EVALUATION OF TOMATO (*Solanum lycopersicum* L.) GENOTYPES UNDER DROUGHT STRESS

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BY

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CERTIFICATE

This is to certify that thesis entitled, "Evaluation of tomato (Solanum lycopersicum L.) genotypes under drought stress" 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 Rozina Akter, Registration No.: 08-02794 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 her.

Dated: December, 2014
Place: Dhaka, Bangladesh

(Prof. Dr. Naheed Zeba)
Supervisor

Dedicated
to
My Beloved
Father Didarul Islam
and
Mother Ayesha Begum

Some commonly used abbreviations

Full word	Abbreviations	Full word	Abbreviations
Agricultural	*Agril.*	Milligram(s)	mg
Agriculture	*Agric.*	Milliliter	mL
And others	*et al.*	Microgram per gram	µg/g
Applied	*App.*	Number	No.
Bangladesh Agricultural Research Council	BARC	Nanometre	nm
Bangladesh Agricultural Research Institute	BARI	Negative logarithm of hydrogen ion concentration (-log[H+])	pH
Bangladesh Bureau of Statistics	BBS	Nitric acid	HNO_3
Biology	*Biol.*	Nutrition	*Nutr.*
Biotechnology	*Biotechnol.*	Perchloric Acid	$HClO_4$
Calcium ion	Ca^{2+}	Percentage	%
Centimeter	cm	Particular pages	pp.
Chlorine ion	Cl^-	Plant Genetic Resource Centre	PGRC
Chlorophyll	Chl	Potassium Chloride	KCl
Completely randomized design	CRD	Parts per million	ppm
Days after transplanting	DAT	Physiology	*Physiol.*
Degree Celsius	°C	Review	*Rev.*
Environment	*Environ.*	Relative water content	RWC
Etcetera	etc.	Research and Resource	*Res.*
Food and Agriculture Organization	FAO	Serial	Sl.
Gram	G	Science	*Sci.*
Gram per liter	g/L	Soil Resource Development Institute	SRDI
Horticulture	*Hort.*	Technology	*Technol.*
International	*Intl.*	That is	i.e.
Journal	*J.*	Ton per hectare	t/ha
Kilogram	Kg	Total soluble solid	TSS
Least Significant Difference	LSD	Ultra Violet	UV
Liter	L	United States of America	U.S.A.
Milligram per liter	mg/L	Videlicet (namely)	viz.

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The Author

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EVALUATION OF TOMATO (*Solanum lycopersicum* L.) GENOTYPES UNDER DROUGHT STRESS

BY

ROZINA AKTER

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 2013 to March 2014 to observe the performances of fifteen tomato genotypes under three different drought treatments. Two factorial experiment including fifteen tomato genotypes viz. G1 (BD-7759), G2 (BD-7292), G3 (BD-7760), G4 (BD-7258), G5 (BD-7762), G6 (BD-7761), G7 (BD-7289), G8 (BD-7291), G9 (BD-7301), G10 (BARI Tomato-11), G11 (BARI Tomato-9), G12 (BARI Tomato-8), G13 (BARI Tomato-7), G14 (BARI Tomato-3) and G15 (BARI Tomato-2) and three drought treatments, T1 (Control), T2 (30 days withholding of water) and T3 (45 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 G4 showed tolerance at moderate drought stress and G6 at severe drought stress.Considering the yield and yield contributing characters, genotype G4, G5 and G6 showed tolerance at moderate drought stress and G7, G13 and G6 showed tolerance at prolonged and severe drought stress. Regarding antioxidant and nutritional traits, G10 for brix (%), G8 for vitamin-C content and G1 for lycopene content showed tolerance at moderate drought stress period and G5, G8 and G13 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 programs.

CHAPTER I
INTRODUCTION

Drought is considered the single most devastating environmental stress, which decreases crop productivity more than any other environmental stress. A continuous shortfall in precipitation (meteorological drought) coupled with higher evapotranspiration demand leads to agricultural drought (Farooq *et al*., 2012). Agricultural drought is the lack of ample moisture required for normal plant growth and development to complete the life cycle. Drought severely affects plant growth and development with substantial reductions in crop growth rate and biomass accumulation. Crop growth models predict that this issue will be more severe in future. Drought impairs normal growth, disturbs water relations, and reduces water use efficiency in plants. Due to drought, the rate of photosynthesis is reduced mainly by stomatal closure, membrane damage, and disturbed activity of various enzymes, especially those involved in ATP synthesis (Yuan *et al*., 2015). Plants display a range of mechanisms to withstand drought, such as reduced water loss by increased diffusive resistance, increased water uptake with prolific and deep root systems, and smaller and succulent leaves to reduce transpirational loss. Low-molecular-weight osmolytes, including glycinebetaine, proline and other amino acids, and polyols also play vital roles in sustaining cellular functions under drought. Plant growth substances such as salicylic acid, auxins, gibberellins, cytokinins, and abscisic acid modulate plant responses toward drought. Plant drought stress can be managed by adopting strategies 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 (*Solanum lycopersicum* L.) has been studied extensively owing to 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 model organism for both basic and applied plant research due to many reasons, including ease to culture under a wide range of environments, short life cycle, photoperiod insensitivity, high self-fertility and homozygosity,

great reproductive potential, ease of controlled hybridization etc. (Foolad, 2007). The cultivated tomato is a well-studied crop species in terms of genetics, genomics and breeding (Meena and Bahadur, 2015). Tomato species are diploid (2n=2x=24) and is a self-pollinated annual crop which belongs to the family solanaceae.

Tomato is important vegetable crops in the world in terms of both production and harvested area (FAOSTAT, 2005). 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). More than 7% of total vitamin-C of vegetable origin comes from tomato in Bangladesh. It contains 94 mL water, 0.5 g minerals, 0.8 g fibre, 0.9 g protein, 0.2 g fat and 3.6 g carbohydrate. It also contains other elements like 48 mg calcium, 0.4 mg iron, 356 mg carotene, 0.12 mg vitamin B1, 0.06 mg vitamin B2 and 27 mg vitamin C in each 100 g edible ripen tomato (BARI, 2010).

The 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 in 2008 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 in the year of 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). Nowadays, tomatoes are grown round the year. Due to increasing consumption of tomato products, the crop is becoming promising. 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 however is not an indication of low yielding potentially of this crop but of the fact that the low yield may be attributed to a number of reasons, 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).

Generally tomato is grown during Rabi season and inadequate soil moisture in this season limits the use of fertilizers and consequently results in decreased yield. Deficiency of water considered as one of the major constraints to successful upland crop production in Bangladesh (Islam and Noor, 1982). The growth, yield and fruit quality of tomatoes can be affected by drought stress, a common abiotic stress for tomato. The cultivation of tomato requires 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 to identify a tolerant genotype is quiet necessary which may hopefully sustain a reasonable yield on drought affected soils. Screening can be an easier method to determine drought tolerant genotypes. With conceiving the above scheme in mind, the present research work has been undertaken in order to fulfill the following objectives:

- to identify the best drought tolerent genotypes based on agromorphogenic, physiological, antioxidant and nutritional traits,
- to determine the response of genotype-treatment interaction on different yield and yield contributing characters as indicators of tolerance and
- to compare the tolerance of genotype, treatment and genotype-treatment interaction for proline as the indicator of drought tolerance.

CHAPTER II
REVIEW OF LITERATURE

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

The crop has received much attention by the researchers on various aspects of its production under different adverse condition especially drought. Many studies on the genetic variability have been carried out in many countries of the world. The work so far done in Bangladesh 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 have been reviewed in this chapter under the followings:

2.1 Tomato

Right now the accepted scientific name for 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 2005 Spooner and his associates proposed a change back to the original nomenclature 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). This name came into wide use, but 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*, making *Solanum*

lycopersicum the correct name (Peralta and Spoonar, 2001). Both names, however, will probably be found in the literature for some time.

Tomato translates to *"wolfpeach"* -- peach because it was round and luscious and wolf because it was erroneously considered poisonous (Fillipone, 2014). The English word “tomato” comes from the Spanish word, *tomate*, which in turn comes from the Nahuatl (Aztec language) word *tomatotl*. It 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).

The tomato is native to western South America and Central America (Filippone, 2014). Tomato is a tropical plant and grown in almost every corner of the world from tropics to within a few degrees of the Arctic Circle. Mexico has been considered the most likely center of domestication of tomato. Italy and Spain are considered secondary centers of diversification (Gentilcore, 2010 and Smith, 1994). The cultivated tomato originated in the Peru-Ecuador-Bolivia area of the South American (Vavilov, 1951). Major tomato producing countries are Spain, Brazil, Iran, Mexico, Greece, Russia, China, USA, India, Turkey, Egypt and Italy (Anonymous, 2010). It is believed that the tomato was introduced in subcontinent during the British regime. It is adapted to a wide range of climates. In tomato (*Solanum lycopersicum* L.), one cultivated species and 12 wild relatives have been reported (Peralta *et al*., 2006). Genetic variation in modern cultivars or hybrids is limited (Chen *et al*., 2009). It is estimated that cultivated tomato genome contains less than 5% of the genetic variation of the wild relatives (Miller and Tanksley, 1990). It has been suggested by Yi *et al*. (2008) that domestication and inbreeding dramatically reduced the genetic variation.

2.2 Drought

Drought can be defined as the absence of adequate moisture necessary for a plant to grow normally and complete its life cycle (Zhu, 2004). Drought is one of the serious environmental factor affecting plant growth, development, yield and quality. It induces various physiological and biochemical adaptations in plants. It has been estimated that up to 45% of the world agricultural lands are subjected to drought (Bot *et al*., 2000). Water deficit leads to the agitation of most of the physiological and biochemical processes and consequently reduces plant growth and yield (Boutraa, 2010). Many authors reported that water deficit reduces the rate of photosynthesis in plants (Cornic, 2000). Leaf water potential (LWP) has been suggested as selection criteria for improving drought tolerance. LWP is recognized as an index for whole plant water status (Turner, 1982) and maintenance of high LWP is considered to be associated with dehydration avoidance mechanisms (Levitt, 1980). The productivity of the crop may be related to physiological attributes like transpiration rate, photosynthetic rate, relative water content (RWC) and LWP. Higher RWC indicates 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 (Haloi and Baldev, 1986).

The adaptive potential of some plant species reducing water losses were achieved by closing of stomata and reduction in the transpiration rate (Tardieu and Davies, 1996). Hence, measurement of transpiration rate is an excellent tool to assess drought tolerant capacity of crop plants. However, reduction of transpiration rate under drought causes increment of leaf temperature is deleterious effect for plants. Abscission of reproductive organs like flower buds and flowers is a major yield limiting factor in vegetable crops (Wien *et al*., 1989). The abscission of floral organs during stresses has been associated with the changes in physiological processes (Aloni *et al*., 1996). In tomato, where the abscission of flowers and flower buds and the reduction in photosynthesis

was more in susceptible cultivars compared to the tolerant cultivars where the abscission was relatively less (Bhatt *et al*., 2009).

Tomato (*Solanum lycopersicum*) is one of the most popular and widely grown vegetables in the world. Considering the potentiality of this crop, there is plenty of scope for its improvement, especially under the drought situation. The concept of drought tolerance has been viewed differently by molecular biologist, biochemist, physiologists and agronomists, the major concern is to enhance 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 screened for drought tolerance or exploited for their cultivation under drought situation. To breed drought tolerant genotypes, it is necessary to identify physiological traits of plants, which contributes to 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.

2.3 Genotypic variation

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

2.3.1 Genotypic variation for agromorphogenic traits

Biometric components, particularly yield contributing components are interrelated with each other and influenced by the environmental conditions.

That is why breeding strategy depends upon the degree of associated characters as well as its magnitude and nature of variation. Genetic variability among the traits is important for selecting desirable types in breeding program. Paul *et al.* (2014); evaluated twenty eight tomato genotypes in randomized complete block design with three replications. The study revealed the genetic variability among the yield contributing traits and their 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 observed in all characters except height of first leaf appearance at seedling stage. Kaushik *et al.* (2011); also evaluated 10 genotypes in randomized block design replicated thrice. The genotypic variation was maximum (424 to 825 qtl/ha) for fruit yield and minimum for fruit width (4.1 to 5.6 cm). A study was conducted on the F2 segregating generations of exotic tomato hybrids to measure the genotypic variation. Analysis of variance for each trait showed significant differences among the genotypes. Selection for fruit clusters per plant, fruits per plant, branches per plant, fruits per cluster, individual fruit weight and fruit yield per plant were found to be effective for the fruit yield improvement of tomato. Direct selection may be executed considering these traits as the main selection criteria to reduce indirect effect of the other characters during the development of high yielding tomato (Ghosh *et al*., 2010).

Fifty-two genotypes of tomato were raised in a randomized block design with two replications by Pradeepkumar *et al*. (2001). Analysis of variance revealed highly significant differences among the genotypes for the 10 biometric characters studied. The important biometric characters such as fruit weight and yield per plant exhibited a range of 1.40-115.0 and 80.00-2370.00 respectively. Similar findings have been reported by Reddy and Reddy (1992). The lowest variation was observed for locule number (2.00-7.00) and total soluble solids (3.20-8.20), which agreed with the results of Pradeepkumar and Tiwari (1999).

2.3.2 Genotypic variation for physiological traits

Water deficit conditions cause water losses within the plant and result in relative water content (RWC) reduction. Therefore, RWC is widely used as one of the most reliable indicators for defining both the sensitivity and the tolerance of plants to water deficit (Rampino *et al*., 2006). A study was conducted by Sivakumar (2014), with 18 tomato 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, CO 3, PKM 1, TNAU THCO 3 and COTH 2. The experiment was undertaken to study the effect of drought on gas exchange and physiological parameters in tomato genotypes in pot culture and reported that relative water content of plant was decreased under drought stress than control. Jureková *et al*. (2011); investigated the physiological responses of six tomato (*Solanum Lycopersicum* L.) cultivars to water stress. Plants were exposed to slow dehydration at the third unfolded leaf stage for 23 days. The relative water content (RWC), leaf area and leaf L-proline were determined under control and stressed condition. Three of the tomato genotypes exhibited reduced growth in leaf area in response to the decreased RWC, whereas other tomato genotypes retained a balanced RWC accompanied by further growth of the leaf area.

Proline is another physiological indicator for screening of genotypes under drought stress. Proline protects plant tissues against drought stress preventing molecular denaturation, scavenges reactive oxygen species and interacts with phospholipids. George *et al*. (2015); investigated 20 genotypes (6232, 6233, 6234, 10584, 10587, 17889, 17902, 17904, 19288, 19289, 19290, 19291, 19893, Avinash-2, Feston, Nagina, Punjab Chohara, Ratan and T-4) from diverse origin for proline estimation that gave a clear reference for drought tolerance in tomato. Among 20 genotypes, “19291” possessed the highest proline contents hence was tolerant to drought conditions. Sankar *et al*. (2007); found that there were significant differences in proline accumulation among the five varieties of bhendi (*Abelmoschus esculentus*) under drought-induced stress treatment. Seven different traditional rice varieties of Assam were evaluated for

their response to osmolyte production under physiological drought condition through simulation 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 substantiated. The results indicated that the varities like *Laodubi*, *Leserihali*, *Beriabhanga* and *Borah* were the best drought sustaining variety as they have high proline content under stress condition.

2.3.3 Genotypic variation for antioxidant and nutritional traits

Tomatoes are widely consumed either as raw or after processing and can provide a significant proportion of the total antioxidants in the diet associated with beneficial health properties. Over the last two or three decades an increasing interest for nutritional and antioxidant attributes in tomatoes has arisen. The screening of antioxidant attributes of tomatoes is subject of a large number of articles (Siddiqui *et al*., 2015; Kavitha *et al*., 2014; Saha *et al*., 2010).

Screening of natural biodiversity for their better quality attributes is of prime importance for quality breeding programmes. Saha *et al*. (2010) screened a set of 53 tomato genotypes for their textural [skin firmness, pericarp thickness and total soluble solids (TSS)] nutritional [phosphorus (P), potassium (K), iron (Fe), zinc (Zn), copper (Cu), manganese (Mn) and titrable acidity] and functional (beta-carotene, lycopene and ascorbic acid) quality attributes. Three sets of data (textural, nutritional and functional attributes) were obtained and analysed for their mutual relationships. Wide variations were observed in most of the measurements, e.g. skin firmness (coefficient of variability (CV) 269-612 g), pericarp thickness (CV 1.4-4.9 mm), potassium (CV 229-371 mg 100 g(-1)), iron (CV 611-1772 mg 100 g(-1)), ascorbic acid (CV 12-86 mg 100 g(-1)), suggesting that there were considerable levels of genetic diversity. Significant correlations ($P < 0.05, 0.01$) were also detected among different attributes of tomato genotypes, such as phosphorus and zinc with a correlation

coefficient of 0.74, ascorbic acid and copper of 0.57, pericarp thickness and lycopene of - 0.52. However, there were no correlations between textural and nutritional attributes. Five factors were computed by principal component analysis that explained 66% of the variation in the attributes, among which all micronutrients other than iron, TSS, firmness and beta-carotene were most important. Functional attributes except beta-carotene played a less important role in explaining total variation. Their knowledge could aid in the efficient conservation of important parts of the agricultural biodiversity. These results were potentially useful for tomato breeders working in the development of new varieties.

Wide germplasm diversity and transferability of antioxidant parameters is the primary requirement for the development of high-antioxidant tomato cultivars. A study was conducted by Kavitha *et al*. (2014) 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 programmes. Wild species and interspecific hybrids between LA-1777 (*Solanum habrochaites*) and an elite genotype 15SBSB recorded very high antioxidant capacity (FRAP), DPPH radical-scavenging ability, and high phenols and flavonoids. Interspecific hybrids also recorded very high total soluble solids (TSS). Significantly higher total carotenoids, lycopene and vitamin C were observed in IIHR-249-1 with moderately higher TSS. Cherry tomato lines IIHR-2866, 2865 and 2864 recorded four to five times higher β-carotene than commercial hybrids/varieties. Based on these results they recommended the use of tomato line IIHR-249-1 in breeding programmes for improving antioxidant capacity, total carotenoids and lycopene, cherry tomato lines, IIHR-2866, 2865 and 2864 for improving β-carotene content, LA-1777 and interspecific hybrids for developing tomato lines rich in antioxidants as well as TSS.

2.4 Effect of drought on developmental stages of plant and crop production

The environmental stresses resulting from drought, temperature, salinity, air pollution, heavy metals, pesticides and soil pH are major limiting factors in crop production (Alqudah *et al*., 2011; Lawlor and Cornic 2002; Hernandez *et al.*, 2001). Among others, drought stress is a main abiotic stress that limits crop production (Forster, 2004). Drought occurs every year in many parts of the world, often with devastating effects on crop production (Ludlow and Muchow, 1990). Worldwide losses in crop yields from drought stress probably exceed the combined losses from all other abiotic stresses (Barnabas *et al.*, 2008). Because water resources for irrigating crops are declining worldwide, the development of more drought-resistant or drought-tolerant cultivars and greater water-use efficient crops is a global concern (Ludlow and Muchow, 1990). In the last several decades, the most productive agricultural regions were exposed to drought stress in most years and in occasional years with severe drought. Commonly, drought stress synchronizes with extreme temperature, leading to even greater severity of drought stress (Barnabas *et al.*, 2008). Drought stress affects crop growth and yield during all developmental stages. The effect of drought on yield is highly complex and involves processes as diverse as reproductive organs, gametogenesis, fertilization, embryogenesis, and seed development stress (Barnabas *et al.*, 2008). There is a need to utilize water efficiently and effectively because water availability is scarce in the dry zone of the world. An experiment was conducted 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 (Vijitha and Mahendran, 2010). They also, investigated to find out the most critical stage/s of the plant growth to moisture stress in order to sustain yield by efficient water management. The result showed that moisture stress at fruit ripening stage reduced the vitamin C contents of fruits. The TSS and acid contents of the fruits were slightly affected by moisture stress when the stress was imposed during the fruit ripening stage but they were not

significant. Vitamin C, TSS and acid contents of fruits were unaffected by moisture stress given during vegetative, flowering and early fruiting stages. Moisture stress reduced the yield of tomato and the stress during the flowering stage showed the highest yield reduction compared to the other growth stages. Hence, the flowering stage is the most critical stage of growth of tomato to moisture stress for the fruit yield.

Reproductive development at the time of flowering is especially sensitive to drought stress (Samarah *et al*., 2009c; Zinselmeier *et al.*,1999, 1995). Therefore, an understanding of how a reproductive process becomes affected by drought is of particular interest for improving drought tolerance (Samarah *et al.,* 2009c). The flowering period of a crop is a critical growth stage and a yield determinate factor in normal growing seasons and in drought stressed regions in particular. An understanding of how crop plants respond to drought stress during reproductive stage is important in maximizing yields in water-limited regions.

Drought stress is a main abiotic stress that limits crop pollination by reducing pollen grain vailability (Trueman and Wallace, 1999; Agren 1996), increasing pollen grain sterility (Schoper, 1986; Al-Ghzawi *et al*., 2009), decreasing pollen grain germination and pollen tube growth (Lee, 1988). Drought stress can also reduce megagametophyte fertility, inhibit the differentiation of young microspores (Satake, 1991), lower the number of dehisced anthers (Sawada, 1987), repress anther development (Nishiyama, 1984), and decrease seed set and seed development (Al-Ghzawi *et al*., 2009).

Increasing evidence indicates that ovary abortion can account for substantial kernel losses when maize experiences low water potential near the time of pollination (Andersen *et al.,* 2002; Zinselmeier *et al.*, 1999; Boyle *et al.*, 1991; Westgate and Boyer, 1985a,b).

Flowering is one of the most important growth stage affected by drought stress. Drought stress interferes with flower period, flower opening, nectar production,

and turgor maintenance of floral organs (Mohan Ram and Rao, 1984). The trend for reduced flower size under drought stress is mirrored in populations of *Clarkia unguiculata* distributed along a natural moisture gradient (Jonas and Geber, 1999). Water stress detrimentally affects flower induction, pollen production and subsequently leads to failure of fertilization and hence grain set (Sheoran and Saini, 1996). Soil water deficits that occur during the reproductive growth are considered to have the most adverse effect on crop yield (Samarah *et al*., 2009a, b; Costa-Franca *et al.*, 2000). Drought stress imposed on plants leads to decrease yield through reducing seed set (Al-Ghzawi *et al.*, 2009; Westgate and Boyer, 1986). Low seed set percentages are regularly related to several factors such as reducing pollen grain availability (Trueman and Wallace, 1999; Agren, 1996), increase ovary abortion (Boyer and Westgate, 2004), increase pollen grain sterility (Al-Ghzawi *et al*., 2009; Schoper, 1986; Westgate and Boyer, 1986;), slow stigma and style elongation (Westgate and Boyer, 1985b), reducing time of pollination (Westgate and Boyer, 1986), lower pollen grain germination activity, pollen tube growth, and less development of fertilized seeds (Lee, 1988).

Many researchers have found that the reduction in number of spikes per plant under drought stress was due to the increase in the number of sterile spikes per plant and the decrease in the number of fertile spikes per plant in six-row barley (Samarah *et al*., 2009a; Mogensen, 1992;). A reduction in number of grains per spike has been reported for barley (Samarah *et al*., 2009a; Agueda, 1999; Mogensen, 1992;) and wheat (Garcia, 2004) under drought stress.

Drought stress not only affects seed production, but many researchers found that drought stress during reproductive growth lowered seed germination and vigor. Seed quality, estimated by standard germination, was lower for seeds harvested from plants grown under drought than seeds harvested from irrigated plants (Smiciklas *et al.*, 1992).

2.5 Effect of different drought treatment on tomato plant

2.5.1 Effect of drought on agromorphogenic traits

Wahb-Allah *et al.* (2011); reported that when tomato plants are subjected to different levels of drought stress under field conditions, it affects plant growth and development. Higher water stress gradually decreases plant height, primary branches, Cluster/plant, fruit/cluster, number of fruits and total yield/plant, individual fruit weight, amino acid content in leaves while total sugar and reducing sugar content in leaves increased with the increase in drought stress. The study was carried out at the Dirab Agricultural Research and Experimental Station of the Faculty of Food and Agriculture Sciences, King Saud University, Riyadh, Saudi Arabia (24° 39' N, 46°44'E). Four commercial tomato cultivars (Imperial, Pakmore VF, Strain-B and Tnshet Star) were used in this study.

Number of fruits reduction in the plants, when they experienced drought stress during the early fruiting stage, would have been due to reduced fruit size and fruit number. The fruits of plant treated at this stage were smaller than those of the control. The reduction in the fruit number was due to dropping of immature fruits. During the period of fruit enlargement, considerable amounts of carbohydrates and water are transported to the fruits. Therefore, size of the fruit largely depends on this phase (Kozlowski, 1972).

Wien *et al*. (1989); found that drought stress causes increase of leaf temperature is deleterious effect for plants. Abscission of reproductive organs like flower buds and immature fruits is a major yield limiting factor in vegetable crops. Nyabundi and Hsiao (2009); reported that tomato plants subjected to different levels of water stress under field conditions had inhibited vegetative growth but enhanced fruit development. This study used four treatments and each replication per treatment comprised ten plants. Sibomana and Aguyoh (2013); conducted a two-factor experiment to test the effects of water stress on growth and yield of tomato was done in Horticulture Research and Teaching Farm, in Egerton University for two seasons in 2009 and 2010.

Results indicated that trere were significant differences were noted between the treatments regarding the number of fruits per plant and average fruit diameter in both trials. Results also showed maturity time decreases with the increasing ogf drought levels in tomato plants. Number of fruits per plant was reduced by between 25 to 34%, while the average equatorial diameter of the fruits was subjected to the highest water stress by 11.5% to 19% lower compared to the control.

Srivastava *et al*. (2012); have found that potential size and average weight of tomato fruits depends on the rate of water accumulation. They observed that it decreased if drought stress would have increased. They also found that drought induced high temperature caused flower drop up to 22.56% and immature fruits drop in the tomato. Kamrun *et al.* (2011); observed no difference in the height of tomato plants subjected to different water levels.

Klepper *et al*. (1971); indicates that the fruit length and diameter changes reflect changes in fruit tissue hydration. On the other hand, well watered plants had an increase in fruit length and diameter compared to the moderate and severe stressed plants. Bhatt *et al*. (2009); found that, in tomato, dropping of immature fruits and the reduction in photosynthesis was more in susceptible cultivars compared to the tolerant cultivars where the abscission was relatively less. Sharp *et al*. (2004); found that plant growth rate is generally inhibited by soil drying, but many results confirmed that root growth is less influenced by the soil water deficit than that of the shoot. The maintenance of, or even promotion of, root growth during soil drying can provide several advantages, such as a better exploitation of soil nutrients and water when environmental conditions are less favorable.

Less irrigation water caused a significant reduction in plant height and fruit weight (Mingo *et al*., 2004). Alternatively, tomato growth parameters and yield were higher at a high irrigation rate and decreased significantly at a low irrigation rate (Tuberosa and Salvi, 2006). Pervez *et al*. (2009); conducted an

experiment to observe the effect of water stress on yield, quality and vigour of tomato seeds. There were four treatments and each replication per treatment comprised ten plants and found that drought stress treatments affected the vegetative growth of plants in most of the cases. The treated plants showed a reduction in biomass production in percentage. Drought stress at flowering stage not only reduces flower formation but also increases flower shedding. Mahendran and Bandara (2000); observed that when plants were exposed to moisture stress at the flowering stage, a severe drop in flowering occurred. Reduction in flower number reduces the amount of final yield. Hence, moisture stress during the flowering stage may have resulted in the highest reduction in yield.

The plants which were exposed to moisture stress during the vegetative stage showed the next highest yield reduction. The yield reduction in the plants when treated at the vegetative stage was due to reduced development of leaves, twigs and branches. Turner *et al.* (2010); gave ample examples of reduction in cell enlargement and vegetative growth caused by water stress. Kirnak *et al.* (2001); assessed comparative yield responses of greenhouse-grown tomato to full and deficit irrigation. They reported that marketable tomato yield was the lowest under conventional deficit irrigation treatments (30 and 50% water deficit).

2.5.2 Effect of drought on physiological traits

Sivakumar, (2014), conducted an experiment to see the effect of drought with three treatments viz., control, Treatment-1(for 30 days) and Treatment-2 (for 45 days) with three replications. He reported that relative water content of plant decreased under drought stress than control. Kirnak *et al*. (2001); also have found that drought stress results in significant decreases in , plant relative water content and vegetative growth; and plants grown under high water stress have less fruit yield and quality. Haloi and Baldev, (1986), reported that the higher plant relative water content (RWC) indicates 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.

Srivastava *et al.* (2012); reported that relative water content and transpiration is important trait for assessment of drought tolerance, and is widely affected by environmental stress conditions. Higher transpiration rate was observed in control plants (100% FC) at all the stages compared to water deficit stress condition (50% FC) in all the genotypes. In an another study, the relative water content (RWC) was determined at 10, 17 and 23 days after treatment application by Jureková *et al*. (2011). Their results showed that during slow dehydration, the leaf RWC declined in all studied genotypes, A statistically significant effect of the sampling date (water stress duration) on RWC values was also observed. However, three of the tomato genotypes exhibited reduced growth in leaf area in response to the decreased RWC, whereas other tomato genotypes retained a balanced RWC accompanied by further growth of the leaf area.

Proline as an inert compatible osmolyte that protects sub-cellular structures and macromolecules under water stress conditions (Szabados and Savoure, 2009) and it is compatible osmo-protectant and osmolyte which accumulates largely under stress conditions (Seki *et al*., 2007). Proline prevents molecular denaturation, scavenges reactive oxygen species and interacts with phospholipids (Kavikishor and Sreenivasulu, 2014). Amino acids involving proline, choline, glycinebetaine are the essential osmo-protectants against drought stress (Kavikishor *et al.,* 2005). Plants generally accumulate compatible solutes such as proline, betaine and polyols in the cytosol to raise osmotic pressure and thereby to maintain both turgor and driving gradient for water uptake (Rhodes and Samaras, 1994) and to protect membranes and proteins (Delauney and Verma, 1993). It has been shown that proline plays an important role in the stabilization of cellular proteins and membranes in the presence of a high osmoticum concentration (Errabii *et al*., 2006). Pan *et al.*

(2006); estimated 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. There was more than 100 % increase in proline content at 40 % F.C. compared with 100 % F.C. treatment.

2.5.3 Effect of drought on antioxidant and nutritional traits

Plant water status controls the physiological processes and conditions which determine not only the quantity but also the quality of growth (Nahar and Gretzmacher, 2002). Since water is essential for plant growth, it is axiomatic that water stress, depending on its severity and duration, will affect plant growth, yield and quality of yield. Nahar and Gretzmacher (2002); conducted an experiment and found that the content of vitamin C increased significantly with water stress. Ripeness classes of tomatoes were determined according to Grierson and Kader, (1986). The tomatoes were red over 90 % under stress (Grierson and Kader, 1986) in all treatments.

Tomato has an important source of antioxidants such as lycopene, vitamin C, phenolics and total soluble solids (% of brix) in human diet and has been linked with decreases risk of heart diseases, diabetes, prostate and various forms of cancer. Lycopene, a precursor of beta-carotene with well-known antioxidant activity and powerful health properties. Current research for new anticancer drugs focuses more on the natural compounds such as physicochemical constituent from the regular human diet. Because of the lack of severe side effects yet efficiently can act on a wide range of receptors or molecular targets involved in carcinogenesis and cardiovascular diseases. *In vivo, in vitro* and clinical studies conducted in recent years have revealed an inverse association between the dietary intakes of lycopene with the risk of prostate cancer (PCa). L-Ascorbic acid (AsA), which is an essential nutrient component for human health and plant metabolism, plays key roles in diverse biological processes such as cell cycle, cell expansion, stress resistance, hormone synthesis, and

signaling. Many scientists have studied quality character as well as anti-carcinogenic properties of tomato on human and many animals. Among them most relevant recent publications are reviewed below:

Lycopene (LYC) is the red pigment and a major carotenoid in tomatoes. Lycopene's antioxidant capacity is roughly twice that of β-carotene. Numerous epidermiological and intervention studies have demonstrated that dietary intake of LYC-rich foods result in decreased incidence of certain cancers, including the prostate, lung, mouth, and colon cancer, coronary heart diseases, cataracts and possibly macular degeneration. Although the tomato is the richest source of lycopene among all fruits and vegetables, its concentration in the fruit of commercial cultivars is rather low, on average ranging from 30 to 60 µg lycopene/g fresh tomato tissue. Using different traditional breeding techniques, Foolad (2007) has developed tomato breeding lines having fruit lycopene content from 100 -200 µg lycopene/g fresh fruit tissue. Lycopene is an important intermediate in the biosynthesis of many carotenoids, including beta carotene, responsible for yellow, orange or red pigmentation, photosynthesis, and photo-protection. Like all carotenoids, lycopene is a polyunsaturated hydrocarbon (an un-substituted alkene). Some of the previous reports on Lycopene experiment are discussed here:

Liu *et al.* (2011); reported that lycopene content is increased in irrigated and moderate stress condition compared to severe drought conditions. Experiment conducted with 10 genotypes and 4 drought treatments.T1 treatment (control), T2 treatment (for 15days), T3 treatment (for 30 days) and T4(for 45 days). From the study it was observed that T2 drought stress gave higher lycopene content and T4 treatment gave lower amount. It showed that after T2 treatment lycopene content had decreased as drought stress increased.

Riggi *et al*. (2008); found that in the well watered treatment higher amounts of lycopene were measured, regardless of the ripening stage compared to drought stress. Favati *et al*. (2009); also found that compared to well irrigated treatment

the lycopene concentration was higher in moderate drought stress tomatoes and lower in severe drought stress. According to Helyes *et al*. (2012); drought stress indirectly affected lycopene concentration by inducing more and larger fruits, and thus 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.

Vitamin C is a principal nutrient of tomato fruit. Although the vitamins only account for a small proportion of the total dry matter of tomato fruit, they are highly significant from the nutritional point of view. Fruit quality mainly vitamin C content changed by moisture stress (Kozlowski, 1972). An experiment was conducted at the agronomy farm of the Faculty of Agriculture, Eastern University, Sri Lanka to determine the changes in fruit quality of tomato. The experimental design was randomized complete block design with five treatments and four replications. Moisture stress was imposed during vegetative, flowering, early fruiting and fruit ripening stages of tomato for a period of four days in each growth stages. The result showed that water stress at fruit ripening stage reduced the vitamin C contents of fruits (Vijitha and Mahendran, 2010). Mahendran and Bandara (2000); reported that water stress reduced the vitamin C content of chilli fruits. The proposed route for vitamin C synthesis commences from D-glucose (Counsel and Horning, 1999). When plants experience drought stress, stomata are close followed by a decline in the CO2 fixation. A reduction in the D- glucose synthesis would have occurred during the period of stress, which in turn may have reduced the synthesis of vitamin C. Drought stress may have reduced the substrate concentration for vitamin C synthesis. Reduction in the substrate may possibly be due to reduced photosynthetic rate.

According to Torrecillas *et al.* (1995); 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. Turgor pressure decrease is thought to be

one of the controlling factors in tomatoes by increasing glucose, fructose and sucrose contents and improved the quality by increasing the concentrations of important acids such as ascorbic acid, malic acid and citric acid.

Another possibility of reduction in the vitamin C content is due to increased leaf temperature. The increase in leaf temperature may be due to lowering of transpirational cooling with the onset of stress. Vitamin C is very sensitive to changes in environmental conditions. It gets oxidized very rapidly when exposed to high temperatures (Davies *et al.*, 1991). The leaf temperature progressively builds up as a consequence of drought stress and contributes towards the reduction of vitamin C **(**Mahendran and Bandara, 2000). Vijitha and Mahendran (2010), determined 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. They found that moisture stress at fruit ripening stage slightly affected the TSS (Brix %) contents of the fruits. TSS of fruits were unaffected by moisture stress given during vegetative, flowering and early fruiting stages. According to Patane and Cosentino (2010), better water supply caused lower Brix, than drought level. Helyes *et al*. (2012); also observed that in drought condition Brix% is increased than control.

CHAPTER III
MATERIALS AND METHODS

This chapter illustrates information concerning methodology that was used in execution of the experiment. It comprises a brief description of locations of experimental site, planting materials, climate and soil, seedbed preparation, layout and design of the experiment, pot preparation, fertilizing, transplanting of seedlings, intercultural operations, harvesting, data recording procedure, statistical and nutritional analysis etc., which are presented as follows:

3.1 Experimental site

The experiment was accomplished in the net house of Genetics and Plant Breeding Department, Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh during the period from November 2013 to March 2014. 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 the map of AEZ of Bangladesh in (Appendix I).

3.2 Planting materials

A total of fifteen genotypes of tomato were collected from PGRC at BARI, Gazipur On October 2013.

3.3 Treatments in the experiment

The two factorial experiment was conducted to evaluate the performance of fifteen tomato genotypes under different drought treatments.

Factor A: Tomato genotypes

In this experiment, fifteen tomato genotypes were used as factor A (Table 1)

Table 1. Name and origin of fifteen tomato genotypes used in the study

Sl. No.	Genotypes No.	Name/Acc No. (BD)	Origin
1	G1	BD-7759	PGRC,BARI
2	G2	BD-7292	PGRC, BARI
3	G3	BD-7760	PGRC, BARI

4	G4	BD-7258	PGRC, BARI
5	G5	BD-7762	PGRC, BARI
6	G6	BD-7761	PGRC, BARI
7	G7	BD-7289	PGRC, BARI
8	G8	BD-7291	PGRC, BARI
9	G9	BD-7301	PGRC, BARI
10	G10	BARI Tomato-11	PGRC, BARI
11	G11	BARI Tomato-9	PGRC, BARI
12	G12	BARI Tomato-8	PGRC, BARI
13	G13	BARI Tomato-7	PGRC, BARI
14	G14	BARI Tomato-3	PGRC, BARI
15	G15	BARI Tomato-2	PGRC, BARI

PGRC=Plant Genetic Resource Centre, BARI=Bangladesh Agricultural Research Institute

Factor B: Different drought treatments

Different drought treatments were employed by witholding of water. Three treatments, T1 (0 days witholding of water/Control) , T2 (30 days witholding of water) and T3 (45 days witholding of water).

3.4 Design and layout of the experiment

The experiment was laid out and evaluated during Rabi season 2013-14 in CRD using two factors. Factor A included 15 genotypes and Factor B included 3 drought treatments. The experiment was conducted in 3 replications and total 135 plastic pots were used.

3.5 Climate and soil

Experimental site was located in the subtropical climatic zone, set aparted by plenty of sunshine and moderately low temperature prevails during October to March (Rabi season) which is suitable for tomato growing in Bangladesh. Weather information and physicochemical properties of the soil used in pot experiment are presented in (Appendix II and Appendix III respectively).

3.6 Seedbed preparation and raising of seedlings

Sowing was carried out on November 4, 2013 in the seedbed. Before sowing, seeds were treated with Bavistin for five minutes. Seedlings of all genotypes were raised in seedbeds in the net house of Genetics and Plant Breeding Department, Sher-e-Bangla Agricultural University, Dhaka-1207. Seeds were sown in rows spaced at 10 cm apart, beds were watered regularly. Seedlings

were raised using regular nursery practices. Recommended cultural practices were taken up before and after sowing the seeds. When the seedlings become 15 days old those were transplanted in the polybag for hardening. After hardening when the seedlings become 30 days old were transplanted to the main plastic pot. Seedbed preparation, raising of seedling, formaldehyde treatment of soil, transfer in polybag for hardening, pot preparation and transplanting to the plastic pots are shown in Plate 1.

3.7 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, 2006. 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 100gm decomposed cow dung (10 tons/hectare). Total decomposed cow dung was applied before transplanting the seedlings to plastic pots.

3.8 Pot preparation and transplanting of seedlings

Weeds and stubbles were completely removed from soil which was used for planting. The soil was treated with Formaldehyde (45%) for 48 hours before filling the polybags and plastic pots to keep soil free from pathogen. Pots were filled up two days before transplanting (December 4, 2013). Each pot was filled

Plate 1. Steps of seed sowing to transplanting. A) Seedbed preparation and sowing of seeds, B) Raising of seedlings, C) Formaldehyde treatment of soil, D) Hardening of seedling in the polybag, E) Plastic pot preparation and F) Transplanting in the plastic pots

with 7 kg soil. The pot size was 20 cm in height, 30 cm in top diameter and 20 cm in bottom diameter. Three pores were made in each plastic pot and then the pores were covered by gravels so that excess water could easily drain out.

When the seedlings become 15 days old, they were transplanted in the polybag for hardening and when the seedlings become 30 days old, they were transplanted in the main plastic pot (one plant/pot).

3.9 Application of drought treatment

Fifteen tomato genotypes were evaluated under different drought treatments (T1- Control condition or 0 Days witholding of water; T2- 30 Days withholding of water and T3- 45 Days withholding of water). Plants in control treatments (T1) were not exposed to drought; whereas plants in T2 and T3 treatments were exposed to drought for 30 days and 45 days respectively. Plants in control treatments (T1) were always irrigated with fresh water. T2 and T3 drought treatments were employed on plants in the plastic pots seven days after transplanting from the polybag. For T2 treatment the application of water was stopped for 30 days. After 30 days withholding of water, plants were re-watered for recovery. For T3 treatment the water was withhold for 45 days, and then re-watered for recovery.

3.10 Intercultural operations

Necessary watering and intercultural operations were provided as and when required (Plate 2). Weeding was performed in all pots as and when required to keep plants free from weeds. Diseases and pest is a limiting factor to tomato production. Experimental tomato plants were treated with Bavistin DF and Cupravit 50 WP to prevent unwanted diseases problem @ 1 g/l and 2 g/l respectively. Leaf miner and aphid are important pest of tomato during growing stage. They were controlled by using Malathion 250 EC @ 0.5 ml/l. Those fungicide and pesticide were sprayed two times, first at vegetative growth stage and next to early flowering stage to manage pest and diseases. When plants were well established, stalking was done to each plant by bamboo stick between

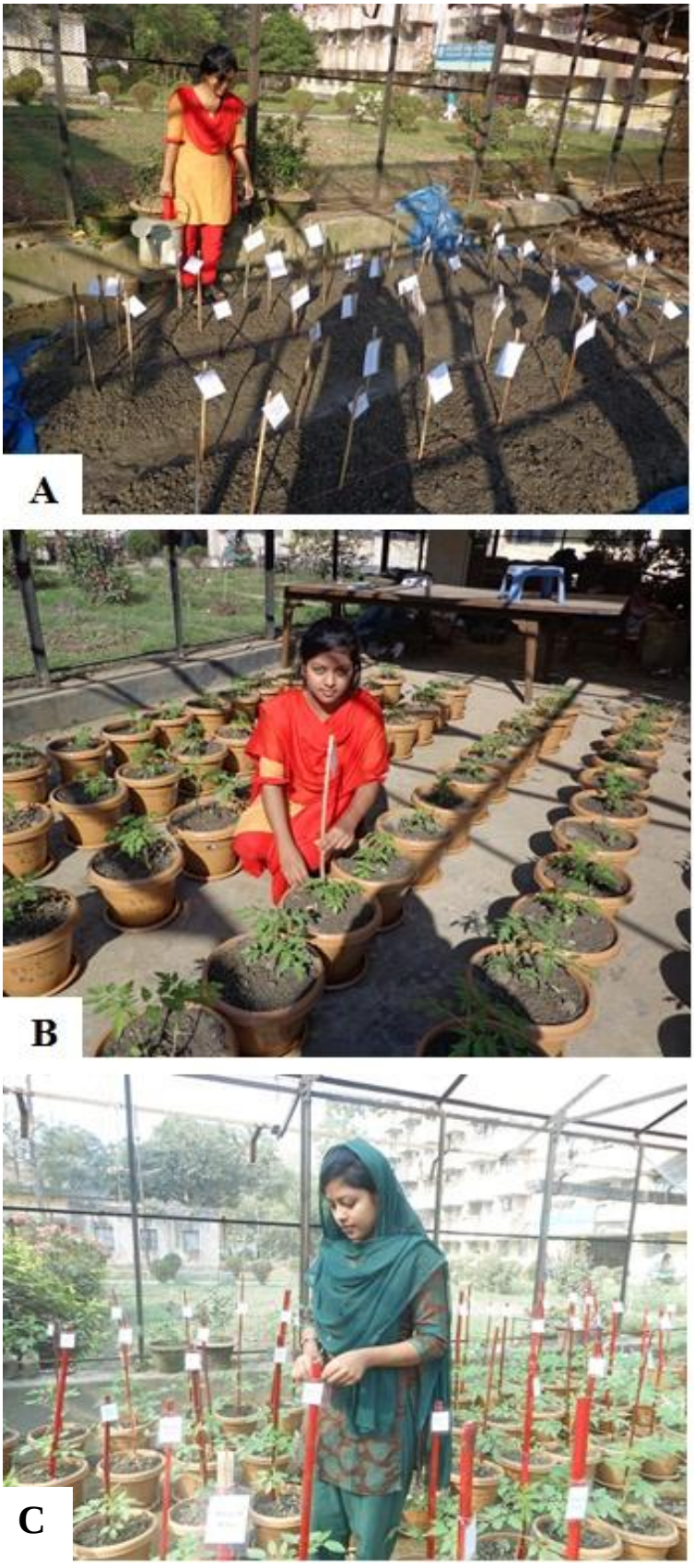

Plate 2. Watering and intercultural operation. A) Watering in the seedbed, B) Stalking in the pots and C) Tagging and labeling of the pots

25-30 DAT to keep the plants erect. Proper tagging and labeling were done for each plant. All the steps of watering and intercultural operations are presented in Plate 2.

3.11 Harvesting and processing

Harvesting of fruits was done after maturity stage. Mature fruits were harvested when fruits turned to red in color. The fruits per plant were allowed to ripe and then seeds were collected and stored at 4^{o}C for future use. Harvesting was started from February 2, 2014 and completed by March 16, 2014.

3.12 Data recording

Data were recorded from each pot based on different biometric, physiological and nutritional traits. Different steps of data collection are presented in Plate 3. Data were recorded in respect of the following parameters:

3.12.1 Agromorphogenic traits

Different biometric traits related to yield and its contributing characters were recorded viz., Days to first flowering, plant height, number of clusters per plant, number of fruits per cluster, number of fruits per plant, days to maturity, average fruit length (mm), average fruit diameter (mm), average fruit weight per plant (g) and yield per plant (kg).

3.12.1.1 Days to first flowering

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

3.12.1.2 Plant height

Plant height of each plant at mature stage measured in cm using meter scale and mean was calculated.

3.12.1.3 Number of clusters per plant

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

Plate 3. Data recording. A) Data recording in net house on number of clusters per plant, number of fruits per cluster, number of fruits per plant etc. B) Data recording in Laboratory on fruit weight, C) Determination of Vitamin-C and D) Absorbance of Lycopene using spectrophotometer

3.12.1.4 Days to maturity

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

3.12.1.5 Number of fruits per cluster

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

3.12.1.6 Number of fruits per plant

The total number of marketable fruits harvested from each plant was recorded.

3.12.1.7 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). Mean was calculated for each treatment.

3.12.1.8 Average fruit weight per plant

Fruit weight was measured by electric precision balance. Average fruit weight per plant was recorded from randomly selecting 5 fruits per plant and mean value was calculated.

3.12.1.9 Yield per plant

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

3.12.2 Physiological traits

Data related to different physiological trait such as Relative Water Content (RWC) and proline content were recorded.

3.12.2.1 Determination of relative water content

The relative water content (RWC) was estimated according to Barrs and Weatherly (1962). The fresh weight of the whole plant was recorded. The plant was floated in water under light until the weight stayed constant to attain full turgid and turgid weight was recorded. Then the plant was kept in hot air oven

at 80°C for 48 hours and the dry weight was recorded. The relative water content (RWC) was calculated by using following formula,

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

3.12.2.2 Determination of proline content

3.12.2.2.1 Proline extraction

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

3.12.2.2.2 Preparation of proline standard curve

80 mg of pure proline was dissolved into 100 mL of distilled water to get 800 ppm proline stock solution for preparing proline standard curve. By diluting this solution, 50 ppm, 100 ppm, 200 ppm, 400 ppm and 800 ppm solution were prepared in 20 mL each. The absorbances were measured with the help of Spectrophotometer at 520 nm. By plotting the concentration of proline (ppm) in 'X' axis and obtained absorbance reading in 'Y' axis a standard curve was prepared (Appendix VI) From the absorbance reading obtained from samples, their respective proline content was estimated in ppm by using proline standard curve and converted into micro gram per gram (µg/g) unit using the following formula:

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

[x= amount of proline in ppm]

3.12.3 Antioxidant and nutritional traits

Data were recorded on the basis of different antioxidant and nutritional traits using ripe fruits viz., Brix (%), Vitamin-C content (mg/100 g) and Lycopene content (mg/100 g).

3.12.3.1 Determination of Brix percentage

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.

3.12.3.2 Determination of Vitamin-C content

Vitamin-C was measured by Oxidation Reduction Titration Method (Tee *et al*., 1988). Single fruit was blend and tomato extract was filtrated by Whatman No.1 filter paper. It was then mixed with 3% metaphosphoric acid solution. The titration was conducted in presence of glacial acetic acid and metaphosphoric acid to inhibit aerobic oxidation with dye solution (2, 6-dichlorophenol indophenol). The solution was titrated with dye. The observations mean gave the amount of dye required to oxidize definite amount of L-ascorbic acid solution of unknown concentration, using L-ascorbic acid as known sample.

3.12.3.3 Determination of Lycopene content

Absorption determination for lycopene content was estimated following the method of Alda *et al*. (2009) by using T60 UV-Visible Spectrophotometer. 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 25 ml 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.

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

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

Where,

m = the weight of the product (g)

E = extinction coefficient

3.13 Statistical analysis

Collected data were statistically analyzed using MSTAT-C computer package program. Mean for every treatments were calculated and analysis of variance for each character was performed by F-test (Variance Ratio). Difference between 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 fifteen tomato genotypes to different drought treatments using agromorphogenic, physiological, antioxidant and nutritional traits. In this chapter the findings of executed 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 Agromorphogenic traits

4.1.1 Plant height

The mean values of plant height for fifteen genotypes under three different treatments (control, 30 days withholding of water, 45 days withholding of water) are presented in Appendix VIII. From the result of the experiment it was observed that plant height showed statistically significant variation among fifteen tomato genotypes (Appendix IV). Tallest plant was obtained from G2 (142.30 cm) whereas shortest from G6 (55.44 cm) (Table 2). The result showed that G2 genotype gives the highest plant height.

The results also revealed that plant height was significantly influenced by drought stress (Appendix IV). Tallest plant was found at T1 (control) (101.50cm) which is statistically significant with T2 (30 days) (100.4 cm) while shortest plant height from T3 (45 days) (84.20 cm) (Table 3). Less irrigation water caused a significant reduction in plant height, when the applied water is reduced, it affects physiological processes and exposes plants to drought stress, which is reflected in low water absorption and transmission to different parts of the plant, as a result plant height gradually decreases. Similar results were reported by Wahb-Allah *et al*. (2011).

Table 2. Genotypic effect on plant height, days to first flowering and number of cluster per plant over drought treatments

Genotype	Plant height(cm)	Days to first flowering	Number of cluster per plant
G_1	119.3 c	36 b	15.89 a
G_2	142.3 a	25.67 d	10.11 c
G_3	117.8 c	26.33 d	12.56 b
G_4	72.56 h	21.33 gh	8.55 de
G_5	80.11 g	20.44 h	7.55 fg
G_6	55.44 i	22.67 e	7.88 efg
G_7	119.8 c	22.56 ef	8.66 d
G_8	125 b	22.33 efg	9.66 c
G_9	88.56 f	28 c	8 def
G_{10}	112 d	22.89 e	8.55 de
G_{11}	73.11 h	38.67 a	7.22 g
G_{12}	74 h	36.89 b	6 h
G_{13}	99.78 e	36 b	4 i
G_{14}	73.11 h	21.44 fgh	6.33 h
G_{15}	76.78 gh	22.56 ef	5.77 h
CV%	18.52	1.09	9.66
LSD0.05	5	1.12	0.76

Fifteen tomato genotypes coded from G_1 to G_{15}

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. Effect of different drought treatments on plant height, days to first flowering and number of cluster per plant

Drought treatments	Plant height(cm)	Days to first flowering	Number of cluster per plant
T_1	101.5 a	26.89	9.24 a
T_2	100.4 a	26.69	8.37 b
T_3	84.02 b	27.18	7.73 c
CV%	18.52	1.09	9.66
LSD0.05	2.24	----	0.44

Three drought treatments viz. T_1, Control; T_2,30 days; T_3, 45days

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

Plant height showed significant interaction effect between tomato genotypes and drought treatments (Appendix IV). Tallest plant was observed in G2T1

(170.30 cm) whereas shortest plant was found from G6T3 (50.67 cm) which was significantly identical with G11T3, G6T1 (56.67 cm) and G6T2 (59.00 cm) (Table 4).

The mean plant height of fifteen genotypes showed significant variation under drought stress. The reduction percentage of plant height at treatment T2 and T3 is presented in Figure 1. Lowest reduction of plant height was observed (0%) in genotype G7 at moderate drought stress (30 days) and genotype G6 (10.59%) showed lowest reduction amongst all genotypes in case of severe drought stress (45 days) (Figure 1).

4.1.2 Days to first flowering

The mean values of days to first flowering for fifteen genotypes under three different treatments (control, 30 days withholding of water, 45 days withholding of water) is presented in Appendix VIII. It was observed from the result of the experiment that there was statistically significant variation was found among the tomato genotypes in respect of days to first flowering from days after transplantation of tomato seedlings (Appendix IV).The longest period required (38.67 days) for flowering in G11 whereas shortest period in G5 (20.44 days) which was statistically identical with G4 (21.33 days) and G14 (21.44 days) (Table 2). The result showed that G5 was early flowering genotype and G11 was the late one.

Days to flowering was not significantly varied by different drought treatments (Apendix IV). Days taken to first flowering was earlier in T2 (30 days) (26.69 days) and late in T3 (45 days) (27.18 days) (Table 3).

Table 4. Interaction effect of tomato genotypes and drought treatments on plant height, days to first flowering and number of cluster per plant

Interaction	Plant height(cm)		Days to first flowering		Number of cluster per plant
G_1T_1	128.3	cd	22.33	mnop	16.67
G_1T_2	123	cde	42.67	a	16.67
G_1T_3	106.7	ghi	43	a	14.33
G_2T_1	170.3	a	31.33	f	11.33
G_2T_2	149.3	b	24	jklm	9.66
G_2T_3	107.3	gh	21.67	nopq	9.33
G_3T_1	130.3	c	28.33	gh	13.67
G_3T_2	121.3	de	25.33	ij	13.33
G_3T_3	101.7	ghi	25.33	ij	10.67
G_4T_1	73.67	mnop	21.67	nopq	9.33
G_4T_2	67.67	pq	20.67	pq	8.33
G_4T_3	76.33	lmno	21.67	nopq	8
G_5T_1	98.33	i	21.33	opq	8.33
G_5T_2	68.33	opq	20	qr	7.66
G_5T_3	73.67	mnop	20	qr	6.66
G_6T_1	56.67	rs	23	lmno	8.33
G_6T_2	59	rs	25	ijk	7
G_6T_3	50.67	s	20	qr	8.33
G_7T_1	127.7	cd	21.33	opq	9.33
G_7T_2	127.7	cd	21.33	opq	8.33
G_7T_3	104	ghi	25	ijk	8.33
G_8T_1	147	b	21.67	nopq	10
G_8T_2	124	cde	23.67	jklm	9.66
G_8T_3	104	ghi	21.67	nopq	9.33
G_9T_1	67.67	pq	28.67	g	8.33
G_9T_2	128.3	cd	20.67	pqr	8
G_9T_3	69.67	nopq	34.67	e	7.66
$G_{10}T_1$	120.7	de	24.33	jkl	9.33
$G_{10}T_2$	109.3	fg	23.33	klmn	8.66
$G_{10}T_3$	106	ghi	21	pq	7.66
$G_{11}T_1$	75.67	lmnop	40	bc	8.33
$G_{11}T_2$	87	j	38	d	7.33
$G_{11}T_3$	56.67	rs	38	d	6
$G_{12}T_1$	78.33	klm	41.67	ab	6.66
$G_{12}T_2$	75	lmnop	31	f	5.66
$G_{12}T_3$	68.67	opq	38	d	5.66
$G_{13}T_1$	100.7	hi	35	e	4.66
$G_{13}T_2$	116	ef	34.67	e	3.66
$G_{13}T_3$	82.67	jkl	38.33	cd	3.66
$G_{14}T_1$	62.67	qr	21	pq	7.66
$G_{14}T_2$	77.67	klmn	23.33	klmn	5.66
$G_{14}T_3$	79	jklm	20	qr	5.66
$G_{15}T_1$	85	jk	21.67	nopq	6.66
$G_{15}T_2$	72	mnop	26.67	hi	6
$G_{15}T_3$	73.33	mnop	19.33	r	4.66
CV%	18.52		1.09		9.66
LSD0.05	8.66		1.94		----

Fifteen genotypes coded from G_1 to G_{15} and three drought treatments viz. T_1, Control; T_2,30 days; T_3, 45 days

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

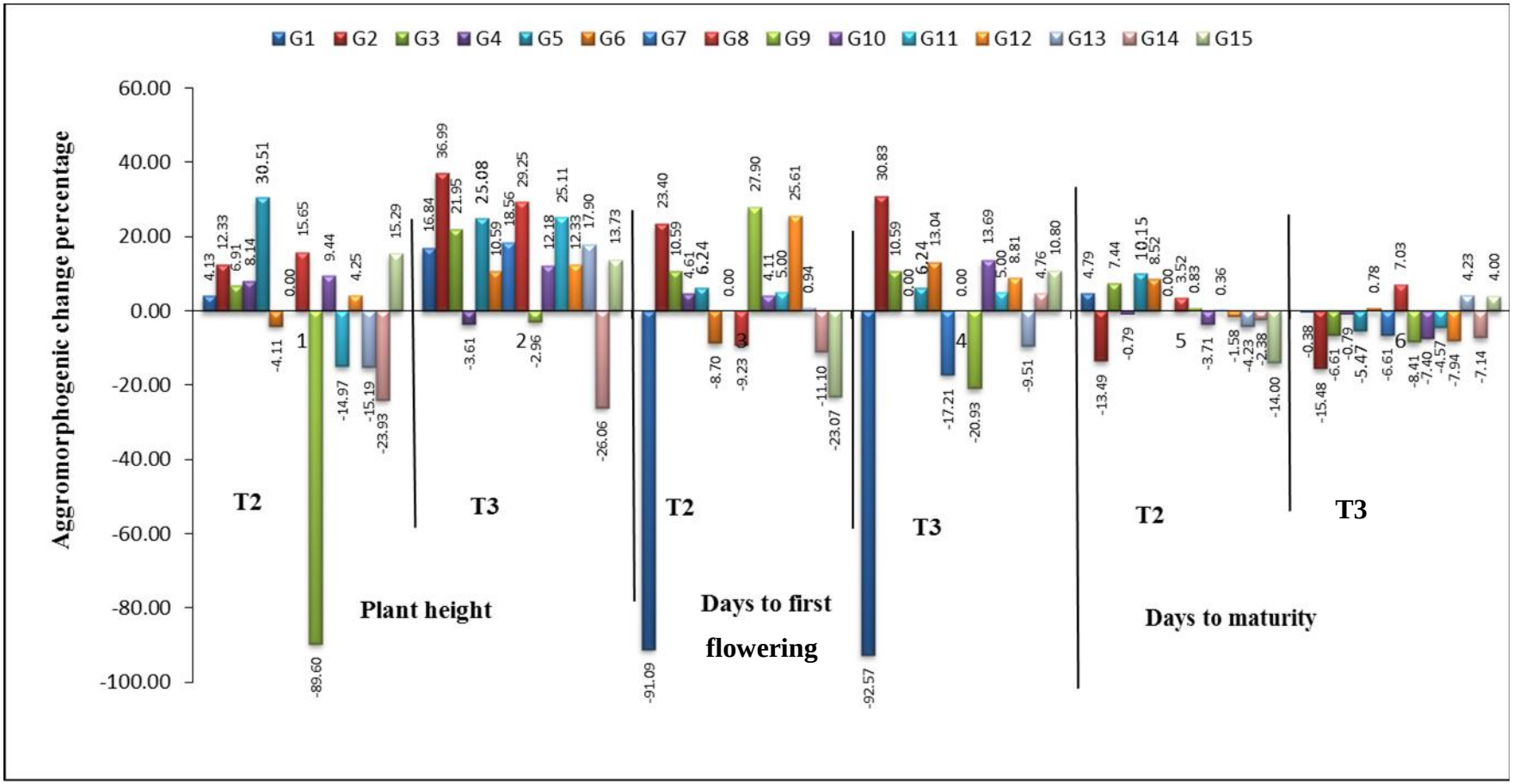

Figure 1. Reduction percentage in plant height, days to first flowering and days to maturity under increasing drought

Days taken to flowering from transplantation of tomato seedlings performed significant variation among interaction of tomato genotypes and drought treatments (Appendix IV). G1T3 treatment required maximum period (43.00 days) which was statistically identical with G1T2 (42.67 days) and G12T1 (41.67 days) for flowering whereas minimum from G15T3 (19.33 days) which is significantly identical to G14T3, G6T3, G5T3, G5T2 (20.00 days) and G9T2 (20.67 days) (Table 4).

The fifteen tomato genotypes varied significantly under drought in days to first flowering. The reduction percentage of days to first flowering at treatment T2 and T3 is presented in Figure 1. Early flowering (maximum reduction) was observed in genotype G9 (27.90%) at moderate drought stress (30 days) and genotype G2 (30.83%) showed maximum reduction amongst all genotypes in case of severe drought stress (45 days) (Figure 1).

4.1.3 Number of cluster per plant

The mean values of number of cluster per plant for fifteen genotypes under three different treatments (control, 30 days withholding of water, 45 days withholding of water) is presented in Appendix VIII. The result showed that number of cluster per plant had statistically significant variation among fifteen tomato genotypes (Appendix IV). Maximum number of cluster per plant (15.89 /plant) was counted in G1 whereas minimum number of cluster per plant (4.000 /plant) was counted in G13 (Table 2). Present experiment referred tomato genotypes G1 produce maximum number of cluster per plant.

Number of cluster per plant of tomato genotypes showed statistically significant variation among drought treatments (Appendix IV). Maximum number of cluster per plant (9.240 /plant) was counted in T1 (control) whereas minimum number of cluster per plant (7.730 /plant) in T3 (45 days) (Table 3).Results showed higher levels of drought stress decreased the number of

cluster per plant in tomato. Similar result was found by Wahb-Allah *et al.* (2011).

Interaction effect of tomato genotypes and drought treatments was not significant for number of cluster per plant (Appendix IV). Maximum number of cluster per plant (16.67/plant) were obtained from G1T1 and G1T2 whereas minimum number of cluster per plant (3.66 /plant) were found in G13T2 and G13T3 (Table 4).

4.1.4 Days to maturity

The mean values of days to maturity for fifteen genotypes under three different treatments (control, 30 days withholding of water, 45 days withholding of water) is presented in Appendix VIII. It was observed from the result of the experiment that there was statistically significant variation in days to first fruit harvest with different tomato genotypes (Appendix IV). Longest period (96.0 days) was required for harvesting in G11 whereas shortest period (74.67 days) was required for G10 (Table 5). The result indicates that G10 was the early maturing genotypes whereas G11 was the late one.

Days to fruit harvest were significantly affected by drought treatments (Appendix IV). Early harvesting was performed in treatment T3 (for 45 days) (87.60 days) treated tomato genotypes and delayed in T1 (control) (84.64 days) which was statistically identical with T2 (30 days) (84.87 days) (Table 6). Maturity time decreases with the increasing drought levels in tomato plants. Similar results were reported by Sibomana and Aguyoh (2013).

Interaction effect of genotypes and drought treatments was found significant for days taken to fruit harvest (Appendix IV). In this case earlier harvesting period (72.00 days) was observed in G10T1 whereas delayed in G11T3 (99.00 days) which was statistically identical with G13T2 (98.67) (Table 7).

Table 5. Genotypic effect on days to maturity, number of fruits per cluster and number of fruits per plant over different drought stress

Genotype	Days to maturity	Number of fruits/cluster	Number of fruits per plant
G_1	89 d	3.88 b	54.33 a
G_2	92.11 c	2.66 de	20.33 d
G_3	80.44 j	3.66 bc	41.22 c
G_4	85.78 f	2.44 e	16.33 ef
G_5	84 g	2.66 de	18.22 e
G_6	83.33 g	2.77 de	20.56 d
G_7	82.44 h	2.77 de	18 ef
G_8	82.33 h	2 f	16.22 f
G_9	81.33 i	2.77 de	17.56 ef
G_{10}	74.67 k	5.88 a	45.67 b
G_{11}	96 a	2.33 ef	11.22 g
G_{12}	86.67 e	3.22 cd	10.11 g
G_{13}	94.67 b	2.55 e	7.333 h
G_{14}	86.67 e	2.33 ef	10.11 g
G_{15}	86.11 ef	2.44 e	10.22 g
CV%	1.09	18.54	9.7
LSD0.05	0.87	0.42	1.92

Fifteen tomato genotypes coded from G_1 to G_{15}

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

Table 6. Effect of different drought treatments on days to maturity, number of fruits per cluster and number of fruits per plant

Drought treatments	Days to maturity	Number of fruits/cluster	Number of fruits per plant
T_1	84.64 b	3.33 a	22.16 a
T_2	84.87 b	2.88 b	20.66 b
T_3	87.60 a	2.66 c	19.67 c
CV%	1.09	18.54	9.7
LSD0.05	0.39	0.2	0.98

Three drought treatments viz. T_1, Control; T_2,30 days; T_3, 45 days

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

Table 7. Interaction effect of tomato genotypes and drought treatments on days to maturity number of fruits per cluster and number of fruits per plant

Interaction	Days to maturity	Number of fruits per cluster	Number of fruits per plant
G_1T_1	90.33 d	4.66	57.67 a
G_1T_2	86 e	3.33	55.33 a
G_1T_3	90.67 d	3.66	50 b
G_2T_1	84 fg	3.33	23 gh
G_2T_2	95.33 c	2.33	18 ijkl
G_2T_3	97 b	2.33	20 hij
G_3T_1	80.67 i	4	46.33 cd
G_3T_2	74.67 m	3.66	44.67 d
G_3T_3	86 e	3.33	32.67 f
G_4T_1	85.33 ef	2.66	17.67 ijkl
G_4T_2	86 e	2.33	17.33 ijkl
G_4T_3	86 e	2.33	14 mnop
G_5T_1	85.33 ef	2.66	20 hij
G_5T_2	76.67 l	2.66	17.33 ijkl
G_5T_3	90 d	2.66	17.33 ijkl
G_6T_1	86 e	2.33	19 ijk
G_6T_2	78.67 jk	3.33	22.33 gh
G_6T_3	85.33 ef	2.66	20.33 hi
G_7T_1	80.67 i	3	13.67 nopq
G_7T_2	80.67 i	2.66	16 klmn
G_7T_3	86 e	2.66	24.33 g
G_8T_1	85.33 ef	2.66	15.67 lmno
G_8T_2	82.33 h	1.66	16.33 klmn
G_8T_3	79.33 ij	1.66	16.67 klmn
G_9T_1	79.33 ij	2.66	15.33 lmno
G_9T_2	78.67 jk	3.33	17 jklm
G_9T_3	86 e	2.33	20.33 hi
$G_{10}T_1$	72 n	6.66	49.67 b
$G_{10}T_2$	74.67 m	6	48 bc
$G_{10}T_3$	77.33 kl	5	39.33 e
$G_{11}T_1$	94.67 c	2.66	12.67 opq
$G_{11}T_2$	94.33 c	2.33	11.67 pqr
$G_{11}T_3$	99 a	2	9.333 rst
$G_{12}T_1$	84 fg	4.33	11.33 pqrs
$G_{12}T_2$	85.33 ef	2.66	10.67 qrst
$G_{12}T_3$	90.67 d	2.66	8.333 stu
$G_{13}T_1$	94.67 c	3	8.333 stu
$G_{13}T_2$	98.67 a	2.33	7.333 u
$G_{13}T_3$	90.67 d	2.33	6.333 u
$G_{14}T_1$	84 fg	2.66	10.67 qrst
$G_{14}T_2$	86 e	2.33	11.33 pqrs
$G_{14}T_3$	90 d	2	8.333 stu
$G_{15}T_1$	83.33 gh	2.66	11.33 pqrs
$G_{15}T_2$	95 c	2.33	11.67 pqr
$G_{15}T_3$	80 ij	2.33	7.667 tu
CV%	1.09	18.54	9.7
LSD0.05	1.51	----	3.33

Fifteen genotypes coded from G_1 to G_{15} and three drought treatments viz. T_1, Control; T_2,30 days; T_3, 45 days
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

The fifteen genotypes varied significantly under drought in days to maturity. The reduction percentage of days to maturity at treatment T2 and T3 is

presented in (Figure 1). Maximum reduction of days to maturity (early maturity) was observed in genotype G5 (10.15%) at moderate drought stress (30 days) and genotype G8 showed maximum reduction (7.03%) amongst all genotypes in case of severe drought stress (45 days) (Figure 1).

4.1.5 Number of fruits per cluster

The mean values of number of fruits per cluster for fifteen genotypes under three different treatments (control, 30 days withholding of water, 45 days withholding of water) is presented in Appendix VIII. Number of fruits per cluster varied significantly varied statistically among different tomato genotypes (Appendix IV). Maximum number of fruits per cluster (5.88 /plant) was obtained from G10 whereas minimum (2.00 /plant) was found in G8 which was statistically identical with G11 and G14 (2.33 /plant) (Table 5). According to the present study G10 obtained the maximum number of fruits per cluster and G8 had minimum number of fruits per cluster.

Number of fruits per cluster varied significantly over drought treatments (Appendix IV). Highest fruits per cluster (3.33 /plant) was found in T1 (control) whereas T3 (45 days) provided the lowest number of fruits per cluster (2.66 /plant) (Table 6). Reduction in fruit number per cluster due to the increase of drought levels was found by Sibomana and Aguyoh (2013). Water stress can accelerate the abscission process, leading in some cases to premature dropping of fruits (Kozlowski 1972).

Interaction of tomato genotypes and drought treatments was not significant on fruit number per cluster (Appendix IV). However maximum numbers of fruits (6.66 /plant) were obtained from G10T1 and minimum numbers (1.66 /plant) from G8T2 and G8T3 (Table 7).

4.1.6 Number of fruits per plant

The mean values of number of fruits per plant for fifteen genotypes under three different treatments (control, 30 days withholding of water, 45 days withholding of water) is presented in Appendix VIII. Number of fruits per plant was significantly varied statistically among different tomato genotypes (Appendix V). Maximum number of fruits (54.33 / plant) was found from G1 whereas minimum (7.333 / plant) was found in G13 (Table 5). According to the present study G1 afforded the maximum number of fruits per plant and G13 was the minimum.

Number of fruits per plant was significantly varied statistically by drought treatments (Appendix V). The highest fruit number (22.16 /plant) was found in T1 (control) whereas T3 (45 days) provide the lowest number of fruits (19.67 /plant) (Table 6). Results showed maximum fruits per plant were found in control. Similar result was found by Wahb-Allah *et al.* (2011). The number of tomato fruits per plant depends on the number of trusses/plant, the number of flowers/truss and the fruit set index (number of fruits/number of flowers) at each truss. Srivastava *et al*. (2012); also found that drought induced high temperature also cause flower drop up to 22.5 and immature fruits drop in the tomato. Number of fruits reduction in the plants, when they experienced drought stress during the early fruiting stage, would have been due to reduced fruit size and fruit number. The fruits of plant treated at this stage were smaller than those of the control. The reduction in the fruit number was due to dropping of immature fruits. During the period of fruit enlargement, considerable amounts of carbohydrates and water are transported to the fruits. Therefore, size of the fruit largely depends on this phase (Kozlowski, 1972).

Interaction of tomato genotypes and drought treatments significantly affects the number of fruits per plant (Appendix V). Maximum number of fruits (57.670 /plant) were obtained from G1T1 which was statistically identical with G1T2 (55.330 /plant) whereas minimum number of fruits (6.333 /plant) was found in G13T3 statistically identical with G13T2 (7.333 /plant), G15T3 (7.667 /plant) and G12T3, G13T1, G14T3 (8.333 /plant) (Table7).

The fifteen genotypes varied significantly under drought in number of fruits per plant. The reduction percentage of number of fruits per plant at treatment T2 and T3 is presented in Figure 2. Number of fruits per plant increased maximum in genotype G6 because the reduction percentage at 30 days was minimum (-17.53%) and also increased in genotype G7 at severe drought stress (45 days) (-77.98% reduction percentage) (Figure 2).

4.1.7 Average fruit weight per plant

The mean values of average fruit weight per plant for fifteen genotypes under three different treatments (control, 30 days withholding of water, 45 days withholding of water) is presented in Appendix VIII. From the result of the experiment it was observed that average fruit weight per plant showed statistically significant variation among tomato genotypes (Appendix V, Plate 4). G13 tomato genotype had the maximum average fruit weight (56.10 g/plant) while minimum fruit weight (7.64 g/plant) was obtained in G10 tomato genotype which was statistically identical with G1 (8.776 g/plant) (Table 8). According to the present study G13 obtained the maximum fruit weight and G10 had the minimum fruit weight.

Average fruit weight per plant showed statistically significant variation with different drought treatments (Appendix V). Maximum average fruit weight (36.45 g/plant) was obtained in T1 (control) whereas minimum average fruit weight (21.40 g/plant) was found in T3 (45 days) (Table 9). Nyabundi and Hsiao (2009); reported that when tomato plants are subjected to 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); reported that tomato growth parameters

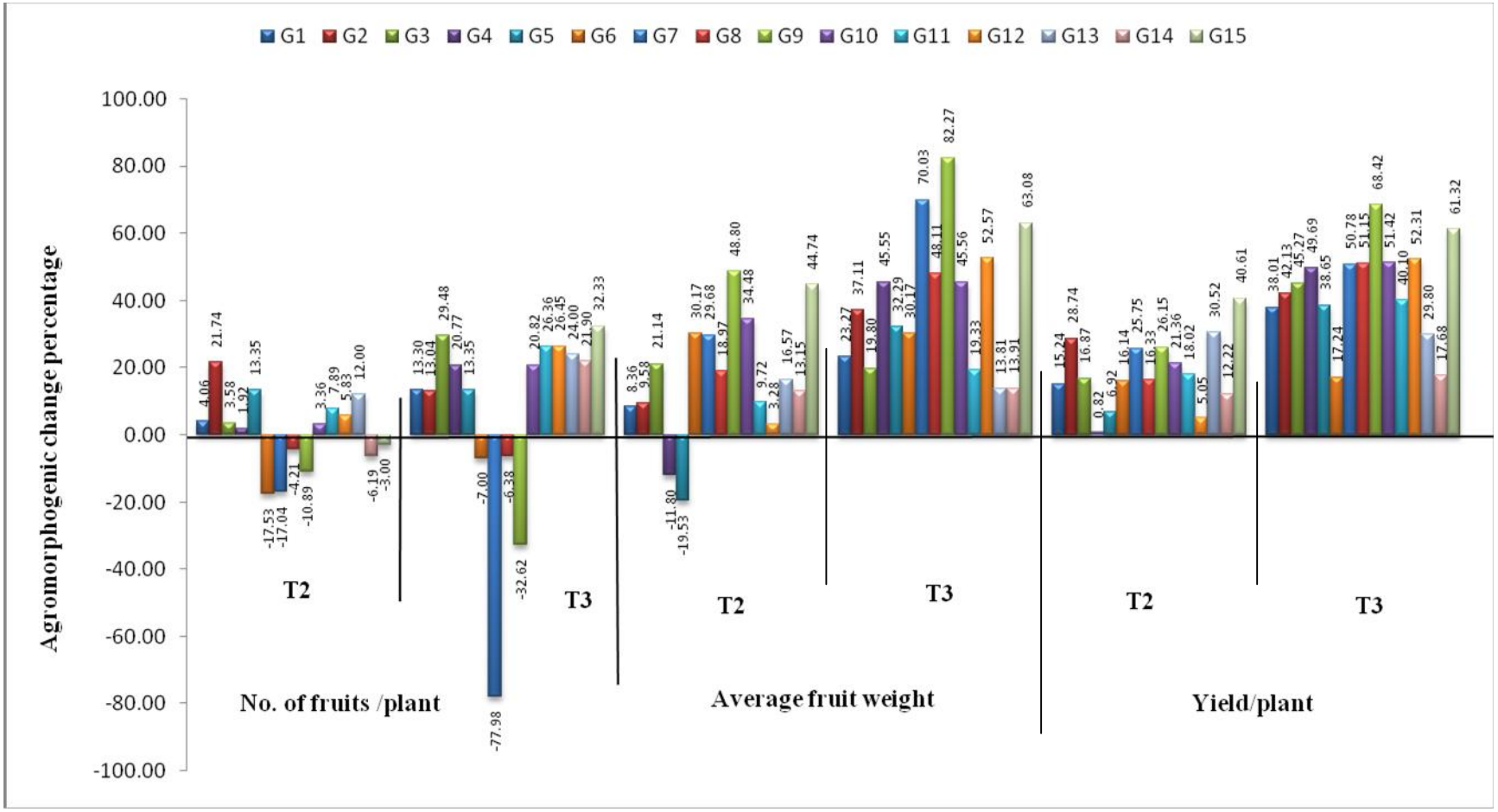

Figure 2. Reduction percentage in no. of fruits/plant, average fruit weight/plant and yield/plant under increasing drought

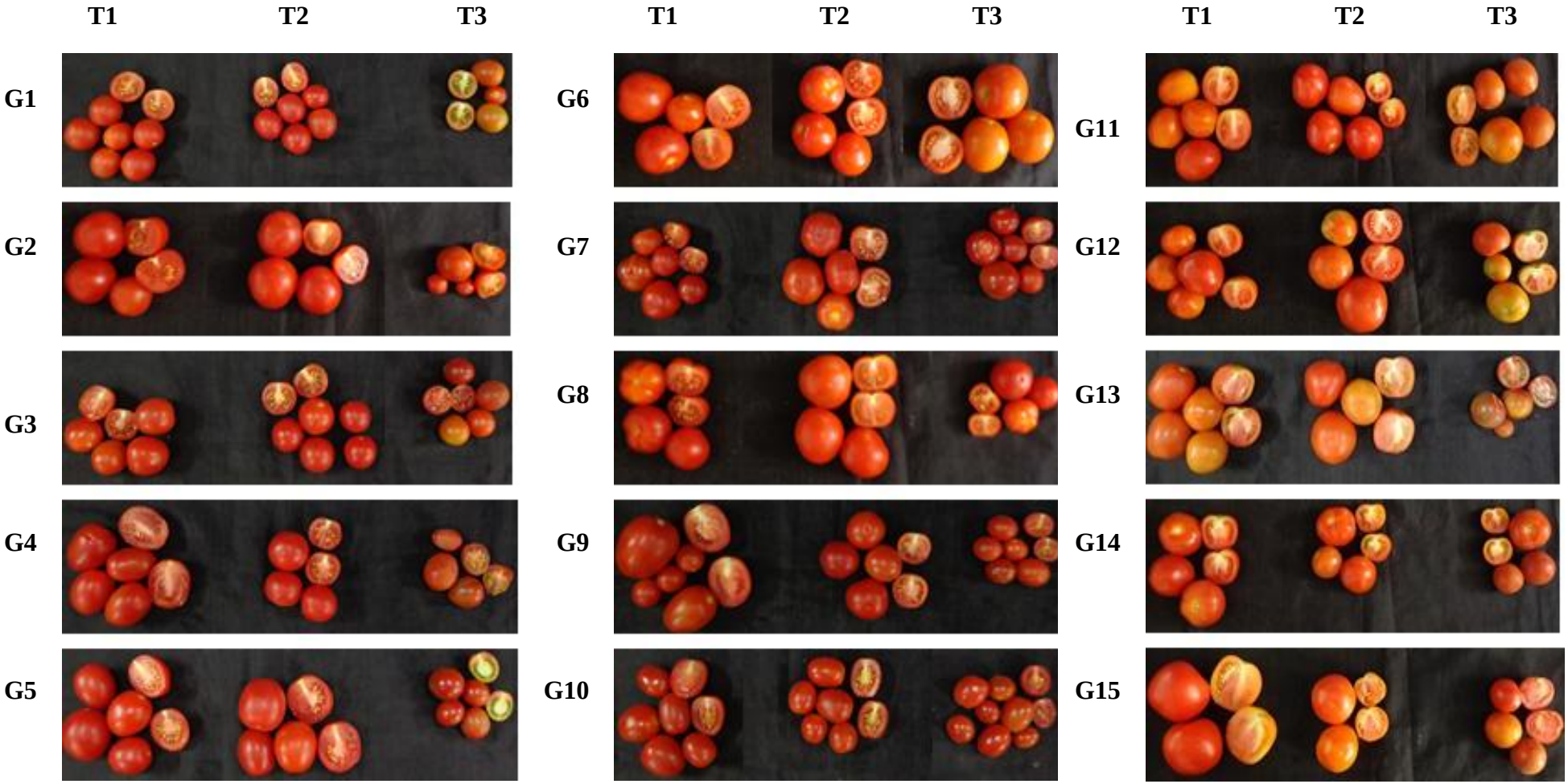

Plate 4. Comparison of fruit morphology in different genotypes of tomato under control and stress conditions. G1 (BD-7759), G2 (BD-7292), G3 (BD-7760), G4 (BD-7258), G5 (BD-7762), G6 (BD-7761), G7 (BD-7289), G8 (BD-7291), G9 (BD-7301), G10 (BARI Tomato-11), G11 (BARI Tomato-9), G12 (BARI Tomato-8), G13 (BARI Tomato-7), G14 (BARI Tomato-3) and G15 (BARI Tomato-2). T1 (Control), T2 (30 days withholding of water) and T3 (45 days withholding of water)

Table 8. Genotypic effect of tomato genotypes on average fruit weight per plant and yield per plant over different drought treatments

Genotype	Average fruit weight per plant (g)	Yield/ Plant (kg)
G_1	8.776 j	0.480 e
G_2	17.88 h	0.388 g
G_3	12.87 i	0.578 a
G_4	22.56 f	0.403 g
G_5	23.63 f	0.441 f
G_6	25.84 e	0.567 ab
G_7	32.84 d	0.523 cd
G_8	32.41 d	0.541 bc
G_9	20.61 g	0.403 g
G_{10}	7.64 j	0.400 g
G_{11}	38.27 c	0.496 de
G_{12}	51.58 b	0.577 a
G_{13}	56.10 a	0.445 f
G_{14}	50.04 b	0.560 ab
G_{15}	36.70 c	0.411 f
CV%	6.16	7.34
LSD0.05	1.68	0.029

Fifteen tomato genotypes coded from G_1 to G_{15}

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

Table 9. Effect of different drought treatments on average fruit weight per plant and yield per plant

Drought treatments	Average fruit weight per plant (g)	Yield/ Plant (kg)
T_1	36.45 a	0.608 a
T_2	29.70 b	0.493 b
T_3	21.40 c	0.342 c
CV%	6.16	7.34
LSD0.05	0.75	0.013

Three drought treatments viz. T_1, Control; T_2, 30 days; T_3, 45 days

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

and yield were higher at a high irrigation rate and decreased significantly at drought stress. Interaction of tomato genotypes and drought treatments significantly affects the average fruit weight (Appendix V). The highest

average fruit weight (63.38 g/plant) was obtained from G12T1 which was statistically identical with G12T2 (61.3 g/plant) and G13T1 (62.42 g/plant) while the lowest average fruit weight (5.673 g/plant) was found in G10T3 which was statistically identical with G10T2 (6.827 g/plant) and G9T3 (6.490 g/plant) (Table 10).

The fifteen genotypes varied significantly under drought in average fruit weight per plant. The reduction percentage in average fruit weight per plant at treatment T2 and T3 is presented in Figure 2. Average fruit weight per plant increased in genotype G5 at moderate drought stress (30 days) (reduction percentage -19.53%) and minimum reduction was found in genotype G13 at severe drought stress (45 days) (13.81%) (Figure 2).

4.1.8 Yield per plant

The mean values of yield per plant for fifteen genotypes under three different treatments (control, 30 days withholding of water, 45 days withholding of water) is presented in Appendix VIII. It was observed from the result of the experiment that the yield per plant was significantly varied statistically among tomato genotypes (Appendix V). Maximum yield (0.578 kg/plant) was found in G3 which was statistically identical with G12 (0.577 kg/plant) and G14 (0.560 kg/plant) whereas minimum yield (0.388 kg/plant) was obtained in G2, which was statistically identical with G10 (0.4000 kg/plant) and G4, G9 (0.403 kg /plant) (Table 8). According to the present study G3 genotype had the maximum yield and G2 had the minimum yield.

The yield per plant was significantly influenced statistically by drought treatments (Appendix V). The yield per plant was maximum (0.608 kg/plant) in

Table 10. Interaction effect of tomato genotypes and drought treatments on average fruit weight per plant and yield per plant

Interaction	average fruit weight per plant	Yield/ Plant (kg)
G_1T_1	9.81 wxy	0.584 efgh
G_1T_2	8.99 xy	0.495 jkl
G_1T_3	7.527 y	0.362 pqr
G_2T_1	21.18 op	0.508 ijkl

G_2T_2	19.15	pq	0.362	pqr
G_2T_3	13.32	stuv	0.294	st
G_3T_1	14.9	rs	0.729	a
G_3T_2	11.75	uvwx	0.606	def
G_3T_3	11.95	tuvw	0.399	nop
G_4T_1	25.42	n	0.485	klm
G_4T_2	28.42	m	0.481	lm
G_4T_3	13.84	rstu	0.244	tu
G_5T_1	24.68	n	0.520	ijkl
G_5T_2	29.5	lm	0.484	klm
G_5T_3	16.71	qr	0.319	rs
G_6T_1	32.35	jkl	0.638	cd
G_6T_2	22.59	no	0.535	hijk
G_6T_3	22.59	no	0.528	ijkl
G_7T_1	49.19	ef	0.703	ab
G_7T_2	34.59	ij	0.522	ijkl
G_7T_3	14.74	rst	0.346	qr
G_8T_1	41.74	g	0.698	ab
G_8T_2	33.82	ijk	0.584	efgh
G_8T_3	21.66	op	0.341	qrs
G_9T_1	36.6	hi	0.589	defg
G_9T_2	18.74	pq	0.435	mn
G_9T_3	6.49	z	0.186	v
$G_{10}T_1$	10.42	vwxy	0.529	ijkl
$G_{10}T_2$	6.827	z	0.416	no
$G_{10}T_3$	5.673	z	0.257	tu
$G_{11}T_1$	42.38	g	0.616	de
$G_{11}T_2$	38.26	h	0.505	jkl
$G_{11}T_3$	34.19	ijk	0.369	opqr
$G_{12}T_1$	63.38	a	0.713	ab
$G_{12}T_2$	61.3	a	0.677	bc
$G_{12}T_3$	30.06	lm	0.340	qrs
$G_{13}T_1$	62.42	a	0.557	fghi
$G_{13}T_2$	52.08	de	0.387	nopq
$G_{13}T_3$	53.8	cd	0.391	nopq
$G_{14}T_1$	55	bc	0.622	de
$G_{14}T_2$	47.77	f	0.546	ghij
$G_{14}T_3$	47.35	f	0.512	ijkl
$G_{15}T_1$	57.29	b	0.623	de
$G_{15}T_2$	31.66	kl	0.370	opqr
$G_{15}T_3$	21.15	op	0.241	u
CV%	6.16		7.34	
LSD0.05	2.91		0.051	

Fifteen genotypes coded from G_1 to G_{15} and three drought treatments viz. T_1, Control; T_2,30 days; T_3, 45 days
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

T1(control) whereas minimum (0.342 kg/plant) in T3 (45days) (Table 9). Drought stress at flowering stage not only reduces flower formation but also increases flower shedding. Mahendran and Bandara (2000); observed that when plants were exposed to moisture stress at the flowering stage, a severe drop in flowering occurred. Reduction in flower number reduces the amount of final yield. Hence, moisture stress during the flowering stage may have resulted in the highest reduction in yield. The plants which were exposed to moisture stress during the vegetative stage showed the next highest yield reduction. The

yield reduction in the plants when treated at the vegetative stage was due to reduced development of leaves, twigs and branches (Turner *et al.*, 2010). Drought stress reduces the yield per plant Kirnak *et al.* (2001) assessed comparative yield responses of greenhouse-grown tomato to full and deficit irrigation. They reported that marketable tomato yield was lowest under conventional deficit irrigation treatments.

Interaction between tomato genotypes and drought treatments significantly affected the yield per plant of tomato (Appendix V). Maximum yield (0.729 kg/plant) was obtained from G3T1 which was statistically identical with G12T1 (0.713 kg/plant), G7T1 (0.703 kg/plant) and G8T1 (0.698 kg/plant) while minimum yield (0.186 kg/plant) from G9T3 (Table 10).

The fifteen genotypes varied significantly under drought in yield per plant. The reduction percentage of yield per plant at treatment T2 and T3 is presented in (Figure 2). Minimum reduction was found in genotype G4 at moderate drought stress (30 days) (0.82%) and in genotype G6 (17.24%) at severe drought stress (45 days) (Figure 2).

4.1.9 Average fruit length

The mean values of average fruit length for fifteen genotypes under three different treatments (control, 30 days withholding of water, 45 days withholding of water) is presented in Appendix VIII. Statistically significant variation was found for average fruit length among tomato genotypes (Appendix V, Plate 4). Maximum fruit length (4.151 cm) was found from G13 while the shortest one found from G10 (2.338 cm) (Table 11).

Average fruit length statistically varied significantly with different drought treatments (Appendix V). Maximum fruit length (3.369 cm) was found in T1 (control) whereas the shortest (2.810 cm) in T3 (45 days) (Table 12). Reduction in fruit length and diameter due to the increase of drought levels was also found by Klepper *et al*. (1971). Results indicated that the fruit length and diameter changes reflect changes in fruit tissue hydration. On the other hand, well

watered plants had an increase in fruit length and diameter compared to the moderate and severe stressed plants. Fruit size is reduced by drought stress mainly because of shorter fruit growth period (Salter *et al*., 1967).

Interaction between tomato genotypes and drought treatments significantly affects the fruit length (Appendix V). Maximum fruit length (4.383 cm) was recorded from G13T3 which was statistically identical with G13T2 (4.230 cm) whereas shortest (2.097 cm) from G6T3 combination which was statistically identical with G3T3 (2.183 cm), G9T3 (2.197 cm) and G10T3 (2.203 cm) (Table 13).

The fifteen genotypes varied significantly under drought in average fruit length. The reduction percentage of average fruit length at treatment T2 and T3 is presented in (Figure 3). Average fruit length increased maximum in genotype G8 (reduction percentage -12.06%) at moderate drought stress (30 days) and also increased in genotype G13 (reduction percentage -14.14%) at severe drought stress (45 days) (Figure 3).

4.1.10 Average fruit diameter

The mean values of average fruit diameter for fifteen genotypes under three different treatments (control,30 days withholding of water, 45 days withholding

Table 11. Genotypic effect on average fruit length and average fruit diameter over different drought treatments

Genotype	Average fruit length (cm)	Average fruit diameter (cm)
G_1	2.511 j	2.402 i
G_2	2.904 hi	3.542 d
G_3	2.537 j	2.442 i
G_4	3.132 ef	2.901 h
G_5	3.390 d	2.891 h
G_6	3.047 fg	3.111 g
G_7	2.840 i	3.240 f
G_8	2.978 gh	3.413 e
G_9	2.827 i	2.938 h

G_{10}	2.338 k	2.058 j
G_{11}	3.542 c	3.316 ef
G_{12}	3.954 b	3.896 b
G_{13}	4.151 a	4.927 a
G_{14}	3.253 e	3.586 d
G_{15}	3.471 cd	3.751 c
CV%	4.41	3.61
LSD0.05	0.129	0.110

Fifteen tomato genotypes coded from G_1 to G_{15}

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

Table 12. Effect of different drought treatments on average fruit length and average fruit diameter

Drought treatments	Average fruit length (cm)	Average fruit diameter (cm)
T_1	3.369 a	3.481 a
T_2	3.196 b	3.366 b
T_3	2.810 c	2.836 c
CV%	4.41	3.61
LSD0.05	0.577	0.049

Three drought treatments viz. T_1, Control; T_2, 30 days; T_3, 45 days

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

Table 13. Interaction effect of tomato genotypes and drought treatments on average fruit length and average fruit diameter

Interaction	Average fruit length (cm)	Average fruit diameter (cm)
G_1T_1	2.670 lmno	2.550 p
G_1T_2	2.630 lmno	2.533 p
G_1T_3	2.233 q	2.123 qr
G_2T_1	3.180 i	4.133 d
G_2T_2	2.777 klm	3.360 hijk
G_2T_3	2.757 klmn	3.133 m
G_3T_1	2.827 kl	2.640 p
G_3T_2	2.600 mnop	2.680 op
G_3T_3	2.183 qr	2.007 rs
G_4T_1	3.253 i	2.863 no
G_4T_2	2.937 jk	2.937 n
G_4T_3	3.207 i	2.903 n
G_5T_1	3.860 ef	3.430 hij
G_5T_2	3.923 cde	3.207 klm
G_5T_3	2.387 pq	2.037 qrs
G_6T_1	3.810 ef	3.850 ef
G_6T_2	3.233 i	3.273 ijklm
G_6T_3	2.097 r	2.210 q
G_7T_1	2.853 kl	3.277 ijklm
G_7T_2	2.853 kl	3.277 ijklm
G_7T_3	2.813 klm	3.167 lm

G_8T_1	2.820	klm	3.447	hi
G_8T_2	3.160	ij	3.533	h
G_8T_3	2.953	jk	3.260	ijklm
G_9T_1	3.503	gh	3.270	ijklm
G_9T_2	2.780	klm	3.357	hijkl
G_9T_3	2.197	qr	2.187	qr
$G_{10}T_1$	2.547	nop	2.157	qr
$G_{10}T_2$	2.263	q	2.087	qrs
$G_{10}T_3$	2.203	qr	1.930	s
$G_{11}T_1$	3.903	de	3.543	gh
$G_{11}T_2$	3.360	hi	3.250	jklm
$G_{11}T_3$	3.357	hi	3.153	m
$G_{12}T_1$	4.100	bcd	3.793	f
$G_{12}T_2$	4.100	bcd	4.480	c
$G_{12}T_3$	3.663	fg	3.413	hij
$G_{13}T_1$	3.840	ef	5.167	a
$G_{13}T_2$	4.230	ab	4.720	b
$G_{13}T_3$	4.383	a	4.893	b
$G_{14}T_1$	3.237	i	3.730	fg
$G_{14}T_2$	3.327	hi	3.770	f
$G_{14}T_3$	3.197	i	3.257	ijklm
$G_{15}T_1$	4.130	bc	4.367	c
$G_{15}T_2$	3.767	ef	4.027	de
$G_{15}T_3$	2.517	op	2.86	no
CV%	4.41		3.61	
LSD0.05	0.223		0.192	

Fifteen genotypes coded from G_1 to G_{15} and three drought treatments viz. T_1, Control; T_2,30 days; T_3, 45 days

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

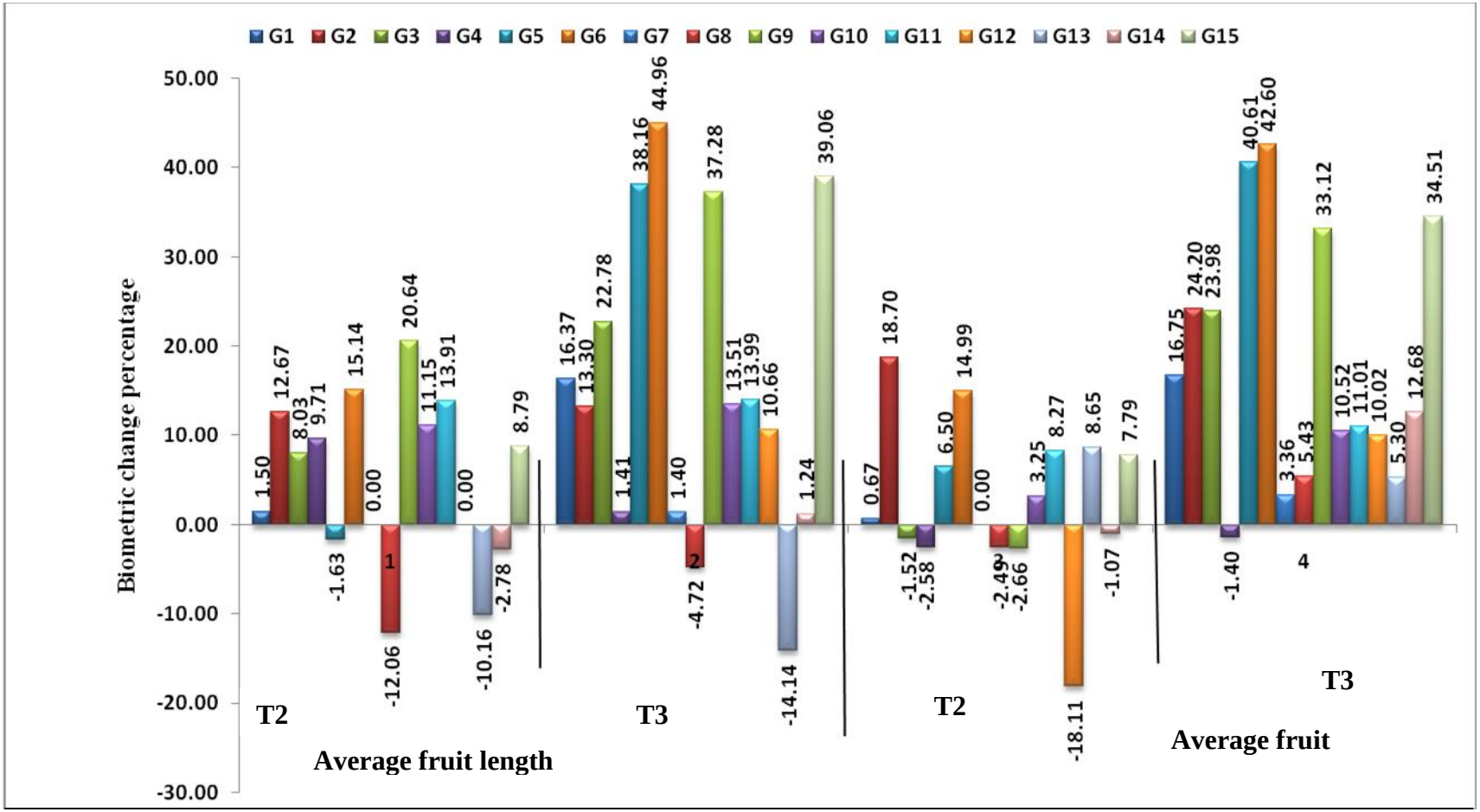

Figure 3. Reduction percentage in average fruit length and and average fruit diameter under increasing drought

of water) is presented in Appendix VIII. Statistically significant variation was recorded for fruit diameter among tomato genotypes (Appendix V, Plate 4). Maximum fruit diameter (4.927 Cm) was obtained from G13 and minimum (2.058 cm) was measured from G10 (Table 11). The mean values of average fruit diameter for fifteen genotypes under three different treatments (control, 30 days withholding of water, 30 days withholding of water) is presented in Appendix VIII. Statistically significant variation was recorded for fruit diameter among tomato genotypes (Appendix V, Plate 4). Maximum fruit diameter (4.927 Cm) was obtained from G13 and minimum (2.058 cm) was measured from G10 (Table 11).

Fruit diameter was significantly varied statistically with different drought treatments (Appendix V). Maximum fruit diameter (3.481 cm) was recorded from T1 (control) whereas minimum (2.836 cm) from T3 (45 days) treatment (Table 12). Reduction in fruit length and diameter due to the increase of drought levels was also found by Klepper *et al*. (1971). Results indicates that the fruit length and diameter changes reflect changes in fruit tissue hydration. On the other hand, well watered plants had an increase in fruit length and diameter compared to the moderate and severe stressed plants.

Interaction between tomato genotypes and drought treatments significantly affects the fruit diameter (Appendix V). Maximum fruit diameter (5.167 cm) was obtained from G13T1 whereas minimum (1.930 cm) from G10T3 which was statistically identical with G3T3 (2.007 cm), G5T3 (2.037 cm) and G10T2 (2.087 cm) (Table 13).

The fifteen genotypes varied significantly under drought for average fruit diameter. The reduction percentage of average fruit diameter at treatment T2 and T3 is presented in Figure 3. Average fruit diameter increased maximum in genotype G12 (reduction percentage -18.11%) at moderate drought stress (30

days) and also increased in genotype G4 (reduction percentage -1.40%) at severe drought stress (45 days) (Figure 3).

4.2 Physiological traits

4.2.1 Relative water content (RWC)

The mean values of Relative water content (RWC) for fifteen genotypes under three different treatments (control, 30 days withholding of water, 45 days withholding of water) is presented in Appendix VIII. It was observed from the result of the experiment that Relative water content (RWC) of leaves showed statistically significant variation among fifteen tomato genotypes (Appendix VI).The highest Relative water content (94.58%) was found in G9 whereas the lowest amount of RWC (71.59%) was found in G6 which was statistically identical with G10 (72.99%) (Table14). The results showed the highest relative water content in G9 tomato genotypes.

Relative water content (RWC) of leaves showed statistically significant variation among drought treatments (Appendix VI). The highest RWC (87.95%) was found in T1 (control) whereas lowest RWC (82.18%) in T2 (for 30 days) (Table 15). Drought stress results in significant decreases in relative water content (Kirnak *et al*. (2001). Haloi and Baldev (1986); reported that the higher relative water content indicated better growth and development, which in turn depends on leaf area. Rapid early growth and maintenance of RWC at reasonably higher level during reproductive phase greatly influences the yield. Sivakumar (2014), also reported that relative water content decreased under drought stress than control.

RWC of leaves was influenced significantly due to interaction betwwen genotypes and drought treatments (Appendix VI). The highest relative water content (99.55%) was found in G9T1 whereas the lowest relative water content (61.76%) in G6T3 (Table 16).

Table 14. Genotypic effect on relative water content and proline content over different drought treatments

Genotype	Relative water content (%)	Proline content (µg/g)
G_1	86.38 f	297.2 d
G_2	88.35 de	268.9 i
G_3	89.19 cd	290 g
G_4	88.75 cde	219.4 k
G_5	73.97 j	277.2 h
G_6	71.59 k	292.2 f
G_7	89.92 c	270 i
G_8	89.84 cd	243.9 j
G_9	94.58 a	216.7 l
G_{10}	72.99 jk	308.3 c
G_{11}	76.95 i	480.6 a
G_{12}	81.34 h	307.8 c
G_{13}	92.36 b	294.9 e
G_{14}	84.44 g	385.6 b
G_{15}	87.60 ef	297.8 d
CV%	1.88	2.59
LSD0.05	1.49	1.6

Fifteen tomato genotypes coded from G_1 to G_{15}

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

Table 15. Effect of different drought treatments on relative water content and proline content

Drought treatments	Relative water content (%)	Proline content (µg/g)
T_1	87.95 a	327.3 a
T_2	82.18 c	288.4 b
T_3	83.53 b	274.3 c
CV%	1.88	2.59
LSD0.05	0.67	0.7

Three drought treatments viz. T_1, Control; T_2, 30 days; T_3, 45 days

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

Table 16. Interaction effect of tomato genotypes and drought treatments on relative water content and proline content

Interaction	Relative water content (%)		Proline content (µg/g)	
G_1T_1	93.35	bcde	220	w
G_1T_2	82.29	qrst	415	d
G_1T_3	83.5	pqrs	256.7	u
G_2T_1	82.28	qrst	285	n
G_2T_2	89.38	hijk	273.3	r
G_2T_3	93.4	bcd	248.3	v
G_3T_1	92.01	bcdefg	278.3	pq
G_3T_2	87.23	klmn	315	jk
G_3T_3	88.33	jklm	276.7	pqr
G_4T_1	91.3	cdefgh	275	qr
G_4T_2	92.08	bcdef	201.7	x
G_4T_3	82.88	qrst	181.7	y
G_5T_1	84.14	opqr	350	h
G_5T_2	67.53	wx	255	u
G_5T_3	70.24	v	226.7	w
G_6T_1	86.2	lmno	296.7	m
G_6T_2	66.82	wx	318.3	j
G_6T_3	61.76	y	261.7	t
G_7T_1	89.49	ghijk	306.7	l
G_7T_2	89.49	ghijk	266.7	s
G_7T_3	90.77	efghij	236.7	w
G_8T_1	93.8	bc	300	m
G_8T_2	85.8	mnop	183.3	y
G_8T_3	89.92	fghij	248.3	v
G_9T_1	97.55	a	283.3	no
G_9T_2	94.42	b	161.7	z
G_9T_3	91.77	cdefgh	205	x
$G_{10}T_1$	66.55	wx	356.7	g
$G_{10}T_2$	68.25	vw	311.7	k
$G_{10}T_3$	84.18	opqr	256.7	u
$G_{11}T_1$	90.41	fghij	380	f
$G_{11}T_2$	65.58	x	388.3	e
$G_{11}T_3$	74.87	u	673.3	a
$G_{12}T_1$	86.00	mnop	338.3	i
$G_{12}T_2$	80.63	t	305	l
$G_{12}T_3$	77.39	u	280	op
$G_{13}T_1$	91.15	defghi	358.3	g
$G_{13}T_2$	92.04	bcdefg	283.3	no
$G_{13}T_3$	93.88	bc	243	w
$G_{14}T_1$	90.13	fghij	426.7	c
$G_{14}T_2$	81.79	rst	456.7	b
$G_{14}T_3$	81.41	st	273.3	r
$G_{15}T_1$	84.81	nopq	455	b
$G_{15}T_2$	89.34	hijk	191.7	y
$G_{15}T_3$	88.64	ijkl	246.7	v
CV%	1.88		2.59	
LSD0.05	2.58		3.63	

Fifteen genotypes coded from G1 to G15 and three drought treatments viz. T1, Control; T2, 30 days; T3, 45 days
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

The fifteen genotypes varied significantly under drought in relative water content (RWC). The reduction percentage of RWC at treatment T2 and T3 is presented in Figure 4. Relative Water Content increased maximum in genotype G2 (reduction percentage -8.63%) at moderate drought stress (30 days) and also increased in genotype G10 (reduction percentage -26.49%) at severe drought stress (45 days) (Figure 4).

4.2.2 Proline content

The mean values of proline content (µg/g) for fifteen genotypes under three different treatments (control, 30 days withholding of water, 45 days withholding of water) are presented in Appendix VIII. The result showed that proline content was varied significantly among the fifteen tomato genotypes (Appendix VI). Maximum proline content (480.6 µg/g) was found in G11 whereas minimum (219.4 µg/g) from G4 (Table 14). According to the study G11 tomato genotypes have the highest proline content.

Proline content in tomato showed variation under different drought treatments (Appendix VI). Maximum proline content was obtained from T1 (327 µg/g) (control) treated plant whereas the lowest (274.3 µg/g) was found in T3 (45 days) (Table 15). Pan *et al.* (2006); estimated 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.

Interaction of tomato genotypes and drought treatments significantly affects proline content in tomato (Appendix VI). Maximum proline content in tomato (673.3 µg/g) was obtained from G11T3 while minimum (161.73µg/g) from G9T2 (Table 16).

The fifteen genotypes varied significantly under drought for proline content**.** The increasing percentage of proline content at treatment T2 and T3 is presented in Figure 4. Increase of proline content was found the highest in

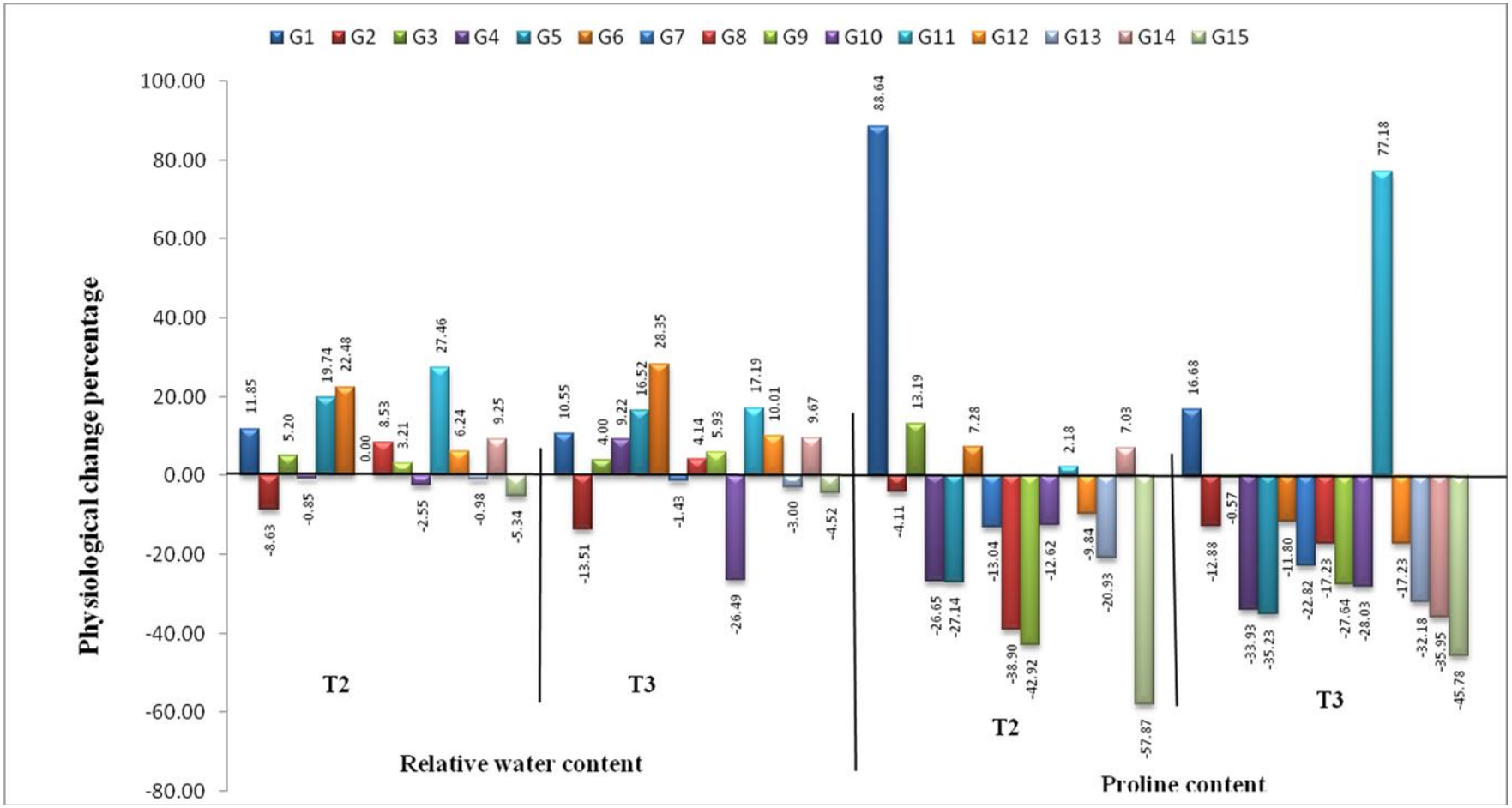

Figure 4. Reduction percentage in relative water content and increasing percentage in proline content under increasing drought

genotype G1 (88.64%) at moderate drought stress (30 days) and in genotype G11 (77.18%) at severe drought stress (45 days) (Figure 4).

4.3 Antioxidant and Nutritional traits

4.3.1 Brix

The mean values of brix (%) for fifteen genotypes under three different treatments (control, 30 days withholding of water, 45 days withholding of water) is presented in Appendix VIII. The result of the experiment it was observed that brix (%) was varied significantly among the fifteen tomato genotypes (Appendix VI). Maximum brix (1.844%) was found in G11 whereas minimum (0.655%) from G2 and G3 which was statistically identical with G5, G15 (0.722%) (Table 17). According to the study G11 tomato genotypes have the highest brix (%).

Brix (%) in tomato showed variation in drought treatments (Appendix VI). Maximum brix (%) was obtained from T3 (1.5495%) (45 days) treated plant whereas lowest (0.695%) was found in T1 (control) (Table 18). Better water supply caused lower brix, than control. The soluble solid content of fruits was often very high without irrigation. In spite of this, the level of Brix yield per hectare remarkably increased as a result of significantly higher yield quantity. Greatest effect of increasing soil water deficit was the rise in fruit firmness, soluble solids and a decrease in fruit size and yield, which is in agreement with (Patane and Cosentino, 2010). Helyes *et al.* (2012); also observed that in drought condition Brix% is increased than control.

Interaction of tomato genotypes and drought treatments significantly affects brix (%) in tomato (Appendix VI). Maximum brix in tomato (3.000%) was obtained from G5T3 while minimum (0.433%) from G2T1 and G14T1 which was statistically identical with G4T2 (0.466%), G11T1 (0.500%), G2T2, G13T1 (0.566%), and G6T1 (0.666%), (Table 19).

Table 17. Genotypic effect on brix, vitamin-C content and lycopene content over different drought treatments

Genotype	Brix (%)	Vitamin-C content (mg/100gm)	Lycopene content	
			472 nm	502 nm
G_1	1.400 bc	11.25 a	17.24 m	7.657 k
G_2	0.655 h	7.90 d	19.60 f	19.98 c
G_3	0.655 h	10.23 b	18.68 h	11.89 g
G_4	1.100 def	5.18 h	17.35 l	10.91 h
G_5	0.722 h	5.80 g	18.22 i	12.12 g
G_6	1.533 b	9.08 c	22.43 e	14.33 e
G_7	1.278 cd	9.83 b	19.41 g	12.61 f
G_8	0.988 efg	6.56 f	23.58 d	19.16 d
G_9	1.178 de	5.57 gh	17.29 lm	19.05 d
G_{10}	1.000 efg	6.39 f	17.69 k	10.89 h
G_{11}	1.844 a	4.15 j	38.22 a	38.54 a
G_{12}	0.833 g	7.26 e	30.74 b	36.98 b
G_{13}	0.966 fg	4.10 j	17.93 j	8.929 j
G_{14}	1.033 ef	3.72 j	17.58 k	9.736 i
G_{15}	0.722 h	4.65 i	27.35 c	12.50 f
CV%	10.97	7.76	2.12	2.22
LSD0.05	0.194	0.49	0.12	0.34

Fifteen tomato genotypes coded from G_1 to G_{15}

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

Table 18. Effect of different drought treatments tomato genotypes on Brix, vitamin-C content and lycopene content

Drought treatments	Brix (%)	Vitamin-C content (mg/100gm)	Lycopene content	
			472 nm	502 nm
T_1	0.695 c	7.96 a	26.47 a	20.58 a
T_2	0.853 b	6.82 b	20.05 b	14.07 c
T_3	1.549 a	5.55 c	18.15 c	14.41 b
CV%	10.97	7.76	2.12	2.22
LSD0.05	0.086	0.22	0.05	0.15

Three drought treatments viz. T_1, Control; T_2, 30 days; T_3, 45 days

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

Table 19. Interaction effect of tomato genotypes and drought treatments on brix, vitamin-C content and lycopene content

Interaction	Brix (%)	Vitamin C content	Lycopene content

					472 nm		502 nm	
G_1T_1	0.600	no	12.8	ab	18.15	t	8.28	uv
G_1T_2	0.633	mno	9.49	gh	17.16	v	7.90	vw
G_1T_3	0.733	jklmno	11.47	cd	16.41	x	6.79	y
G_2T_1	0.433	p	6.90	lm	23.16	j	17.02	m
G_2T_2	0.566	nop	11.43	cde	20.22	p	27.12	g
G_2T_3	0.966	hijklm	5.39	nopq	15.42	z	15.80	no
G_3T_1	1.100	ghi	13.20	a	22.60	k	19.16	kl
G_3T_2	1.000	ghijkl	10.61	ef	17.80	u	8.60	tu
G_3T_3	1.200	fgh	6.87	lm	15.64	y	7.91	vw
G_4T_1	0.633	mno	6.87	lm	21.64	l	18.91	l
G_4T_2	0.466	op	5.38	nopq	16.14	y	7.20	xy
G_4T_3	1.067	ghij	3.29	tuv	14.28	z	6.617	y
G_5T_1	0.700	klmno	8.40	ij	20.43	o	15.63	o
G_5T_2	0.900	hijklmn	6.08	mn	18.42	s	12.07	r
G_5T_3	3.000	a	2.94	uvw	15.82	y	8.657	tu
G_6T_1	0.666	lmnop	10.10	fg	28.53	g	12.43	r
G_6T_2	0.766	ijklmno	11.95	bc	18.15	t	14.17	p
G_6T_3	2.400	b	5.21	opq	20.60	o	16.38	n
G_7T_1	0.600	no	7.90	jk	22.70	k	19.50	jk
G_7T_2	0.866	hijklmn	10.68	def	19.32	r	6.30	z
G_7T_3	1.500	def	10.91	def	16.20	y	12.04	r
G_8T_1	1.000	ghijkl	3.70	stu	30.55	f	23.51	h
G_8T_2	1.000	ghijkl	7.18	kl	19.39	r	10.02	s
G_8T_3	1.533	def	8.80	hi	20.82	n	23.94	h
G_9T_1	0.633	mno	8.90	hi	19.92	q	13.45	q
G_9T_2	0.766	ijklmno	2.84	vw	16.92	w	23.90	h
G_9T_3	1.600	de	4.993	pqr	15.02	z	19.80	j
$G_{10}T_1$	1.033	ghijk	13.50	a	20.85	n	16.03	no
$G_{10}T_2$	2.000	c	3.42	stuv	17.68	u	7.50	wx
$G_{10}T_3$	2.500	b	2.26	wx	14.54	z	9.143	t
$G_{11}T_1$	0.500	op	3.70	stu	43.60	b	40.63	c
$G_{11}T_2$	0.966	hijklm	4.86	qr	37.84	d	32.20	d
$G_{11}T_3$	1.033	ghijk	3.89	st	33.23	e	42.80	b
$G_{12}T_1$	0.766	ijklmno	5.50	nopq	44.94	a	53.33	a
$G_{12}T_2$	0.800	ijklmno	5.83	nop	24.74	h	28.03	f
$G_{12}T_3$	1.333	efg	10.47	f	22.55	k	29.59	e
$G_{13}T_1$	0.566	nop	7.00	l	18.42	s	15.50	o
$G_{13}T_2$	0.733	jklmno	3.74	stu	17.18	v	5.60	z
$G_{13}T_3$	1.800	cd	1.57	xy	18.19	t	5.687	z
$G_{14}T_1$	0.433	p	7.20	kl	21.42	m	13.28	q
$G_{14}T_2$	0.733	jklmno	2.94	uvw	16.32	xy	10.20	s
$G_{14}T_3$	1.00	ghijkl	1.04	y	15.01	z	5.727	z
$G_{15}T_1$	0.766	ijklmno	3.80	st	40.12	c	21.96	i
$G_{15}T_2$	0.600	no	5.90	no	23.47	i	10.20	s
$G_{15}T_3$	1.567	de	4.27	rs	18.46	s	5.35	z
CV%	10.97		7.76		2.12		2.22	
LSD0.05	0.336		0.85		0.19		0.59	

The fifteen genotypes varied significantly under drought in brix (%) of tomato fruit. The increasing percentage of brix at treatment T2 and T3 is presented in Figure 5. Increase of brix (%) was found highest in genotype G10 (increasing

percentage 93.61%) at moderate drought stress (30 days) and in genotype G5 (increasing percentage 328.57%) at severe drought stress (45 days) (Figure 5).

4.3.2 Vitamin-C content

The mean values of vitamin-C content for fifteen genotypes under three different treatments (control, 30 days withholding of water, 45 days withholding of water) are presented in Appendix VIII. From the result of the experiment it was observed that vitamin-C content varied significantly among the fifteen tomato genotypes (Appendix VI). Maximum Vitamin-C content (11.25 mg/100 g) was found in G1 whereas minimum (3.72 mg/100 g) from G14 which was statistically identical with G13 (4.10 mg/100 g) and G11 (4.150 mg/100 g) (Table 17). According to the study G1 tomato genotypes have the highest Vitamin-C content.

Vitamin-C content in tomato showed variation by the drought treatments (Appendix VI). Maximum Vitamin-C content was obtained from T1 (control) (7.96 mg/100 g) treated plant whereas the lowest (5.55 mg/100 g) was found in T3 (45 days) (Table 18). Mahendran and Bandara (2000); reported that water stress reduced the vitamin-C content of chilli fruits. The proposed route for vitamin-C synthesis commences from D – glucose (Counsel and Horning, 1999). When plants experience drought stress, stomata close followed by a decline in the CO_2 fixation. A reduction in the D – glucose synthesis would have occurred during the period of stress, which in turn may have reduced the synthesis of vitamin C. Contrary to this study, 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

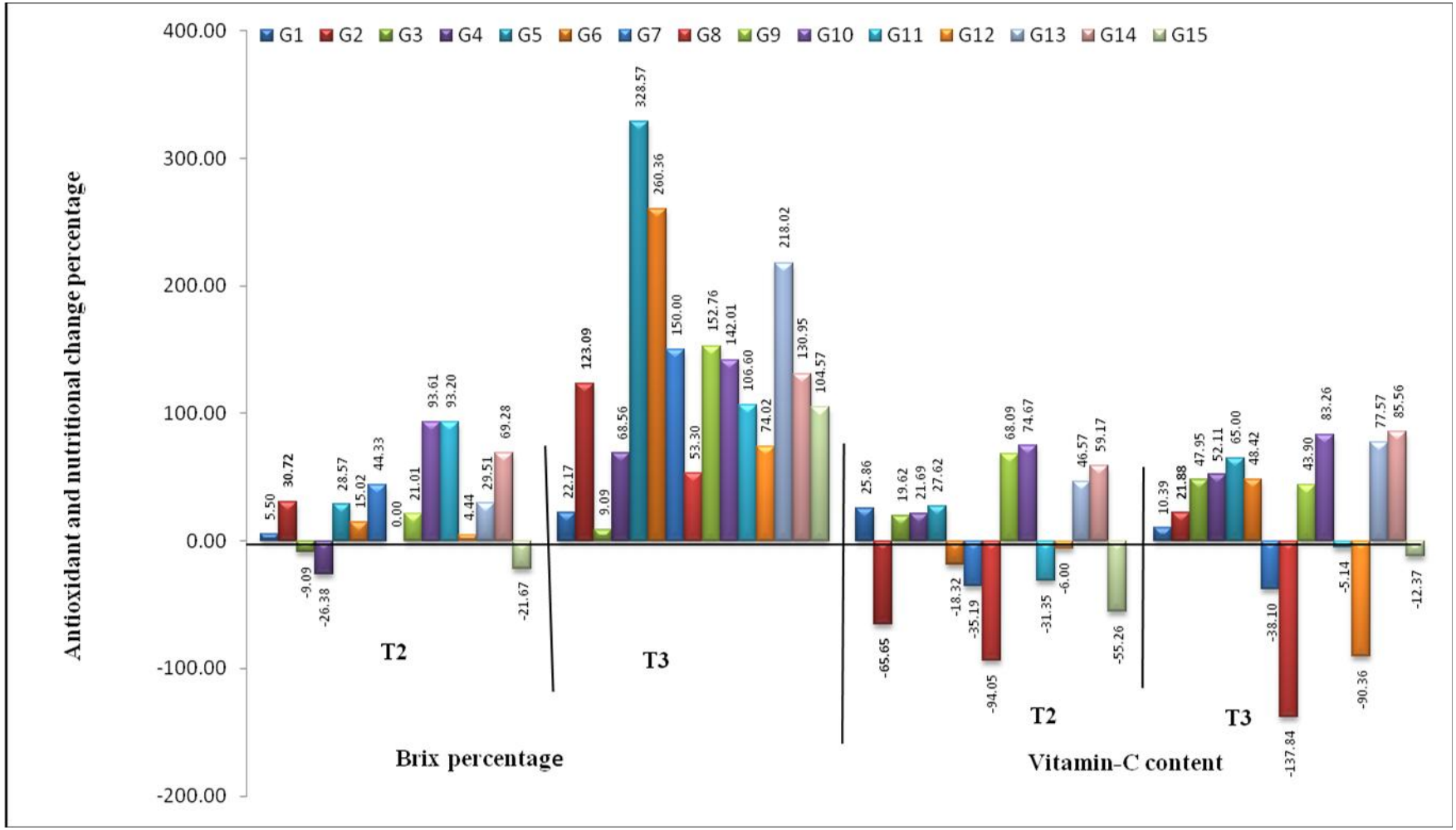

Figure 5. Increasing percentage in brix and reduction percentage in vitamin-C content under increasing drough

closing of stomata. Turgor pressure decrease is thought to be one of the controlling factors in tomatoes by increasing glucose, fructose and sucrose contents and improved the quality by increasing the concentrations of important acids such as ascorbic acid, malic acid and citric acid. Interaction of tomato genotypes and drought treatments significantly affects vitamin-C content (Appendix VI). Maximum Vitamin-C content in tomato (13.50 mg/100 g) was obtained from G10T1 which was statistically identical with G3T1 (13.20 mg/100 g) while minimum (1.04 mg/100 g) from G14T3 which was statistically identical with G13T3 (1.57 mg/100 g) (Table 19).

The fifteen genotypes varied significantly under drought in vitamin-C content. The reduction percentage of vitamin- C content at treatment T2 and T3 is presented in Figure 5. Vitamin-C content increased maximum in genotype G8 both at moderate drought stress (30 days) and at severe drought stress (45 days) (reduction percentage -94.05% and -137.84% respectively) (Figure 5).

4.3.3 Lycopene content

The mean values of lycopene content for fifteen genotypes under three different treatments (control, 30 days withholding of water, 45 days withholding of water) is presented in Appendix VIII. It was observed from the result of the experiment that Lycopene content of tomato showed statistically significant variation among fifteen tomato genotypes (Appendix VI). The highest lycopene content was found in G11 (38.220 mg/100 g) in case of 472 nm and G11 (38.540 mg/100 g) in case of 502 nm, whereas the lowest amount of lycopene was found in G1 (17.240 mg/100 g) which was identical with G9 (17.290 mg/100 g) in case of 472 nm and G1 (7.675 mg/100 g) in case of 502 nm. (Table17).

Lycopene content of tomato showed statistically significant variation among drought treatments (Appendix VI). Highest lycopene content were found in T1 (control) in both case of 472 nm (26.470 mg/100 g) and 502 nm (20.580 mg/100 g) whereas

lowest lycopene content were found in T3 (45 days) in case of 472 nm (18.150 mg/100 g) and in T2 (30 days) in case of 502 nm (14.070 mg/100 g) (Table 18).Compared to well irrigated the lycopene concentration was higher in moderate drought stress tomatoes and lower in severe drought stress (Favati *et al*., 2009). Liu *et al*. (2011); also observed that lycopene content is increased in irrigated and moderate stress condition compared to severe drought conditions and experiment conducted with 10 genotypes and 4 drought treatments.T1 treatment (control) T2 treatment (for 15days), T3 treatment (30 days) and T4 (45 days). From the study it observed that T2 drought stress gave higher lycopene content and T4 treatment gave lower amount. It showed that after T2 treatment lycopene content had decreased as drought stress increased. Drought stress indirectly affected lycopene concentration by inducing more and larger fruits, and thus 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 (Helyes *et al*., 2012).

Lycopene content of leaves was influenced significantly among interaction of tomato genotypes and drought treatments (Appendix VI). Highest lycopene content was found in G12T1 (44.94043 mg/100 g) in case of 472 nm and G12T1 (53. mg/100 g 330) in case of 502 nm. Whereas lowest lycopene content in case of 472 nm found in G4T3 (14.28 mg/100 g) which was statistically identical with G10T3 (14.54 mg/100 g), G14T3 (15.010 mg/100 g), G9T3 (15.020 mg/100 g), G2T3 (15. mg/100 g 420) and in case of 502 nm found in G15T3 (5.350 mg/100 g) which was statistically identical with G13T2 (5.600 mg/100 g), G13T3 (5.687 mg/100 g) ,G14T3 (5.727 mg/100 g) and G7T2 (6.300 mg/100 g) (Table 19).

The fifteen genotypes varied significantly under drought in lycopene content. The reduction percentage of lycopene content at treatment T2 and T3 is presented in Figure 6. In case of 472 nm minimum reduction of lycopene content was observed in G1 (5.45%) at moderate drought stress (30 days) and in G13 (1.25%) at severe drought stress (45 days). In case of 502 nm lycopene content increase maximum in genotype G9 both at moderate drought stress (30 days) and at severe drought stress (45 days) (reduction percentage -77.70% and -47.21% respectively) (Figure 6).

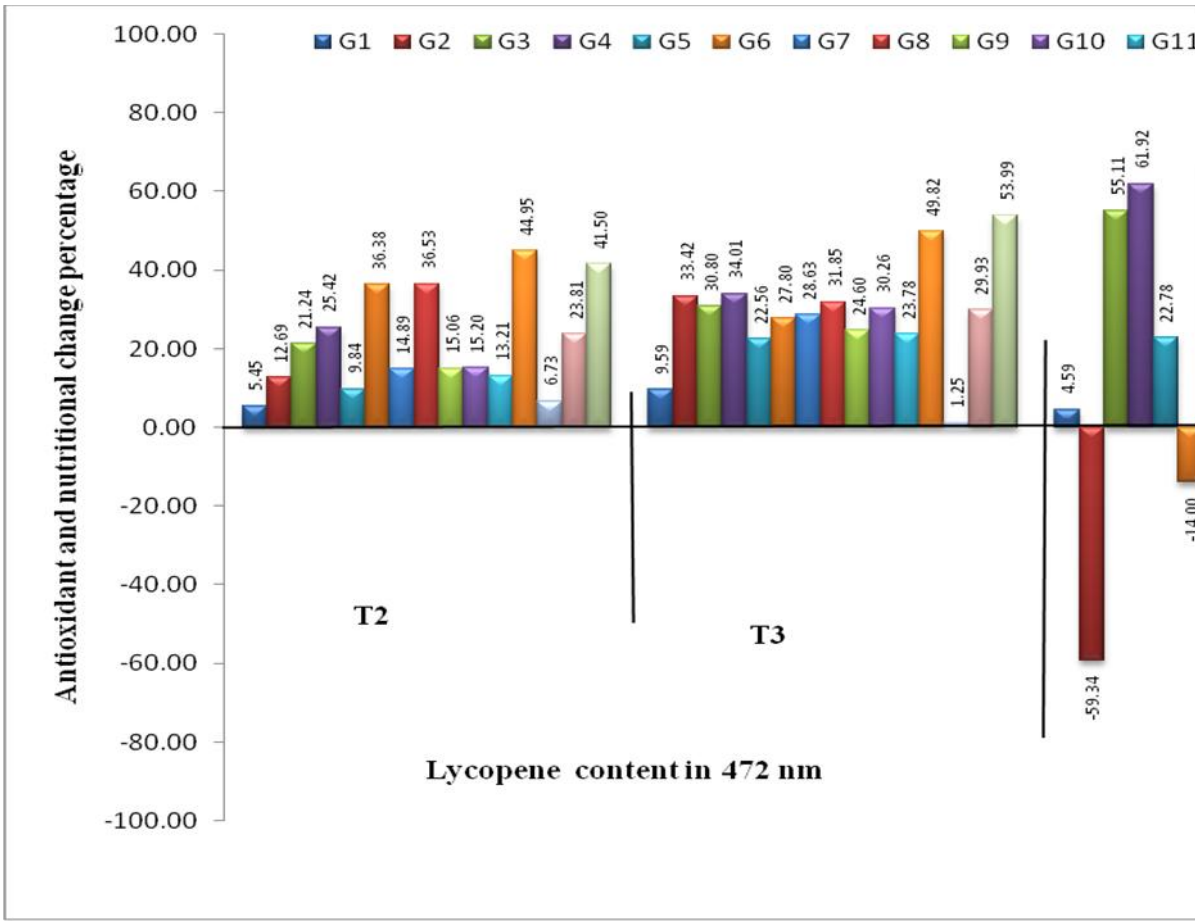

Figure 6. Reduction percentage in lycopene content under increasing drought

SUMMARY AND CONCLUSION

Tomato (*Solanum lycopersicum* L.) belongs to the Solanaceae family is one of the important vegetable in Bangladesh and total production is low as compared to total demand. Large amounts of land in northern region of Bangladesh remain uncultivable due to high level of drought. The affected areas of Bangladesh are increasing rapidly. To overcome the drought problem, drought stressed soils can be used to grow drought-tolerant plants. Thus development of drought tolerant crops is a key global agricultural goal. Tomato plant is moderately tolerant to drought stress but exact drought level may depend on cultivar sensitivity. Evaluation followed by screening can be an easier method to determine drought tolerant genotypes.

A pot experiment was conducted to observe the performances of fifteen tomato genotypes under three different drought treatments. The experiment was conducted at the net house of Genetics and Plant Breeding Department, Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh, during the months of November 2013 to March 2014. Two factorial experiment included 15 tomato genotypes viz. G1 (BD-7759), G2 (BD-7292), G3 (BD-7760), G4 (BD-7258), G5 (BD-7762), G6 (BD-7761), G7 (BD-7289), G8 (BD-7291), G9 (BD-7301), G10 (BARI Tomato-11), G11 (BARI Tomato-9), G12 (BARI Tomato-8), G13 (BARI Tomato-7), G14 (BARI Tomato-3) and G15 (BARI Tomato-2) and three drought treatments viz. T1 (Control), T2 (30 days withholding of water) and T3 (45 days withholding of water) were outlined in Completely Randomized Design (CRD) with three replications.

Collected data were statistically analyzed for the evaluation of tomato genotypes under different drought treatments. Among interactions of tomato genotypes and drought treatments, in case of plant height, the tallest plant (170.3 cm) was observed in G2T1 whereas the shortest plant (50.67 cm) was found from G6T3 at mature stage. In combination of tomato genotypes and drought levels, early flowering was observed in G15T3 (19.33 days)

interactions and G1T3 required maximum period (43 days) for flowering. Early harvesting period (72.00 days) was observed in G10T1, whereas delayed in G11T3 (99.00 days). In interaction of tomato genotypes and drought treatments maximum number of fruits (57.67/plant) were obtained from G1T1 and minimum number of fruits (6.33/plant) were found in G13T3.The highest average fruit weight (63.38 g/plant) was obtained from G12T1 while the lowest average fruit weight (5.673 g/plant) was found in G10T3. Considering yield per plant, maximum yield (0.729 kg/plant) was obtained from G3T1 while minimum yield (0.186 kg/plant) from G9T3. Maximum fruit length (4.383 cm) was recorded from G13T3 interaction whereas shortest (2.097 cm) from G6T3 interaction. In case of diameter of fruit, maximum fruit diameter (5.167 cm) was obtained from G13T1 interaction whereas minimum (1.930 cm) from G10T3 interaction.

Drought stress adversely affects the physiology of tomato at all stages of growth and development. Observation of physiological characters played important role for the selection of suitable genotype for future breeding purpose. Genotypes showed significant variation in physiological characters such as, relative water content and proline content. In case of relative water content, the highest relative water content (99.55%) was found in G9T1 interaction whereas the lowest relative water content (61.76%) in G6T3 interaction. Maximum proline content (673.3 µg/g) in tomato was obtained from G11T3 interaction while minimum (161.73 µg/g) from G9T2 interaction.

Not only the yield characters but also the antioxidant and nutritional characters were adversely affected by high drought. The genotypes varied significantly in their antioxidant and nutritional characters as maximum brix in tomato (3.00%) was obtained from G5T3 interaction while minimum (0.43%) from G2T1 and G14T1 interaction. The highest amount of vitamin-C content (13.50 mg/100 g) in tomato was obtained from G10T1 interaction while minimum (1.04 mg/100 g) from G14T3 interaction. Among interactions of genotypes and treatments, the highest lycopene content was found in G12T1 in both absorbance 472 nm

(44.94 mg/100 g) and 502 nm (53.33 mg/100 g), whereas, the lowest lycopene content was found in G4T3 (14.28 mg/100 g) in absorbance of 472 nm and in G15T3 (5.35 mg/100 g) in absorbance of 502 nm.

Analyzing the data of this study it can be concluded for agromorphogenic traits as, fruits per plant increased in genotype G6 at moderate drought stress and in genotype G_7 at severe drought stress. The average fruit weight per plant increased in genotype G5 at moderate drought stress and minimum reduction was found in genotype G13 at severe drought stress. Yield per plant reduced minimum in genotype G4 at moderate drought stress and in genotype G6 at severe drought stress. As an indicator of drought tolerance, relative water content increased maximum in genotype G2 at moderate drought stress and also in genotype G10 at severe drought stress. The highest proline content was found in genotype G1 at moderate drought stress and in genotype G11 at severe drought stress. Regarding antioxidant and nutritional traits, increase of brix (%) was found the highest in genotype G10 at moderate drought stress and in genotype G5 at severe drought stress. vitamin-C content increased maximum in genotype G8 both at moderate drought stress and at severe drought stress. The lowest reduction of lycopene content was observed in G1 at moderate drought stress (30 days) and in G13 at severe drought stress (45 days) at 472 nm. In case of 502 nm lycopene content increased maximum in genotype G_9 both at moderate drought stress (30 days) and at severe drought stress (45 days).

Regarding yield performance G4 could be recommended for moderate drought stress region and G6 for severe drought stress region. Considering the yield character, genotype G6, G5 and G4 could be recommended to the farmers for cultivation in the northern region of Bangladesh for moderate drought stress and genotype G7, G13 and G6 could be recommended for prolonged and severe drought stress. Regarding antioxidant and nutritional traits G10 for brix (%), G8 for vitamin-C content and G1 for lycopene content could be recommended at moderate drought stress period and G5, G8 and G13 for prolonged and severe drought stress.

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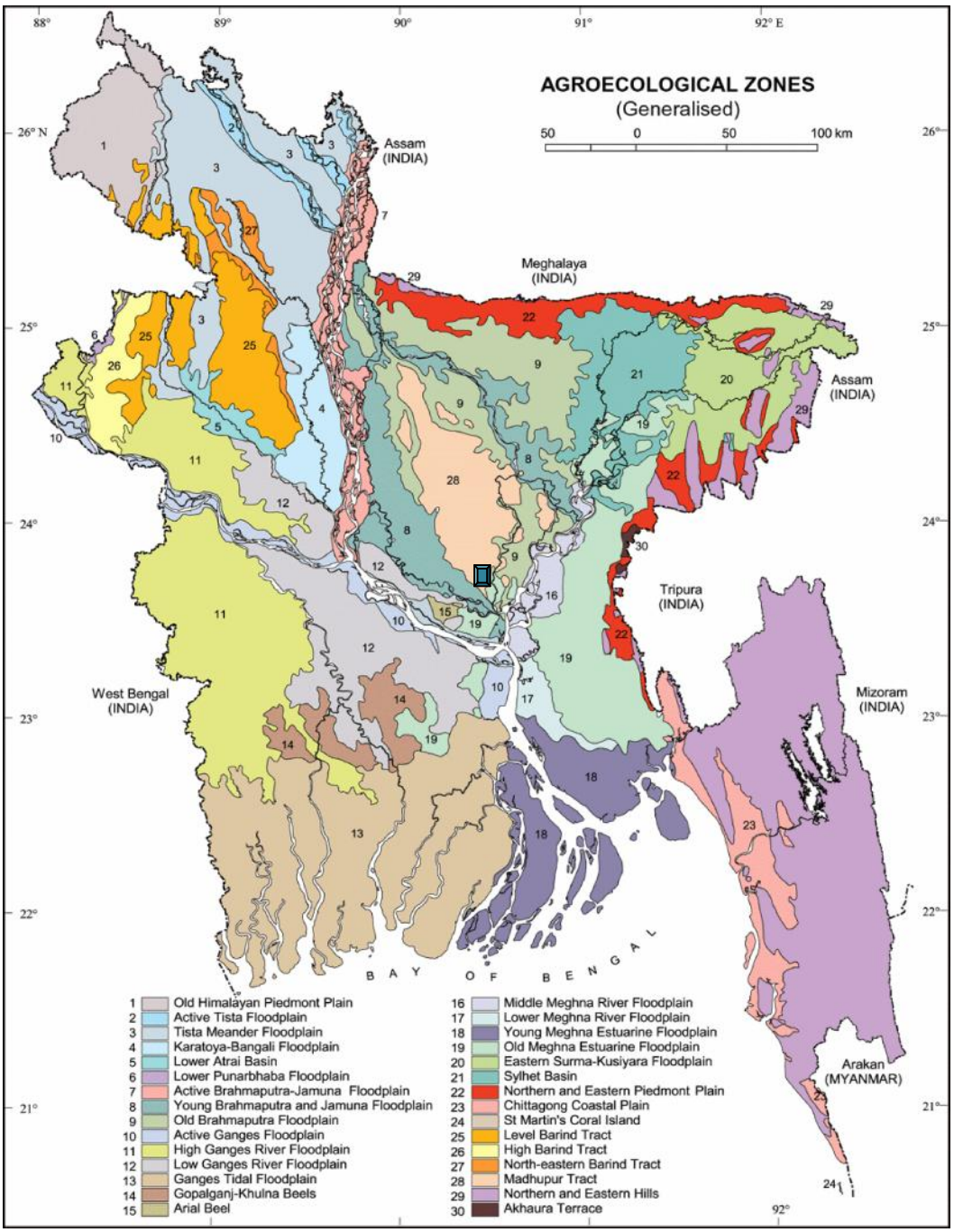
APPENDICES

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 October 2013 to March 2014.

Month	Year	Monthly average air temperature (^{o}C)			Average relative humidity (%)	Total rainfall (mm)	Total sunshine (hours)
		Maximum	Minimum	Mean			
Oct.	2012	29.36	18.54	23.95	74.80	Trace	218.50
Nov.	2012	28.52	16.30	22.41	68.92	Trace	216.50
Dec.	2012	27.19	14.91	21.05	70.05	Trace	212.50
Jan.	2013	25.23	18.20	21.80	74.90	4.0	195.00
Feb.	2013	31.35	19.40	25.33	68.78	3.0	225.50
Mar.	2013	32.22	21.25	26.73	72.92	4.0	235.50

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 plant height, days to first flowering, number of cluster /plant, days to maturity and number of fruits/cluster

Source of variation	Degrees of freedom (df)	Mean Sum of Square				
		Plant height	Days to first flowering	Number of cluster/plant	Days to maturity	Number of fruits/cluster
Factor A (genotype)	14	5939.09*	386.96*	75.05*	282.45*	8.15*
Factor B (drought)	2	4316.08*	2.71NS	25.87*	121.91*	5.18*
A×B	28	598.78*	61.08*	0.96NS	55.56*	0.46NS
Error	90	28.52	1.43	0.67	0.87	0.37

* Significant at 0.01 level of probability; NS Non significant

Appendix V: Analysis of variance of the data on number of fruits /plant, average fruit weight, yield /plant, average fruit length and average fruit diameter.

Source of variation	Degrees of freedom	Mean Sum of Square				
		Number of	Average fruit	Yield/plant (kg)	Average fruit	Average fruit

	(df)	fruits/plant	weight/plant (g)		length (cm)	diameter (cm)
Factor A (genotype)	14	1824.17*	2094.26*	0.047*	2.38*	4.41*
Factor B (drought)	2	78.25*	2555.79*	0.799*	3.68*	5.33*
A×B	28	30.72*	149.64*	0.011*	0.42*	0.32*
Error	90	4.22	3.23	0.001	0.01	0.01

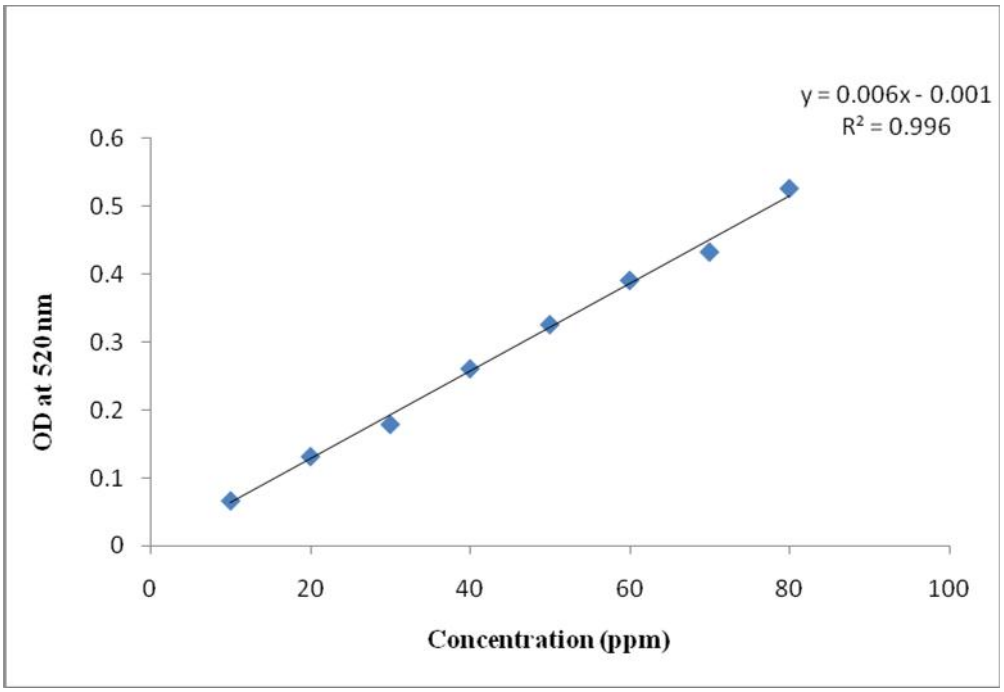
* Significant at 0.01 level of probability; NS Non significant

Appendix VI: Analysis of variance of the data on relative water content (RWC), proline content, brix, vitamin-C and lycopene content

Source of variation	Degrees of freedom (df)	Mean Sum of Square					
		Relative Water Content (RWC) (%)	Proline Content (µg/g)	Brix (%)	Vitamin-C (mg/100 g)	Lycopene content (mg/100 gm)	
						472nm	502nm
Factor A (genotype)	14	492.42*	37963.541*	0.979*	52.131*	338.74*	804.31*
Factor B (drought)	2	409.39*	33925.589*	9.277*	65.204*	855.76*	603.19*
A×B	28	115.31*	17090.768*	0.383*	23.123*	37.76*	96.17*
Error	90	2.53	3.022	0.043	0.277	0.01	0.13

* Significant at 0.01 level of probability; NS Non significant

Appendix VII. Proline standard curve



Genotype	plant height (cm)			Days to first flowering			Number of cluster per plant			Days to maturity			Nu
	T1	T2	T3	T1	T2	T3	T1	T2	T3	T1	T2	T3	T1
G1	128.3	123	106.7	22.33	42.67	43	16.67	16.67	14.33	90.33	86	90.67	4.6
G2	170.3	149.3	107.3	31.33	24	21.67	11.33	9.66	9.33	84	95.33	97	3.3
G3	130.3	121.3	101.7	28.33	25.33	25.33	13.67	13.33	10.67	80.67	74.67	86	4
G4	73.67	67.67	76.33	21.67	20.67	21.67	9.33	8.33	8	85.33	86	86	2.6
G5	98.33	68.33	73.67	21.33	20	20	8.33	7.66	6.66	85.33	76.67	90	2.6
G6	56.67	59	50.67	23	25	20	8.33	7	8.33	86	78.67	85.33	2.3
G7	127.7	127.7	104	21.33	21.33	25	9.33	8.33	8.33	80.67	80.67	86	3
G8	147	124	104	21.67	23.67	21.67	10	9.66	9.33	85.33	82.33	79.33	2.6
G9	67.67	128.3	69.67	28.67	20.67	34.67	8.33	8	7.66	79.33	78.67	86	2.6
G10	120.7	109.3	106	24.33	23.33	21	9.33	8.66	7.66	72	74.67	77.33	6.6
G11	75.67	87	56.67	40	38	38	8.33	7.33	6	94.67	94.33	99	2.6
G12	78.33	75	68.67	41.67	31	38	6.66	5.66	5.66	84	85.33	90.67	4.3
G13	100.7	116	82.67	35	34.67	38.33	4.66	3.66	3.66	94.67	98.67	90.67	3
G14	62.67	77.67	79	21	23.33	20	7.66	5.66	5.66	84	86	90	2.6
G15	85	72	73.33	21.67	26.67	19.33	6.66	6	4.66	83.33	95	80	2.6

Appendix VIII. Mean values of different agromorphogenic, physiological, antioxidant and nutritional traits under control and drought stress treatment

T1 : control; **T2** : 30 days withholding water; **T3** : 45 days withholding water

Appendix VIII (Cont'd).

Genotype	Number of fruits per plant			Average fruit weight per plant (g)			Yield / Plant (Kg)			Average fruit length (cm)			Avera
	T1	T2	T3	T1	T2	T3	T1	T2	T3	T1	T2	T3	T1
G1	57.67	55.33	50	9.81	8.99	7.527	0.584	0.495	0.362	2.67	2.63	2.233	2.55
G2	23	18	20	21.18	19.15	13.32	0.508	0.362	0.294	3.18	2.777	2.757	4.133
G3	46.33	44.67	32.67	14.9	11.75	11.95	0.729	0.606	0.399	2.827	2.6	2.183	2.64
G4	17.67	17.33	14	25.42	28.42	13.84	0.485	0.481	0.244	3.253	2.937	3.207	2.863
G5	20	17.33	17.33	24.68	29.5	16.71	0.52	0.484	0.319	3.86	3.923	2.387	3.43
G6	19	22.33	20.33	32.35	22.59	22.59	0.638	0.535	0.528	3.81	3.233	2.097	3.85
G7	13.67	16	24.33	49.19	34.59	14.74	0.703	0.522	0.346	2.853	2.853	2.813	3.277
G8	15.67	16.33	16.67	41.74	33.82	21.66	0.698	0.584	0.341	2.82	3.16	2.953	3.447
G9	15.33	17	20.33	36.6	18.74	6.49	0.589	0.435	0.186	3.503	2.78	2.197	3.27
G10	49.67	48	39.33	10.42	6.827	5.673	0.529	0.416	0.257	2.547	2.263	2.203	2.157

G11	12.67	11.67	9.33	42.38	38.26	34.19	0.616	0.505	0.369	3.903	3.36	3.357	3.543
G12	11.33	10.67	8.333	63.38	61.3	30.06	0.713	0.677	0.34	4.1	4.1	3.663	3.793
G13	8.333	7.333	6.333	62.42	52.08	53.8	0.557	0.387	0.391	3.84	4.23	4.383	5.167
G14	10.67	11.33	8.333	55	47.77	47.35	0.622	0.546	0.512	3.237	3.327	3.197	3.73
G15	11.33	11.67	7.667	57.29	31.66	21.15	0.623	0.37	0.241	4.13	3.767	2.517	4.367

T1 : control; **T2** : 30 days withholding water; **T3** : 45 days withholding water

Appendix VIII (Cont'd).

Genotype	**Relative water content (RWC)**			**Proline content (µg/g)**			**Brix (%)**			**Vitamin-C content (mg/100 g)**			**Lycopene content (mg/100 g)**					
													472 nm			**502 nm**		
	T1	**T2**	**T3**	**T1**	**T2**	**T3**	**T1**	**T2**	**T3**	**T1**	**T2**	**T3**	**T1**	**T2**	**T3**	**T1**	**T2**	**T3**
G1	93.35	82.29	83.5	220	415	256.66	0.6	0.633	0.733	12.8	9.49	11.47	18.15	17.16	16.41	8.28	7.9	6.79
G2	82.28	89.38	93.4	285	273.33	248.33	0.433	0.566	0.966	6.9	11.43	5.39	23.16	20.22	15.42	17.02	27.12	15.8
G3	92.01	87.23	88.33	278.33	315	276.66	1.1	1	1.2	13.2	10.61	6.87	22.6	17.8	15.64	19.16	8.6	7.91
G4	91.3	92.08	82.88	275	201.66	181.66	0.633	0.466	1.067	6.887	5.38	3.29	21.64	16.14	14.28	18.91	7.2	6.617
G5	84.14	67.53	70.24	350	255	226.66	0.7	0.9	3	8.4	6.08	2.94	20.43	18.42	15.82	15.63	12.07	8.657
G6	86.2	66.82	61.76	296.66	318.33	261.66	0.666	0.766	2.4	10.1	11.95	5.21	28.53	18.15	20.6	12.43	14.17	16.38
G7	89.49	89.49	90.77	306.66	266.66	236.66	0.6	0.866	1.5	7.9	10.68	10.91	22.7	19.32	16.2	19.5	6.3	12.04
G8	93.8	85.8	89.92	300	183.33	248.33	1	1	1.533	3.7	7.18	8.8	30.55	19.39	20.82	23.51	10.02	23.94
G9	97.55	94.42	91.77	283.33	161.66	205	0.633	0.766	1.6	8.9	2.84	4.993	19.92	16.92	15.02	13.45	23.9	19.8
G10	66.55	68.25	84.18	356.66	311.66	256.66	1.033	2	2.5	13.5	3.42	2.26	20.85	17.68	14.54	16.03	7.5	9.143
G11	90.41	65.58	74.87	380	388.33	673.33	0.5	0.966	1.033	3.7	4.86	3.89	43.6	37.84	33.23	40.63	32.2	42.8
G12	86	80.63	77.39	338.33	305	280	0.766	0.8	1.333	5.5	5.83	10.47	44.94	24.74	22.55	53.33	28.03	29.59

G13	91.15	92.04	93.88	358.33	283.33	243.33	0.566	0.733	1.8	7	3.74	1.57	18.42	17.18	18.19	15.5	5.6	5.687
G14	90.13	81.79	81.41	426.66	456.66	273.33	0.433	0.733	1	7.2	2.94	1.04	21.42	16.32	15.01	13.28	10.2	5.727
G15	84.81	89.34	88.64	455	191.66	246.66	0.766	0.6	1.567	3.8	5.9	4.27	40.12	23.47	18.46	21.96	10.2	5.35

T1 : control; **T2** : 30 days withholding water; **T3** : 45 days withholding water