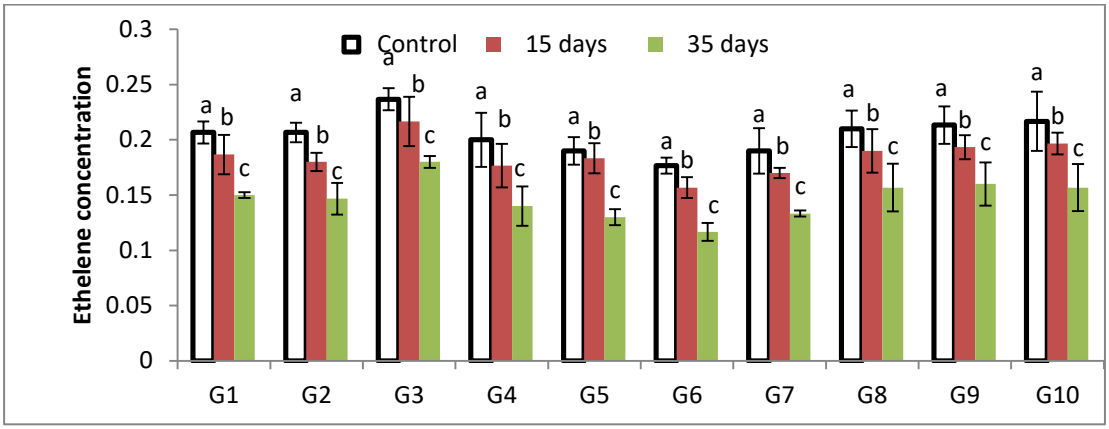


Figure 19. Interaction of genotype and stress treatment effects on the ethylene concentration

4.1.2.2.2 % Membrane Stability Index

Interaction of the genotypes and drought stress showed statistically significant variation in the term of the membrane stability index (Appendix IV). The maximum membrane stability index was found in the G_1T_1 (7.50 %) and lowest membrane stability index was found in the $G_{10}T_3$ (0.653 %) (Table 4) .This result showed that membrane stability index reduced with the increase of the drought stress interaction. Similar result was found in the Dwivedi *et al.(*2018).

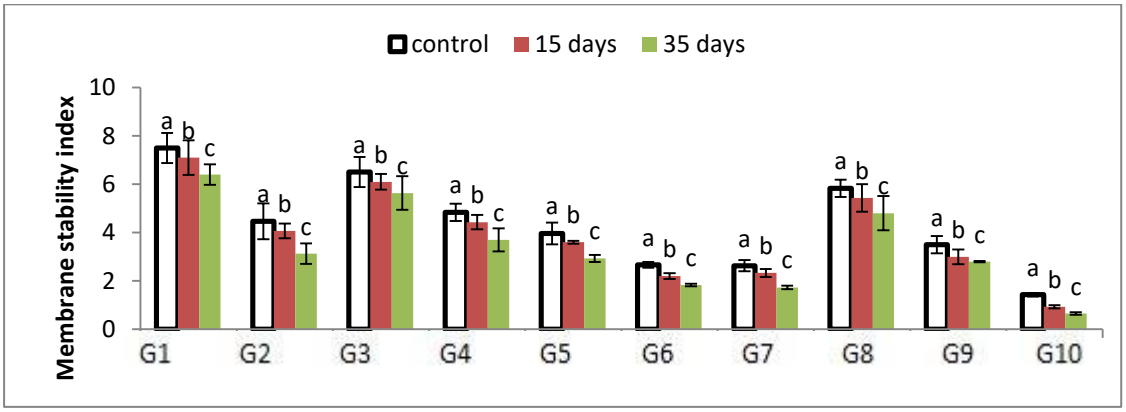


Figure 20 . Interaction of genotype and stress treatment effects on the membrane stability index

4.1.2.3.2 Chlorophyll content (%)

Interaction of the genotypes and the drought stress was showed statistically significant variation in the term of chlorophyll content in the (Appendix IV). The maximum chlorophyll content was found in the G_2T_1 (257 %) and lowest amount of the chlorophyll was found in the $G_{10}T_3$ (50.33 %) (Table 4) . This result showed that incrase the interaction of drought stress decreases the chlorophyll content similar result was found from the Khayatnezhad *et al.(*2012) **.**

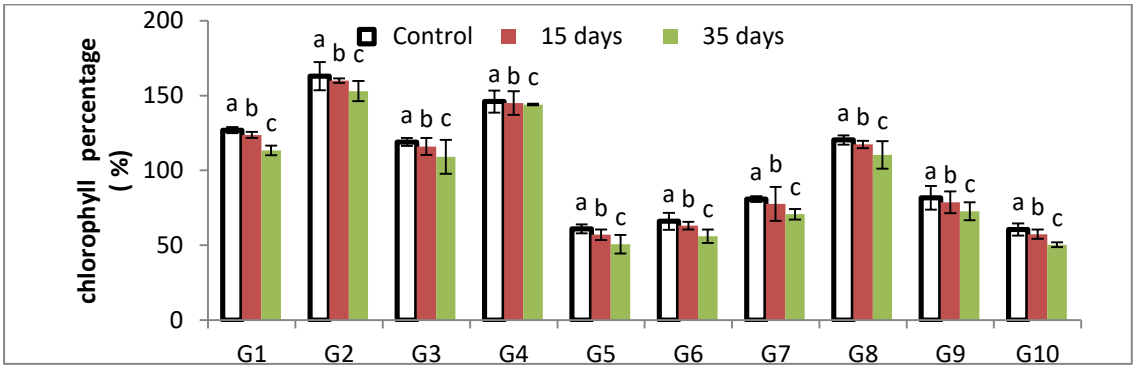


Figure 21. Interaction of genotype and stress treatment effects on the chlorophyll percentage

4.1.2.4.2 Relative Water Content

Interactions of the genotypes and drought stress was showed statistically significant variation in the term of relative water content in the (Appendix IV).The highest amount of the moisture was found in the G_7T_1 (68 %) and lowest amount of moisture was found in the G_3T_3(29.35 %) (Table 4) **.**This result showed with the increase of drought stress interaction decreases the relative water content like this similar result was found from the Soltys-Kalina *et al.* (2016).

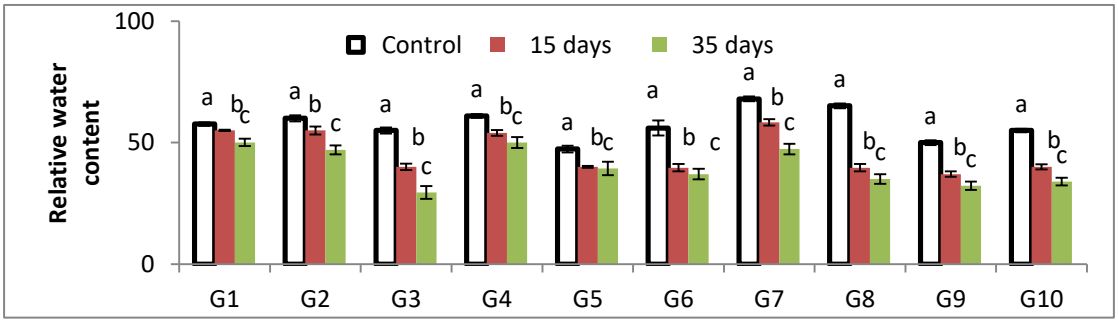


Figure 22. Interaction of genotype and stress treatment effects on the relative water content

4.1.2.5.2 Moisture in fruit (%)

Interaction of the genotypes and drought stress was showed statistically significant variation in the term of moisture in the fruit (Appendix iv). The highest amount of the moisture content was found in the $G_{10}T_1$ (20.66 %) and the lowest amount of moisture was found in the G_9T_3(3.05 %) (Table 4) .This result indicated that increase the drought level interaction reduces the moisture content in the fruit similar result was found in Nahar *et al.* (2011) .

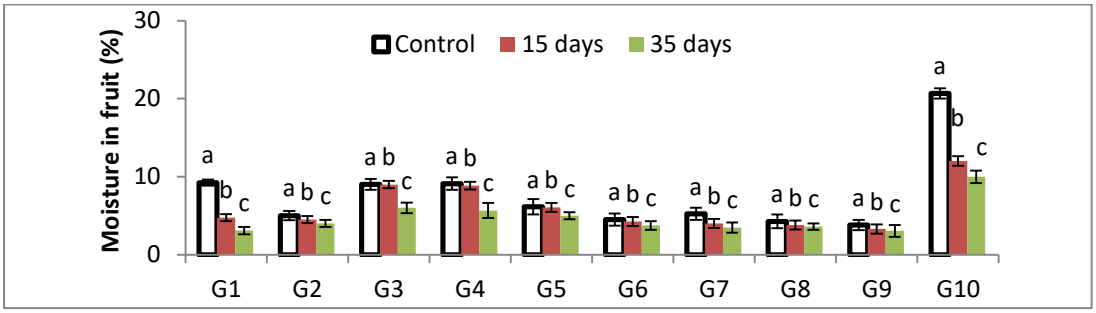


Figure 23. Interaction of genotype and stress treatment effects on the moisture in fruit

4.1.2.6.2 Dry matter content in fruit (%)

Interaction of the genotypes and drought stress was showed statistically significant in the term of dry matter of fruit in the (Appendix IV).The highest amount of dry matter in the fruit was found G_1T_1 (76 %) and lowest amount of dry fruit was found from the G_8T_3 (36.33) (Table 4) .This result indicated that increase the interaction of drought stress reduces the dry matter content similar result was found in the Hale *et al.*(2005).

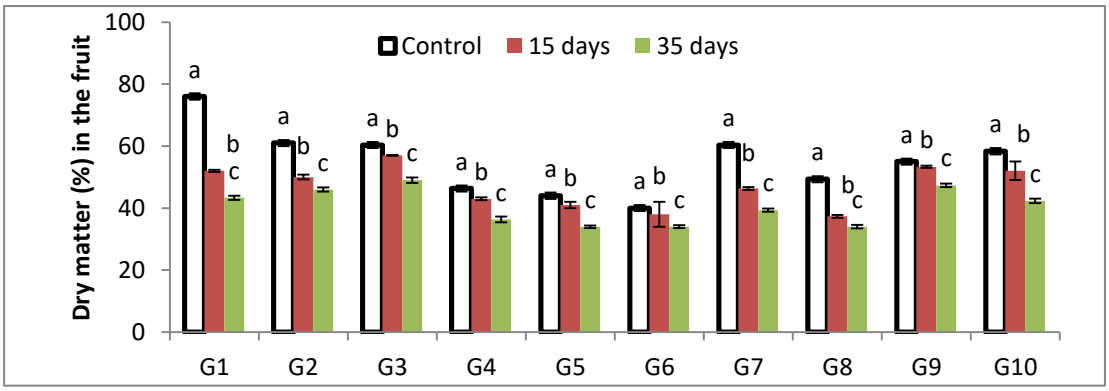


Figure 24. Interaction of genotype and stress treatment effects on the dry matter (%)

4.1.2.7.2 Proline content (µg /g)

Interaction of the genotypes and drought stress was showed statistically significant variation in the term of proline content (Appendix IV**) .**The highest amount of the proline was found in the G_4T_1 (291.82 µg/g**)** and the lowest amount of proline was found in $G_{10}T_3$ (38.67 µg/g) (Table 4) **.**This result showed that the amount of proline in grown tomatoes under drought stress and showed increased proline concentrations. Similar result was found from the Nasrin *et al. (*2020).

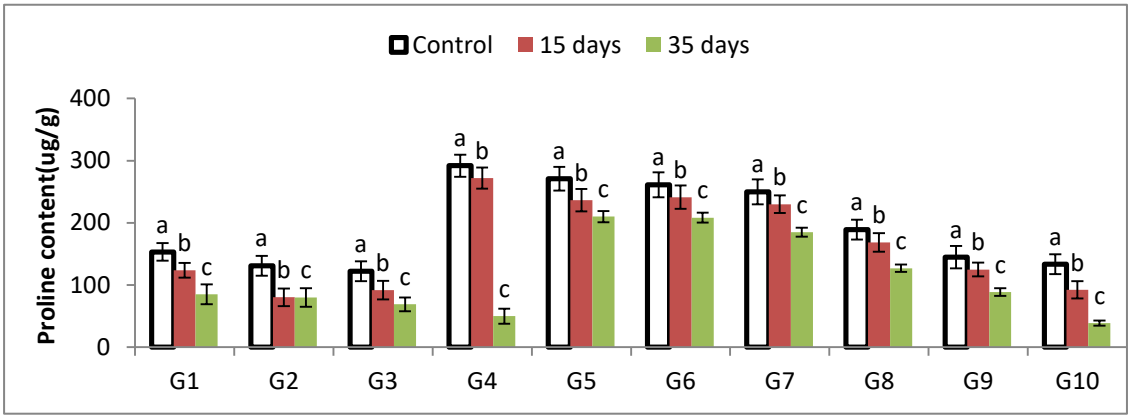


Figure 25. Interaction of genotype and stress treatment effects on the proline concentration

4.1.3.2 Nutritional traits

Nutritional traits viz, % Brix, pH of fruit, % titrable acidity, vitamin C an lycopene content were presented and discussed in this section. ANOVA was presented in (Appendix IV) respectively. Data were arranged in table and Figure for better understanding.

4.1.3.2 Brix content (%)

Interaction of the genotypes and drought stress was showed statistically significant in variation in the term of the Brix content in the (Appendix IV). The maximum amount of the Brix content (%) was found in the G_6T_1 (12.66 %) and the minimum amount of the Brix content was found in the $G_{10}T_3$(3.56 %) (Table 4) **.** Under stress condition disaccharide sucrose converted into monosaccharide glucose and fructose which was measured by reducing sugar. Stress tolerant genotypes produced relatively less reducing sugar than susceptible genotype; this result was found in the Begum *et al.*

(2012).

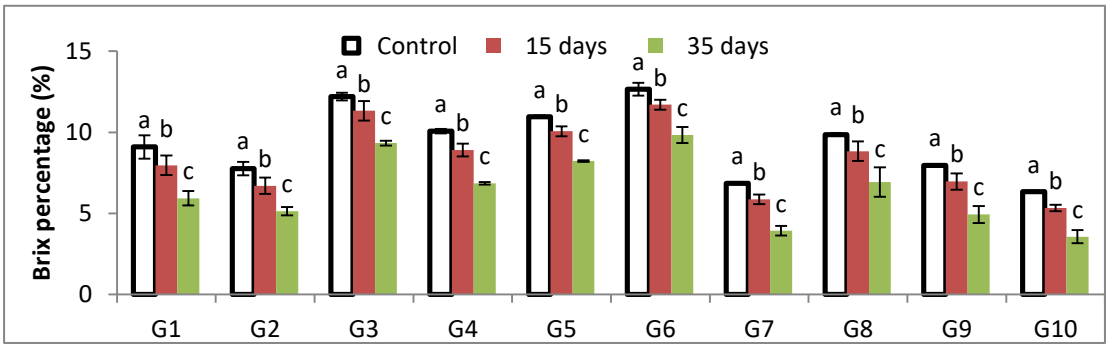


Figure 26. Interaction of genotype and stress treatment effects on the Brix percentage

4.2.3.2.2 pH of fruit

Interaction of the genotypes and drought stress was showed statistically significant in the term of pH of the fruit (Appendix IV).The maximum amount of the pH of the fruit was found in the G_5T_1(3.64) and the minimum amount of the pH was found in the G_2T_3(2.50 %) (Table 4).The result indicated that when drought stress increases then pH amount increases. Similar result was found from the result observed by Ahmed I.M *et al.(*2018).

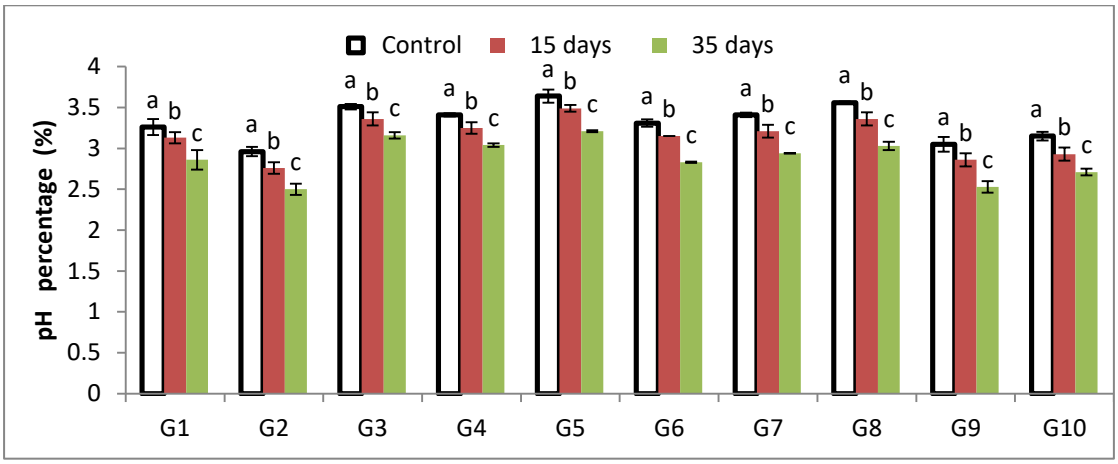


Figure 27. Interaction of genotype and stress treatment effects on the pH

4.1.3.3.2 Titrable Acidity (%)

Interaction of the genotypes and drought stress was showed statistically significant in the term of titrable acidity (%) in the (Appendix IV) .The maximum amount of the titrable acidity was found from the G_3T_1 (4.7 %) and the lowest amount was found in G_4T_3 (1.4 %) (Table 4) .This result showed that titrable acidity increases with the

increase of the drought stress .Similar result was found by the Ahmed I.M *et al.* (2018)

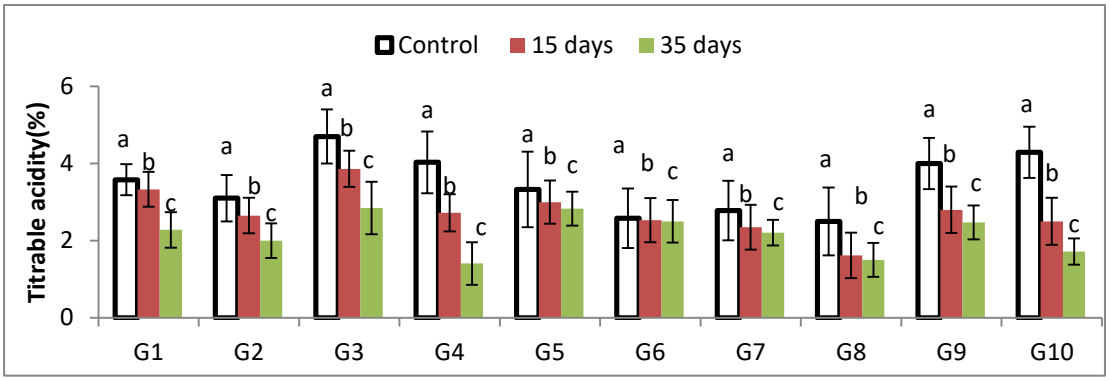


Figure 28. Interaction of genotype and stress treatment effects on the titrable acidity

4.1.3.4.2 Vitamin C content (mg/ 100 g)

Interaction of the genotypes and drought stress was showed statistically significant in the term of Vitamin C (Appendix IV) .The maximum amount of the vitamin C was found in $G_{10}T_1$(6.23 mg/ 100 g**)** and lowest amount of the vitamin C was found in G_5T_3(3.85 mg/ 100 g) (Table 4). Torrecillas *et al.* (1995) observed that the concentration of vitamin-C increased with increasing water stresses. A lowering of water potential due to stress causes a wide range of changes in physiological responses from a decrease in photosynthesis to closing of stomata.

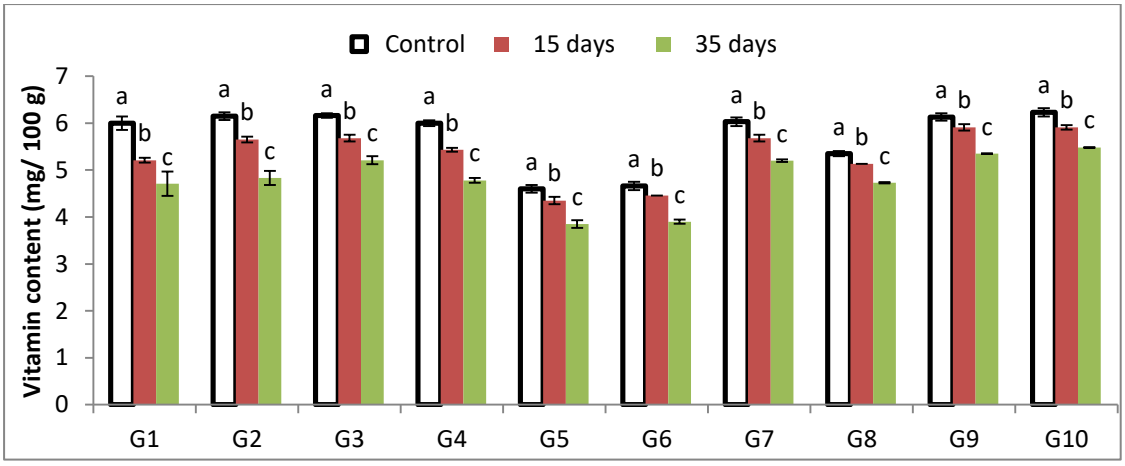


Figure 29. Interaction of genotype and stress treatment effects on the Vitamin-C content

4.1.3.5.2 Lycopene content (mg/ g)

Interaction of the genotypes and the drought stress was showed statistically significant in the term of lycopene content (Appendix IV).The highest amount of the lycopene content in (472 nm) was found in the G_3T_1(22 mg/ g) and the lowest amount of lycopene was found in the G_2T_3(2 mg/ g). (Table 4).In case of (502 nm) the highest amount of the lycopene was found in the G_4T_1 (21.3 mg/ g) and the lowest amount of the lycopene was found in the $G_{10}T_3$ (3.06 mg/ g) (Table 4**).** Drought stress indirectly increases lycopene concentration. It had a dilution effect on ingredients. By the higher lycopene production per unit area the higher yield could account for the concentration loss of individual fruits was showed by Helyes *et al*. (2012).

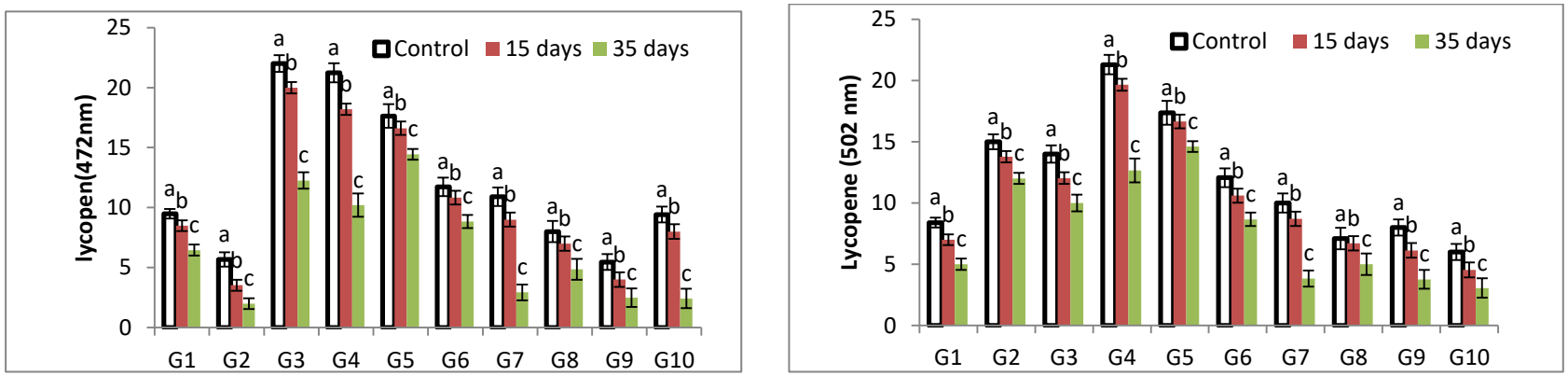


Figure 30. Interaction of genotype and stress treatment effects on Lycopene content (at 472 nm and 502 nm)

CHAPTER V

SUMMARY AND CONCLUSION

Tomato (*S. lycopersicum)* belongs to the Solanaceae family is one of the important vegetable in Bangladesh and total production still low as compared to total demand. In the northern region of the Bangladesh remain uncultivable due to high level of drought. The drought affected areas of Bangladesh are increasing rapidly. Thus development of the drought tolerant crops is a main global agricultural goal. Tomato plants is moderately tolerant to drought stress but exact drought level may depend on cultivar sensitivity .Screening of genotypic differences can be easier method to determine drought tolerant genotypes.

A pot experiment was conducted to observe the performances of the ten tomato genotypes under three different drought treatments. The experiment was conducted at the net house of the Genetics and Plant Breeding Department, Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh, during the month of November 2018 to the April 2019. The two factorial experiment includes ten tomato genotypes viz, G_1(Raja local), G_2(BARI tomato -16), G_3(BARI Tomato-3), G_4(BARI Tomato-15), G_5(BARI tomato-2), G_6(BARI Tomato-18), G_7(BARI Tomato-19), G_8(BARI Tomato-14), G_9(BARI Tomato-11), G_{10}(ROMA VF) and three drought treatments viz. T_1(Control), T_2(15 days withholding of water), and T_3(35 days withholding of the water) were outlined in Completely Randomized Design(CRD) with three replications.

Collected data were statistically analyzed for the genotypic differences of the tomato genotypes and drought treatments. From genotypic analyses all the phenotypic variance was greater than genotypic variance, phenotypic co efficient variation was greater than genotypic co efficient variation. Plant height , number of leaves/plant ,leaves area index, day to first flowering, number of cluster /plant, dry matter content in fruits(%) , fruit length, average fruit weight, yield / plant, root length ,shoot root ratio were showed high heritability with high genetic advance means that there was active involment of active gene which help to select the best parameter. In case of the

plant height, The tallest plant was observed in G_9 (88.22 cm) , Where the shortest plant was G_7 (22.14 cm) .The highest number of leaves are found in G_1(139) where lowest number of the leaves is G_7(30.79). The maximum leaves area index was found in G_7 (33.77 cm^2) where the minimum leaves area index was in G_6 (12.66 cm^2). The highest number of branches was found in G_1 (4.22) where lowest numbers of the branches was found in the G_4 and G_6 (2.66) .The first day of flowering found in the G_9(29 day) and lowest number of the first flowering was found in the G_5 (19.66 days) where G_4 (20.6 days) ,G_6 (20.11 days) were statistically similar .The early fruit setting was found in the G_5(21.33) and lately fruit setting was found in the and G_6 (13) where G_1,G_7,and G_8 were similar in fruit setting . The highest day of maturity was found in the G_{10} (71.66) and lowest day maturity was found in the G_4 (39.66) .The highest number of cluster was found in the G_1 (8.44) and the lowest number of cluster was found in the G_{10} (3.44) and G_5 , G_9 (4.22) were statically similar. The highest number of the flower was found in the G_4 (11.33) and whereas the lowest number of the flower was found in the G_5 (7.66), where G_2, G_9 (10) were statistically similar. The highest number of the fruit length was found in the G_8 (10.33) and lowest number of the fruit per cluster is G_3 (6.66) where G_5 ,G_7 (8.33) and G_6 (8.11) was statistically similar. The highest number of the fruit was found in the G_4, G_5 (5.77) and the lowest number of the fruit per plant was found in the G_7 (3.66) .The highest the length was found in the G_5 (55 mm) where G_8 (53.40 mm), and G_9 (54.1) were statistically significant. On the other hand the lowest fruit length found in the G_2 (37.33). The highest diameter of tomato was found in the G_4 (8.68 mm), G_2 (8.02 mm). On the other hand lowest diameter was found in G_9 (2.70 mm) and G_{10} (2.76 mm) which was statically similar. The maximum weight of the tomato was found in the G_5 (294.44 g) and lowest average of the fruit weight was found in G_8 (68.99 g).The highest amount yield was found in the G_5 (523.44 g) and lowest yield was found in the G_8 (194.67 g). The highest number of the root length was found in G_6 (91.22 cm) and lowest number of the length was found in G_7 (37.68 cm) . The highest shoot root ratio was found in G_9 (12) and lowest shoot root ratio was G_1, G_3 (6.66).The highest number of the skin diameter was found in G_6 (6.98 mm) ,G_{10} (7.12 mm) and the lowest skin diameter was the G_9 (3.76 mm).The highest ethylene concentration was found in the G_3 (0.21 ppm)

and lowest concentration was observed in G_6 (0.15 ppm). The highest membrane stability index was found in the G_1 (7 %) where lowest membrane stability index was found in G_6 &G_7(2.23 %) .The hight amount of the chlorophyll was found in the G_4 (252.4%) and the lowest amount of chlorophyll was found in G_{10} (56.06 %). The highest amount of relative water was found in the G_{10} (70.97) and on the other hand the lowest amount of the relative water was found in the G_8(25.45) where G_4 (37.30), and G_7(38.03) were statistically similar. The highest amount of the moisture was found in the G_9 (20.33 %) and lowest amount of moisture was found in G_8 (3.46 %) ,G_6(3.90 %) and G_7(3.95 %) were statistically similar. The highest amount of the dry matter was found in the G_{10} (71.60 %) and lowest amount of the dry matter was found in G_4 (39.61%) **.**The highest amount of the proline contents was found in the G_4 (341.81 µg/g) and lowest amount of the proline content was found in G_7 (161.67 µg/g) .Where G_1.G_2, G_8, G_9 &G_{10} were statistically similar**.** The highest amount of the brix percentage was the G_5 (11.6%) and lowest amount of the brix percentage was G_9 (5.07 %).The highest amount pH percentage was found G_4 (3.45 %) and the lowest amount of the pH was found in the G_{10} (2.74%).The highest amount of the tartaric acid was found in the G_3 (3.82 %) and the lowest amount of tartaric acid was G_7 (1.78 %).The highest amount of the vitamin C was found in G_2(5.68 %) and G_2, G_8, G_9,& G_{10} were statically similar. On the other hand the lowest amount of the vitamin C was found G_4 (4.26) G_5 (4.34) were statistically similar. The highest amount of the lycopene amount G_3 (19.87 mg/ 100 g) at (472 nm) and (502 nm).On the other hand the lowest amount of lycopene was found in the G_9 (3.45 mg/ 100 g) at the (472 nm) and (502 nm).

In interaction of tomato genotype with drought stress, there was significance variation in physiological traits. In genotype and drought interaction, the highest number of the brances per plant was found in the G_1T_1 (144.33) and lowest number was found in the G_7T_3 (22.33). The maximum leaves area index was found in the treatment from G_1T_1 (32 cm^2) and minimum leaves area index was G_5T_3 (9.33 cm^2).The highest number of the branches was found in the G_1T_1 (5.33) and the lowest number of the branches was found in the G_9T_3 (1.66) and G_5T_3, G_8T_3 (1.66) both were similar. The longest day of the first flowering was found in the G_8T_1 (33.33) , G_9T_1(33.33) and shortest day of the

first day flowering found from the G_3T_3(14.66). The longest day of the first fruit setting was found in the G_9T_1 (24.33) similar result found in G_5T_1 (24) and lowest day was found from the G_6T_3 (9.60) .The highest days of the fruit maturity was found in the $G_{10}T_1$(76 days) and the lowest days of fruit maturity was found in G_4T_3(34 days) . The highest number of the cluster per plant was found from the G_1T_1 (9.33) and similarly G_1T_2(9.1) and lowest number was found from G_8T_3(2.33) and $G_{10}T_3$(2.33) both were similar. The highest number of the flower per cluster found in G_4T_1(12.60) and lowest number of the flower per cluster found in the G_5T_3(6).The highest number of the fruit per cluster was found in the G_8T_1(11.66) and lowest number of the fruit per cluster was found in the G_3T_3(5). The highest number of the fruit per plant was found from the G_4T_1 (7.33) and lowest number of the fruit was found in the G_7T_3, G8T3, $G_{10}T_3$ (2.33) all were similar. The maximum fruit length was found from the G_5T_1 (57mm) and G_9T_1 (57mm) both were similar. On the other hand the minimum fruit length was found in the G_2T_3 (34mm).The highest diameter of the tomato was found in the G_4T_1(9.6mm) and lowest diameter was found in the G_7T_3(2.3) and G_6T_1, G_6T_2, G_6T_3, G_7T_1, G_7T_2, G_7T_3 , $G_{10}T_3$ were similar. The maximum average fruit weight was found in the G_2T_1(321.67 gm) and minimum weight was found in the G_8T_3(39.33gm).The maximum average fruit weight was found in the G_2T_1(321.67 gm) and minimum weight was found in the G_8T_3(39.33gm).The maximum average fruit weight was found in the G_2T_1(321.67 gm) and minimum weight was found in the G_8T_3 (39.33gm). The highest yield was found in the G_6T_1(549 gm) and G_6T_2(529 gm) both was similar and on the other hand the lowest the yield per plant was found in the $G_{10}T_3$ (27.67 gm) .The maximum root length (cm) found in the G_4T_1(93.33cm) and minimum root length was found in theG_2T_3 (34.28) , G_2T_2 (36.44 cm), G_2T_1(38.07 cm), G_3T_3(38.59 cm) ,G_5T_2 (38.06 cm),G_5T_3(35.07 cm) were similar in the length. The longest shoot root ratio was found in the G_1T_1 (13.33) and the shortest shoot root ratio found in the G_3T_3 (5) .The maximum skin diameter was found in the G_9T_1 (13.29 mm) and minimum skin diameter was found from the G_3T_3 (4.50 mm).The maximum concentration of the ethylene concentration was found from the G_3T_1(0.23 mm) and minimum concentration was found from the G_6T_3(0.11 mm).The maximum membrane stability index was found from G_1T_1 (7.50 %) and lowest membrane

stability index was found in the $G_{10}T_3$(0.93 %).The maximum chlorophyll content was found in the G_4T_1(257 %) and lowest amount of the chlorophyll was found from the $G_{10}T_3$(50.33 %) .The highest amount of the moisture was found in the G_7T_1 (68 %) and lowest amount of moisture found in the G_3T_3 (29.35 %). The highest amount of the moisture content was found from the $G_{10}T_1$ (20.66 %) and lowest amount moisture was found from the G_9T_3 (3.05 %).The highest amount of dry matter in the fruit was found G_1T_1(76 %) and lowest amount of dry fruit was found from the G_8T_3(36.33).The highest amount of the proline was found from the G_4T_1(291.82 μg) and lowest amount of proline was found from $G_{10}T_3$(38.67 μg).The maximum amount of the Brix content (%) was found from the G_6T_1 (12.66 %) and minimum amount of the Brix content was found from the $G_{10}T_3$(3.56 %).The maximum amount of the pH of the fruit was found from the G_5T_1(3.64) and minimum amount of the pH was found in the G_2T_3(2.50 %).The maximum amount of the titrable acidity was found from the G_3T_1(4.7 %) and lowest was found in the $G_4T_3$1.4 %) (Table 4)

The maximum amount of the vitamin C was found in the interaction of $G_{10}T_1$(6.23 mg/ 100 g**)** and lowest amount of the vitamin C was found in the G_5T_3(3.85 mg/ 100 g).The highest amount of the lycopene content in case of the 472 nm was found in the G_3T_1(22 mg/ g) and the lowest amount of the lycopene was found in G_2T_3(2 mg/ g).In case of 502 nm the highest amount of the lycopene was found G_4T_1(21.3 mg/ g) and lowest amount of the lycopene was found in the $G_{10}T_3$(3.06 mg/ g).

From the above experiment, **on the basis of agromorphic traits**

- First flowering was observed in the G_5 (19.66 days),
- Maximum number of clustering, early fruit setting were found in the G_5 (21.33 days)
- The number of fruit per plant was found in the G_5(5.77) ,
- Average fruit length was found in the G_5(294 mm), and
- The highest fruit weight was found in the G_5 (0.523kg/plant) per plant .

On the basis of physiological traits

- Maximum amount of the relative water content was found in the G_{10} (56.06 %)
- Maximum amount of dry matter was found in the G_{10} (71.60%) and
- Maximum amount of the proline content was found in the G_4 (161.67 μg /g)

On the basis of nutritional traits

- Maximum brix content was found in the G_5 (11.6 %)
- Maximum amount of Vitamin C was found in the G_2 (5.68 %)
- Maximum amount of lycopene was found in the G_3(19.87 mg/ 100 mg)
- Maximum pH content was found in the G_4 (3.45 %)

From the above experiment, the following could be recommended

- G_5 could be recommended at moderate drought condition for early flowering, early fruit setting, early maturity and higher dry matter content, higher cluster per plant, fruit per cluster, higher no. of fruit per plant and higher yield.
- G_4 could be recommended for the cultivation at moderate drought prone area for its highest amount of pH, and proline content.
- In the combination of drought stress with genotype G_8 gives first flowering G_8T_2 (29.30 a-c days) ,No. of flower per cluster G_8T_2 (10.66ab),Yield G_6T_2(0.529 kg/plant) .

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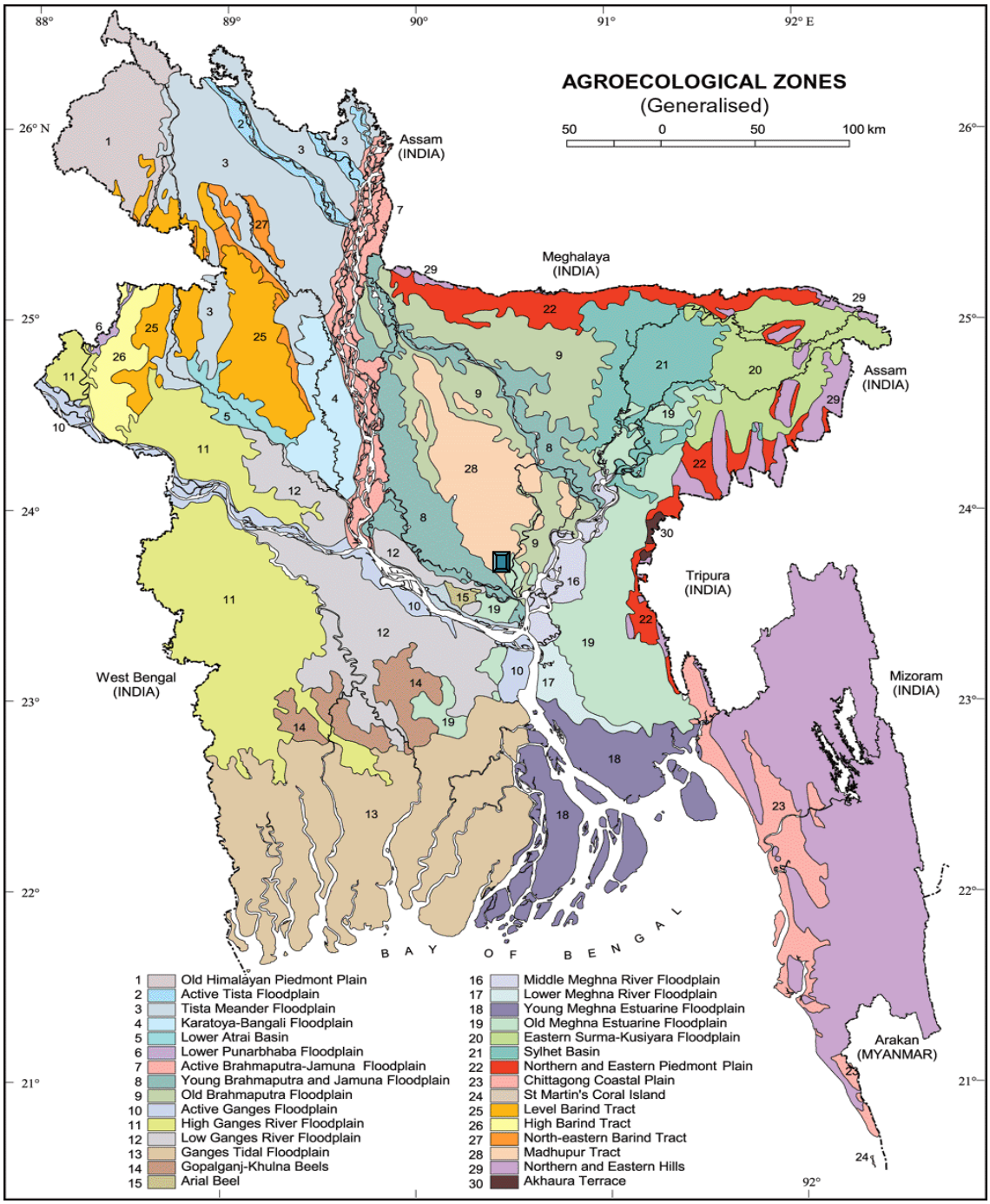
Appendix I. Map showing the experimental site under the study



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 (^{o} C)			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 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)	9	3532.67**	7641.13**	2.75**	349.01**	349.01**	78.95**	762.44**	18.51**	11.51**
Factor B (Treatment)	2	3110.22**	1473.73**	34.31**	756.93**	338.41**	308.23 **	302.89**	39.67**	68.40**
A x B	18	35.23*	9.58*	2.17*	147*	42.88*	40.42*	2.70 *	2.60*	0.99*
Error	58	11.41	2.86	0.39	49.52	14.2	13.04	0.85	0.85	0.33

*Significant at 0.05 level of probability; ** Significant at 0.01 level 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)	9	11.51**	6.40**	332.55**	762.44**	53035.9**	0.0125**	6.144**	28**	11.35**
Factor B (Treatment)	2	68.34**	49.63**	372.31**	768.67**	33726.2**	2**	147.23**	68.34**	34.88 **
A x B	18	1	2.28 *	31.66 *	8.2 *	49 *	0.060**	2.5**	3.9*	7.81*
Error	58	0.33	0.57	10.22	2.34	16	0.005	0.512	1.3	2.27

*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	Proline	% Brix	Vitamin C
Factor A (Genotype)	9	0.002 NS	31.05 **	1838.3 **	1800.5 **	237.75 **	4.564 **	73375 **	2.669 *	3.98 **
Factor B (Treatment)	2	0.025 NS	6.10 **	844.11 **	843.3 **	3.91 **	782.4 **	29037.3 **	18.64 **	5.28 **
A x B	18	0.002 NS	1.734 *	8.98 *	84.1 *	2.70 *	1.956*	45200 **	1.602*	0.79 *
Error	58	0.001	0.51	2.66	27.7	0.675	0.652	8840	0.5338	0.19

*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			
		Lycopene (472 nm)	Lycopene (502 nm)	pH of fruit	Titrable Acidity
Factor A (Genotype)	9	3.02 **	1.52 **	0.62 **	4.55 **
Factor B (Treatment)	2	57.678 **	65.54 **	0.345 **	2.44 **
A x B	18	1.51 *	0.509 *	0.2067 *	1.39*
Error	58	0.379	0.168	0.06897	0.39888